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GRA 19703 Master Thesis

How can the Norwegian Maritime Industry Successfully Work Toward Net Zero-Emission Supply Chain Operations by 2050?

Hand-in date:
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Supervisor:
Erna Engebrethsen

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BI NORWEGIAN BUSINESS SCHOOL

Abstract

The shipping sector plays a vital role in the Norwegian economy and significantly contributes to international shipping. Norway's rich maritime heritage has positioned the country favorably within the shipping industry. With the growing emphasis on climate action and industries striving to reduce emissions and mitigate greenhouse gases, the shipping sector shares a collective objective of achieving as close to zero-emission as possible by 2050.

The purpose of this study is to explore strategies, opportunities and factors that can facilitate the industry's transition toward sustainability, considering the unique strengths and resources of the Norwegian maritime sector. Therefore, the research question is: *How can the Norwegian maritime industry successfully work toward zero-emission supply chain operations by 2050?* To answer the research question this master thesis used a qualitative research method with semi-structured interviews. Following a review on relevant literature, empirical data was collected by interviews with experts in the industry, which provided valuable insights into the industry's perspectives, experiences, and challenges related to the emerging market of zero-emission shipping. Additional information from climate and sustainability reports was gathered to examine the current situation and evaluate drivers, conditions and barriers in the market of zero-emission.

Our analysis of theoretical and empirical findings shows that collaboration between stakeholders is crucial in developing a robust market and for the industry to reach their goals by 2050. The market of zero-emission shipping needs supply and demand equilibrium, leading to an increased pressure on the authorities to engage and commit in the transition with leading players to ensure products and services are effectively managed in the end. The lack of certainty and development in the zero-emission market presents challenges for companies operating in the maritime industry. However, the findings highlight the Norwegian cluster's position as a frontrunner in innovation and the Norwegian cluster showcases its commitment to achieving sustainability objectives while concurrently driving economic growth. The Norwegian maritime sector has the potential, by working closely with stakeholders in the market and leveraging the driving forces, to overcome the barriers presented, to reach their goals by 2050.

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We would like to thank Erna Engebrethsen, our master's program supervisor at BI Norwegian Business School, for her support and inspirational lectures throughout our program. Her feedback, honesty, and encouragement have been highly appreciated in our work.

Furthermore, we thank the nine participants who generously shared their time and expertise for our study. The insightful discussions and inspiring topics were invaluable. Without their theoretical and practical knowledge of shipping and port operations, marine regulations, shipping technology, and sustainable practices, our research question would have remained unanswered, leaving our master's thesis incomplete. We express our utmost gratitude for their contributions.

Writing this thesis has been challenging. We owe our success to each other. We deeply appreciate the hard work and dedication exhibited by both of us as a team member, and eagerly anticipate the exciting chapters that lie ahead. Lastly, we wish to express our gratitude to our families and friends for their support during this remarkable journey.

BI Norwegian School of Business

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Julie Elde

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

CfD	Contract for Difference
CII	Carbon Intensity Index
CO_2	Carbon Dioxide
CSR	Corporate Social Responsibility
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ship Index
ETS	Emission Trading System
EU	European Union
GHG	Greenhouse Gas
GSP	Green Shipping Practices
IMO	International Maritime Organization
LNG	Liquefied Natural Gas
LSP	Logistics Service Providers
NO_X	Nitrogen Oxides
R&D	Research and Development
RBV	Resource-Based view
SC	Supply Chain
SCM	Supply Chain Management
SDG	Sustainable Development Goals
SEEMP	Ship Energy Efficiency Management Plan
SO_X	Sulfur Oxide
SQB	Status Quo Bias
SSS	Short-Sea Shipping
TAM	Technology Adoption Model
TPB	Theory of Planned Behavior
UN	United Nations

Chapter 1 – Introduction

This master's thesis examines how the Norwegian maritime industry can enable factors to successfully transition toward net zero-emission supply chains by the year 2050. The maritime sector is crucial for Norwegian logistics and global trade, but it also contributes to greenhouse gas emissions, necessitating transformative changes to meet sustainability goals. The research draws upon qualitative methods and interviews with industry experts. The primary objective of our thesis is to gain valuable perspectives from stakeholders within the market of zero-emission solutions while identifying enablers and barriers encountered during this transition process. The introduction chapter establishes the thesis context, significance of the topic, presents the research question, set of limitations and outlines the thesis structure.

1.1 Background

The global shipping industry is crucial in facilitating international trade, connecting economies, and enabling the exchange of goods and resources across continents (Raza, 2020). Ships are notably energy-efficient consuming significantly lower energy per unit of cargo than trucks, trains, or planes (Zis, Psaraftis, Panagakos, & Kronbak, 2019). This provides an attractive selection given the rise in demand, fuel expenses and diminished risk of maritime vessel traffic (Lister, 2015). International shipping is the backbone of global trade, accounting for 80-90% of all worldwide trade activities (Abreu, Santos & Cardoso, 2023), and is therefore an essential contributor to the global economy.

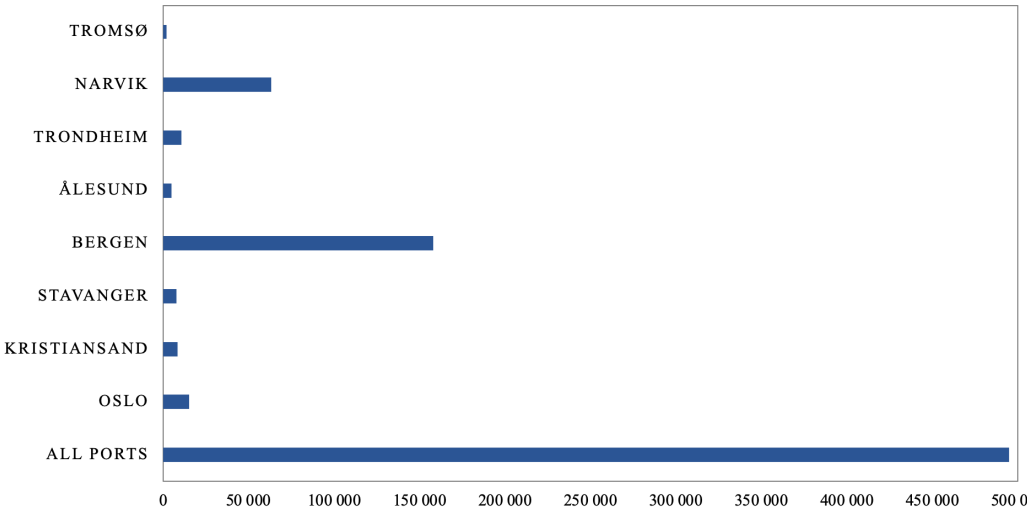
Norway has a long history of maritime activity, dating back to the Viking Age, with shipping, shipbuilding and fishing being fundamental industries (Reve & Sasson, 2012, p. 84). The importance of the maritime sector to the Norwegian economy has remained consistent throughout the 20th century, positioning Norway as a leading player in international shipping (Tenold, 2019). With the fourth-largest merchant fleet worldwide under its control, Norway is widely recognized as a maritime superpower (International Trade Administration, 2022). Table 1 demonstrates a large and stable Norwegian merchant fleet in 2022, expected to remain substantial in the coming years (Statistics Norway, 2023a). This industry plays a significant role in the national economy, contributing NOK

175 billion in value and employing around 88,000 individuals in 2022 (Norwegian Shipowners Association, 2023).

		% Change	
	2022	2021 - 2022	2017 - 2022
All Vessels	1 592	-0,7	10,5
Tonnage, measured (gross tonnes)	19 009 029	-1,3	13,2
NOR - Norwegian Ordinary Ship Register			
Vessels	900	-2,3	1,7
Tonnage, measured (gross tonnes)	2 040 314	-4,3	3,1
NIS - Norwegian International Ship Register			
Vessels	692	1,5	24,5
Tonnage, measured (gross tonnes)	16 968 715	-1	14,6

Table 1. The composition of the Norwegian Merchant fleet in 2022 consisting of vessels for transport, with a gross tonnage of 100 tonnes or more, registered in NIS and NOR (Statistics Norway, 2023a).

The geographical features of Norway, including the coastline that spans over 100,000 kilometers, fjords and natural harbors, have contributed to its strong maritime presence (Ministry of Climate and Environment, 2015). With advanced infrastructure, a rich maritime heritage and a robust maritime culture, these factors have propelled Norway's international standing in shipping (Norwegian Ministry of Trade, Industry and Fisheries, 2022). Table 2 demonstrates a substantial cargo transportation to and from Norway in 2022, with Bergen being the largest port in tonnes (Statistics Norway, 2023b). Approximately 90% of all cargo destined for Norway is transported by sea, with ships accounting for half of the domestic cargo transportation within the country (Norwegian Ministry of Trade, Industry and Fisheries, 2021).



	All ports	Oslo	Kristiansand	Stavanger	Bergen	Ålesund	Trondheim	Narvik	Tromsø
4th quarter 2022	49 505 975	1524 491	842 432	778 166	15817 617	494 480	1059 907	6334 325	193 165

Table 2. Cargo transported to and from the largest Norwegian ports in tonnes in 2022 (Statistics Norway, 2023b).

Shipping has long been integral to the Norwegian economy. However, the reliance on fossil fuels in the industry presents environmental challenges, including greenhouse gas (GHG) emissions and air pollution, contributing approximately 2-3% of annual GHG emissions (Balcombe et al., 2019; Giese, Wagner & Boatemaah, 2021). Addressing global warming and climate change has become urgent, necessitating transformative changes across industries (UNFCCC, 2001). Anthropogenic GHG emissions have amplified adverse effects, such as rising temperatures, sea levels and altered weather patterns, with consequences for ecosystems and human health (Giese et al., 2021). Norway is experiencing the impacts of climate change, including increased precipitation and reduced snow cover duration (Meld. St. 13 (2020-2021)).

The international shipping industry is on the verge of a significant transformation, with the primary objective to eliminate GHG emissions as rapidly as possible within this century. The 2015 Paris Agreement marked a crucial milestone in international climate cooperation, with nations worldwide committing to keeping the rise in temperatures below 2 degrees Celsius (Hessevik, 2022). In addition, called for the reduction of emissions by 45% by 2030 and to reach net zero by 2050. Net zero or zero-emission refers to reducing GHG emissions to as close to zero as possible, with any remaining emissions being reabsorbed by the oceans (Connelly & Idini, 2022). For the first time, a consensus was reached on reducing GHG emissions from transportation sectors. In response to this agreement, the United Nations (UNs) International Maritime Organization (IMO) set forth an ambitious strategy in 2018 to lower GHG emissions from the shipping industry by 50% by 2050, compared to the 2008 levels (IMO, 2018; Jafarzadeh & Schjølberg, 2018) (Figure 2).

As illustrated in Figure 1, to achieve net zero-emission by 2050, a reduction of nearly 15% in international emissions from 2021 to 2030 is required (Connelly & Idini, 2022). Norway, similar to the majority of nations worldwide, demonstrates a steadfast commitment to mitigating GHG emissions following the objectives outlined in the Paris Agreement in cooperation with the European Union (EU). Norway has committed to reducing emissions of GHGs by 55% by 2030 compared to 1990 (Norwegian Ministry of Trade, Industry and Fisheries, 2022), with a target of being a low-emission society by 2050. The table below

demonstrates where the international- and Norwegian CO_2 emissions must be in 2030 in order to reach the 2050 goal of net zero (Statistics Norway, 2023c: Connelly & Idini, 2022). To reach net zero-emission necessitates the adoption of low- and zero-carbon fuels and technologies for oceangoing vessels, which should be driven by technological innovation, supportive policies and collaboration across the value chain (Connelly & Idini, 2022).

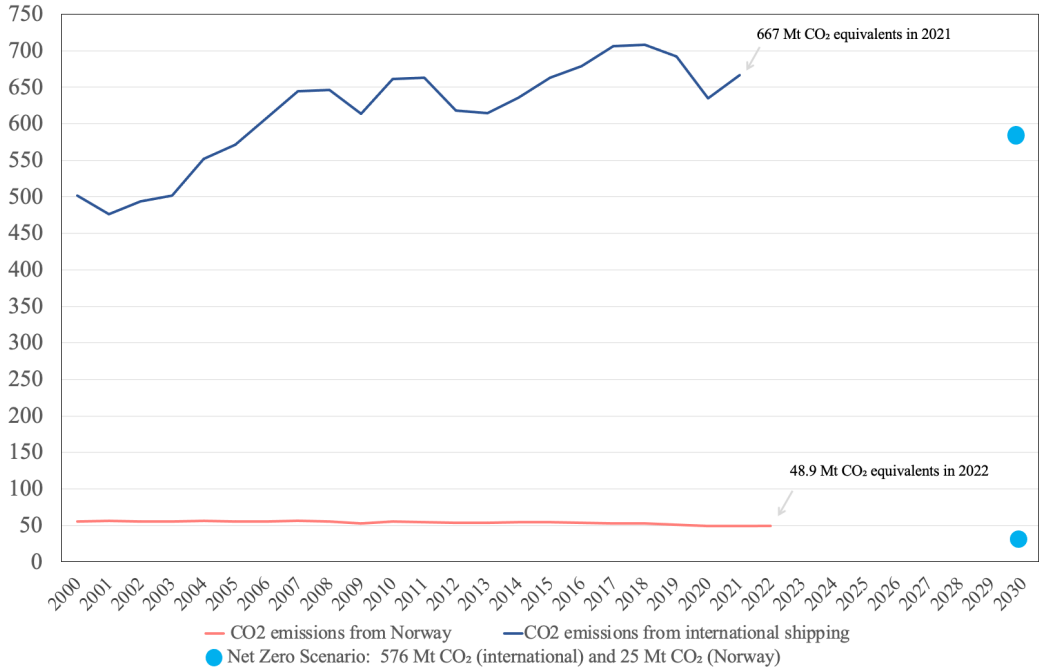


Figure 1. CO_2 emissions from international shipping and Norway in the net zero, 2000-2030 (Statistics Norway, 2023c: Connelly & Idini, 2022).

Recognizing the industry's environmental impact, Norway, with a 24% share in the low- and zero-emission shipping segment, actively supports the zero-emission movement (Norwegian Ministry of Trade, Industry and Fisheries, 2021). The maritime industry in Norway aims to be at the forefront of sustainable shipping, emphasizing the use of emerging technologies and alternative fuels to transition toward the market of zero-emission shipping (Norwegian Ministry of Climate and Environment, 2019). The Government's action plan for green shipping, released in 2019, promotes the development of low- and zero-emission solutions for all vessel categories, boost the competitiveness of the maritime sector and facilitates the export of related technologies (Meld. St. 13 (2020-2021)). To achieve climate neutrality by 2050, propulsion strategies such as biogas, methanol, hydrogen, ammonia and electrification are being evaluated for short-sea shipping (Norwegian Shipowners Association, 2023). Table 3 summarizes the targets, objectives and the guiding principles to reduce GHG emissions and promote

sustainability in the maritime industry (Norwegian Ministry of Climate and Environment, 2019; Climate Change Act, 2017, §1-4).

Objectives and Targets		Description
Climate target for 2030: Climate Change Act agreement between Norway and the EU	→	Reduce GHG emissions by 50-55 % by 2030 compared to 1990 levels.
Norwegian National Transportation Plan 2022-2023	→	Align with the Paris Agreement and aim to reduce GHG emissions by 45% by 2030, compared to 2005 levels.
Norwegian government objectives for domestic shipping	→	Reduce emissions from domestic shipping and fisheries by 50% by 2030.
Norwegian government objective for vessel development	→	Encourage the development of low- and zero-emission solutions for all vessel categories.
Climate target for 2050: Norwegian government objective for a low-emission society	→	The target is for Norway to become a low-emission society by 2050. In addition, achieve reductions of GHG emissions of the order of 90-95 % by 2050 from the level in the reference year 1990

Table 3. The goals and objectives of the Norwegian maritime industry made by the authors

However, achieving emission reduction goals necessitates a comprehensive and transformative process for the country, requiring expedited action to align with government ambitions. Active engagement from relevant stakeholders, along with robust government support, is crucial for the development and adoption of low- and zero-emission technologies within the maritime sector. Collaborative efforts and encouragement are essential for revitalizing environmentally friendly fleets and enhancing the industry's competitive advantage. Programs such as Maritime CleanTech and the Green Shipping Programme are actively advocating for the adoption of cleaner technologies and lobbying IMO for a prohibition of fossil fuels by 2050 (International Trade Administration, 2022). To support the decarbonization of the marine industry, significant funding programs are available to encourage research, innovation and the adoption of green solutions. Notable entities such as Enova, Innovation Norway, the Norwegian Research Council and the NO_X Fund play active roles in promoting innovative technologies and sustainable infrastructure (Norwegian Ministry of Climate and Environment, 2019; Hessevik, 2022).

The Norwegian maritime industry represents all segments in the shipping industry, including offshore, deep-sea and short-sea, with the short-sea sector showing

greater promise in implementing new zero-emission strategies and technologies (Norwegian Ministry of Climate and Environment, 2019). Therefore, our research focuses on the short-sea sector within Norway. Short-sea shipowners, also known as coastal shipping operators, play a crucial role in transporting goods and passengers within Norway, between Norwegian and European ports, and within European ports (Bengtsson, Fridell & Andersson, 2013). The short-sea shipping (SSS) sector encompasses various vessel types, including dry cargo ships, gas tankers, bulk carriers, tankers, chemical ships, passenger ships, container ships, and ro-ro ships. These vessels operate on single voyages and fixed contracts (Norwegian Port Association, 2023). The short-sea segment experienced a 3% growth rate in 2022, consistent with previous years, and is expected to grow by approximately 15% in 2023 (Norwegian Shipowners Association, 2023). The SSS sector offers economic competitiveness, consumes less energy and serves as a testing ground for new fuels and technical solutions due to potentially easier access at bunkering terminals. Setting it apart from deep-sea shipping that relies on globally available fuels and high-density energy sources (DNV GL, 2019; Medda & Trujillo, 2010). Norway has approximately 550 registered SSS enterprises, generating NOK 9 billion in annual revenue and employing around 10,000 seafarers (Norwegian Port Association, 2023).

The shipping industry, renowned for its conservative nature attributed to substantial investments and operational costs, faces uncertainty regarding the choice of green technology for future ships (Zis, 2019). This uncertainty poses risks for shipping companies and cargo owners, as vessels ordered now are expected to operate until 2050. Existing fleets will continue to emit GHGs until then, even if technologically advanced zero-emission vessels become available and economically viable (Norwegian Shipowners Association, 2023). Retrofitting methods can reduce emissions but may face obstacles due to high costs (Norwegian Shipowners Association, 2023).

To achieve the government's goal of reducing GHG emissions from domestic shipping and fishing by 55% by 2030, a funding requirement of over NOK 12 billion is estimated (Grimsby et al., 2023). However, the fleet cannot be adjusted until access to alternative fuels and the necessary infrastructure is available. This requires establishing a new value chain (Grimsby et al., 2023). Considering the

entire value chain is essential for understanding and managing risks associated with investments in green maritime infrastructure. Furthermore, there is a reluctance to invest in alternative fuel production without secured demand and customers, making managing market demand a critical risk factor for attracting institutional capital (Grimsby et al., 2023). This challenge applies to all alternative fuels linked to green hydrogen, green ammonia or biofuel (Grimsby et al., 2023).

The establishment of precise emission targets by the government (Norwegian Ministry of Climate and Environment, 2019) has paved the way for an expanding market of low- and zero-emission technologies and solutions. To meet transportation requirements and enhance the competitiveness of the Norwegian economy, it is imperative for the maritime industry to seize the opportunities presented by this market, recognizing the vital role of the short-sea sector and the customers. By capitalizing on the emerging market of zero-emission shipping, the industry can improve supply chain operations, sustainability practices and maintain a competitive advantage.

1.2 IMO and International Shipping Regulatory Framework

The shipping industry operates globally, with vessels crossing oceans and being managed from various countries. International shipping is regulated by the UN's IMO, as addressing global warming necessitates a unified effort from the international community. Establishing regulations through IMO ensures widespread support and effective implementation, preventing unfair treatment and promoting fair competition while maintaining environmental standards. IMO has implemented stricter environmental requirements for international shipping, leading to a future increase in global demand for environmentally friendly technologies and alternative fuels (IMO, 2018). In addition, the UN has established a comprehensive framework of maritime laws and goals (Stopford, 2009, p.658), such as the 2015 Sustainable Development Goals (SDGs), which reflect an increased emphasis on sustainable development and environmental concerns (UN, 2019; Koilo, 2020). The SDGs provide an overall framework for addressing the major national and global challenges facing the world today.

As shown in Figure 2, IMOs ambitious strategy to reduce GHG emissions by 50% by 2050 (IMO, 2018; Jafarzadeh & Schjølberg, 2018), aims to improve the energy

efficiency of individual ships and reduce the carbon intensity of the entire sector. They opt to achieve a reduction of emissions per unit of transport activity by at least 40% by 2030 and 70% by 2050, thereafter reaching zero-emission as soon as possible within this century (Ortiz-Imedio et al., 2021; Hoecke et al., 2021; Atilhan et al., 2021; Joung, Kang, Lee, & Ahn, 2020).

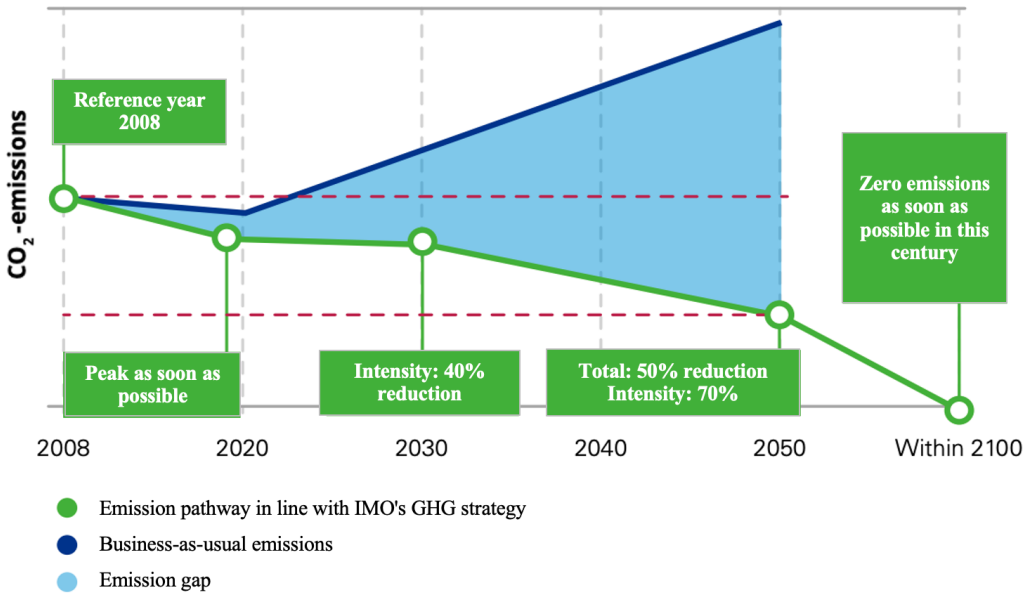


Figure 2. The vision of IMO and levels for GHG emissions (Joung, Kang, Lee, & Ahn, 2020).

Through the 2018 initial IMO strategy for reducing GHG emissions on ships, a framework for further action of goals is to be implemented in the short-term (2018–2023), medium-term (2023–2030), and long-term (after 2030) as shown in Figure 3 (Giese et al., 2021). However, a final plan is not expected until 2023 (Serra & Fancello, 2020; DNV, 2022).

2018	2023	2030	2050
IMO adopts initial strategy to reduce GHG emissions	**Short-term decarbonization deadline**	**Mid-term decarbonization deadline**	**Long-term annual GHG reduction deadline**
Sets a series of GHG emissions reduction milestones through 2050.	Requires finalized short-term measures to reduce CO2 emissions by 2030.	Mandates an average 40 percent reduction in CO2 emissions per transport work by 2030 compared with 2008 levels.	Requires a 50 percent reduction in total annual GHG emissions by 2050 and encourages efforts to phase out GHG emissions completely.

Figure 3. IMO rules and goals for international shipping made by the authors.

To make progress in reaching its goals by 2030 IMO, through the Marine Environment Protection Committee, has implemented mandatory measures for short-term GHG reduction. In Figure 4, four new IMO regulations aimed at reducing maritime carbon emissions and the environmental impact of shipping

will go into effect on January 1 2023. These are the EEXI (Energy Efficiency Existing Ship Index), the CII (Carbon Intensity Indicator) and the SEEMP (The Ship Energy Efficiency Management Plan) (UNCTAD, 2022; Poulsen et al., 2016; Christodoulou & Cullinane, 2021). In addition, the EEDI (The Energy Efficiency Design Index) was made mandatory to minimize CO_2 emissions from new ships through technical efficiency improvements (Christodoulou & Cullinane, 2021). The EEDI is presently the only carbon emissions regulation in international shipping to reduce CO_2 emissions, and it is predicted that the global shipping fleet will not be completely EEDI compliant until 2040-2050.

All Ships EEXI	All ships CII	SEEMP	New ships only EEDI
All ships of 400 GT or more are required to calculate their EEXI and implement technical means to enhance their energy efficiency.	All ships of 5,000 GT or more are required to calculate and report their operational CII, which relates CO2 emissions to the capacity of the and distance traveled.	Is the improvement mechanism for CII ratings. It includes objectives and planning, as well as new technologies and practices to increase fuel efficiency through operational improvements for both new and existing ships, as well as self-evaluation, verification, and company auditing procedures.	Promotes the use of energy-efficient equipment and engines in the design of new ships to reduce pollution and sets minimum energy efficiency standards per capacity mile (e.g., tonne mile) for various ship types and sizes.
Solutions to achieve the required EEXI: i) Propeller optimization ii) Power limitation	Solutions to achieve the required CII: i) Ship speed optimization ii) Alternative fuels	It is a mandatory plan for all ships with the goal of reducing fuel consumption in ship operations	Solutions to achieve the required EEDI: i) Improved hull design ii) Reduced electric consumption iii) Waste heat recovery

Figure 4. Mandatory measures for short-term GHG reduction made by the authors.

1.3 Contracts for Difference and EU Emissions Trading System

The green shift in Norway's maritime industry, aimed at maintaining international power and adopting zero-emission solutions, is not solely driven by regulations. However, the uncertainty surrounding future green technologies poses a significant threat to shipping companies as investments with long lifespans remain uncertain. Companies are primarily responsible for seizing market opportunities and addressing the challenges of the green shift. Nevertheless, the magnitude of the promise necessitates greater state involvement through an active and ambitious industrial policy that competes with the private sector (Norwegian Shipowners Association, 2023; Norwegian Ministry of Trade, Industry, and Fisheries, 2022).

Contracts for difference (CfDs) facilitate the development of a large-scale value chain for alternative fuels, crucial for achieving long-term zero-emission goals (Grimsby et al., 2023). A CfD bridges the gap between the market price and the required “strike price” for a fuel or technology. It offers financial support to ensure sufficient returns for project developers and private investors. Unlike

traditional subsidies, CfDs have a fixed time limit, known as the “contract”, which prevents lingering subsidies beyond their intended purpose (Clark et al., 2021). CfDs help bridge the price gap between traditional and climate-friendly fuels or technologies, enabling the supply of fuels or technology and reducing risks (Clark et al., 2021). Authorities utilize CfDs to support the adoption of emission-free fuels and associated infrastructure during the transition period (Grimsby et al., 2023). Institutional investors rely on long-term agreements with shipping companies and vessels to finance green ammonia or hydrogen production facilities, mitigating investment risks (Grimsby et al., 2023). The willingness and ability of shipowners and cargo owners to manage the risk of cost on green ammonia or hydrogen are pivotal for successfully implementing these agreements.

Starting from January 1 2024, European and international shipping in European waters will be included in the EU emissions trading system (ETS), requiring them to pay for their GHG emissions (Torvanger, Tvedt, and Hovi, 2023). In Norway, carbon pricing is a key climate policy instrument, with more than 80% of the country's GHG emissions being subject to a carbon tax or included in the EU ETS (Norwegian Ministry of Climate and Environment, 2019). Carbon pricing incentivizes emission reductions but may not fully justify the cost of developing new environmental technologies. To mitigate costs and risks during the transition, targeted support programs may be necessary, focusing on initiatives with future competitiveness without support.

1.4 Purpose of the Thesis

The purpose of this master's thesis is to examine how the Norwegian industry can successfully transition toward net zero-emission supply chain operations by the year 2050. The research aims to identify strategies, actions and factors that can enable the industry transition towards a zero-emission supply chain. Understanding the primary drivers and barriers of this transition is crucial for developing effective strategies, implementing zero-emission measures and fostering collaboration among diverse stakeholders, thereby establishing a solid foundation for the zero-emission market.

This research contributes to ongoing efforts of mapping the maritime supply chain by evaluating the current state of green shipping strategies in the Norwegian

maritime industry, examining the regulatory frameworks supporting this transition and identifying the critical stakeholders in achieving sustainability goals. This comprehensive analysis will provide policymakers, industry leaders and other relevant parties with a roadmap to navigate the route toward sustainability. In the dynamic shipping environment, ships must meet current requirements and anticipate and meet future expectations (Norwegian Shipowners Association, 2023). As the market expands a pressing question arises about who should navigate the change toward these goals.

Our shared curiosity and enthusiasm for the subject at hand inspired this investigation. Three key factors motivated us personally to conduct this research. First, we are highly concerned about the environmental impact of the maritime industry, especially in terms of emissions of GHG and air pollution. We acknowledge the urgent need for sustainable practices and seek to mitigate these adverse effects. Second, we recognize the importance of the Norwegian maritime industry to the economy of the nation, trade network and regional transport of goods. We are motivated to examine how the industry can align with sustainability goals while maintaining its economic significance and competitiveness. Finally, we are intrigued by the potential of zero-emission shipping as an innovative solution to environmental issues. We are eager to investigate strategies for zero-emission and identify opportunities for the Norwegian maritime industry to adopt these innovations and acquire a competitive edge on the international market.

1.5 Research Question

Based on the background information and purpose presented above, our research sets sail to answer the following research question:

> How can the Norwegian maritime industry successfully work toward zero-emission supply chain operations by 2050?

The significance of addressing the environmental impact of the maritime industry constitutes the basis for the research question, as evidenced by the facts and figures presented in the introduction. The shipping industry is known to generate numerous externalities, including GHG emissions, air pollution and other

environmental issues (Balcombe et al., 2019; Giese et al., 2021). Consequently, it is essential to develop a deeper understanding of how the Norwegian maritime industry can transition to more sustainable practices and zero-emission, considering its challenges and opportunities.

The research question incorporates the aspect of sustainability and seeks to identify strategies and approaches that can transform the supply chain operations of the maritime industry. We aim to contribute to the industry's overall objective of enhanced sustainability and competitive advantage by exploring these issues. To adequately answer the primary research question, it is necessary to consider the maritime industry's broader context and influence factors. This includes investigating the market, economic, regulatory and technological factors that significantly influence the transition of the industry toward sustainability. We argue that incorporating this comprehensive understanding is essential for providing meaningful insights and recommendations. By getting insight from experts within the field of shipping operations, green technology, sustainable practices and regulatory bodies, we aim to answer the following sub-questions:

1. What collaborative efforts and partnerships are needed to support the achievement of zero-emission in the Norwegian maritime industry?
2. How do cargo-owners perceive the integration of zero-emission shipping, and how does it impact their supply chain operations?

These sub-questions explore specific areas of interest important to our primary research question. Understanding the collaborative efforts and partnerships within the maritime supply chain will cast light on the actions and stakeholders required to achieve zero-emission. In addition, understanding the perspective of cargo owners regarding the implementation of zero-emission shipping will provide valuable insight into the potential challenges, benefits and effects on their supply chain operations. By addressing these sub-questions, we can understand the strategies, perspectives and repercussions associated with the sustainable transformation of the Norwegian maritime industry.

1.6 Justification and Contribution to the Research Area

In developing the study's objectives and research question, we sought to combine our aim to advance scientific knowledge with our desire to understand the transition to zero-emission shipping, address sustainability concerns and investigate the challenges and opportunities in the maritime shipping sector. This topic of interest was chosen because it is considered relevant and essential for companies to ensure environmental responsibility, comply with regulatory requirements and adapt to the rapidly changing landscape of the marine industry.

To ensure contribution to existing scientific knowledge, we examined the research's relevance, novelty, contribution and feasibility. The research question is highly *relevant* due to the topic of zero-emission shipping and the challenges faced by maritime shipping in Norway. This is particularly significant in the context of sustainable development, climate change mitigation and global efforts to reduce GHG emissions. Researchers have highlighted the importance of addressing environmental concerns for enhanced sustainability and supply chain operations (Geissdoerfer et al., 2017). This holds true, especially for the Norwegian maritime sector, which faces sustainability concerns, institutional and stakeholder pressures, and the need to leverage the emerging market for zero-emission shipping.

The literature emphasizes stakeholder engagement, collaboration, drivers and strategies for sustainable shipping practices. In addition, how they influence the behavior and practices of shipping companies to achieve sustainability goals (Yuen, Wang, Wong and Zhou, 2017). Additionally, addressing barriers influencing the transition to sustainability, as argued by the literature, is crucial for enhanced sustainability and competitive advantage in the context of zero-emission shipping (Shin, Thai and Yuen, 2018). Therefore, considering the substantial issues related to sustainability and the transition to zero-emission shipping in Norway, we contend that addressing these challenges and drivers are vital across various sectors and for stakeholders involved in the Norwegian maritime industry.

Reviewing existing papers on the topic, we discovered that our research is characterized as *novel*, despite sustainability in shipping being a widely discussed topic among researchers. By focusing on the practical aspect of implementing

zero-emission solutions, we delve deeper into the current situation, challenges and opportunities specific to the Norwegian maritime shipping sector. Hence, we argue that the study contributes to the existing literature by bridging the gap between theoretical discussions about sustainability, stakeholder theory, supply chain and practical implementation in the Norwegian maritime industry. By exploring the perspectives and experiences of stakeholders involved in the sector, we aim to provide valuable insights and practical recommendations for achieving sustainable and zero-emission shipping practices.

To ensure the *feasibility* of the study, we conducted expert interviews with a subset of key stakeholders in the Norwegian shipping sector. These stakeholders include shipping companies, regulatory authorities and industry experts specializing in green shipping technology. Most of the participants are part of a collaborative initiative or working group that addresses various issues and opportunities related to sustainable shipping and zero-emission. These engagements not only ensure the feasibility of our research but also enhance the relevance and practical applicability of our findings to the industry's real-world challenges and needs.

1.7 Limiting the Scope of the Research

While this thesis offers valuable insights into the potential of zero-emission shipping to transform the supply chain operations of the Norwegian maritime industry, it is essential to acknowledge the following limitations. Firstly, it focuses primarily on the Norwegian maritime industry, specifically the Norwegian short-sea shipping sector. Therefore, it does not extensively cover deep-sea shipping. This limits the generalizability of our findings to the broader maritime industry and their applicability beyond the Norwegian shipping sector. Additionally, the perspectives captured in this study represent key stakeholders in the Norwegian maritime industry including shipping companies, governmental bodies and industry associations, caution should be exercised when applying the findings to other contexts. It is worth noting that Norway demonstrates a relatively high level of ecological awareness, technological knowledge and competitive advantage compared to other countries worldwide.

While our research is focused on the 2050 goals, it is important to acknowledge that the Norwegian sector has proactively implemented its own goals, positioning itself ahead in the journey towards zero-emission supply chain operations. Therefore, we recognize the significance of incorporating mid-term goals by 2030. We acknowledge that this subject is new and potentially has limited data available. Limited access to reliable data sources or incomplete data sets could restrict the depth and accuracy of the analysis. This limitation may require researchers to rely on estimates or assumptions, potentially affecting the robustness of the findings and recommendations.

Furthermore, despite efforts to include participants with diverse backgrounds and viewpoints, the qualitative research methodology relied on a limited number of interviews with industry experts, and the sample size may not fully capture the entire range of opinions and experiences within the industry. Time limitations during the study may have resulted in some recent developments or emerging practices not being fully captured, indicating the need for further research on these dynamic aspects. Despite efforts to maintain objective, qualitative research is subject to bias and subjectivity, although robust data analysis methods were employed to mitigate these issues. In addition, the study's reliance on qualitative interviews as primary and organizational documentation as secondary sources introduce limitations, such as potential recall bias, individual perspectives and incomplete information due to its sensitive or proprietary nature.

Additional research is needed to establish a clear vision for the widespread implementation of zero-emission shipping in the maritime industry. Given these limitations, we interpret the results of this study with caution, recognizing the contextual factors at play. Our aim is at the findings will provide valuable insights for industry stakeholders, policymakers and researchers to better understand the opportunities and challenges associated with transforming supply chain operations through zero-emission shipping.

1.8 Thesis Outline

Chapter 1 introduced the background, purpose, motivation and significance of the thesis, justifying the study of zero-emission shipping in the Norwegian maritime industry. It established the context for the research, emphasizing the need to

transform the Norwegian maritime supply chain for sustainability and competitive advantage. In addition, a set of limitations was presented. Further, chapter 2 covers green shipping solutions for zero-emission shipping and cargo owners perspectives on the transition from road to sea. Chapter 3 reviews relevant theories, research and frameworks, establishing the theoretical foundations and identifying research gaps, emphasizing stakeholders, collaboration and sustainability, and a conceptual framework is presented. The chosen research approach, including strategy validation, design considerations and data collection is outlined in chapter 4. It argues for the selection of qualitative research with expert interviews.

Chapter 5 presents the qualitative interview results from key industry actors, highlighting stakeholders' opinions, practices and experiences with zero-emission shipping. Chapter 6 analyzes and discusses the main conclusions, connecting empirical findings with the theoretical framework from the third chapter. It aims to fully understand the research question and how the Norwegian maritime industry can successfully work toward zero-emission supply chain operations. Chapter 7 provides an executive summary of the research, highlighting significant findings for the Norwegian maritime industry to achieve zero-emission by 2050. The paper concludes with industry implications and future research.

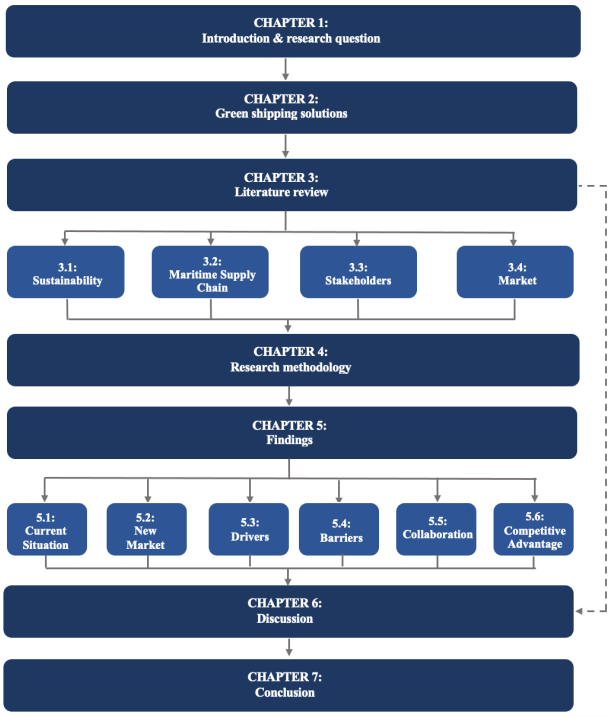


Figure 5. Illustration of thesis structure

Chapter 2 – Alternative Fuels, Energy Efficiency Measures and Cargo Transition from Road to Sea

This chapter provides an overview of the current solutions, fuels, technologies and energy efficiency measures the industry is working on implementing toward a globalized zero-emission market. In addition, a section on cargo owners perspective on changing cargo transportation from road to sea is presented.

3.1 Electrification and Alternative Fuels

Governments, stakeholders and customers are pressuring shipping companies to adopt technologies and propulsion methods that support decarbonization and GHG reduction (Norwegian Shipowners Association, 2023). Markets that promote the use of green technologies must be quickly developed if an effective green transition is to be accomplished. To achieve climate neutrality by 2050, shipping companies are exploring and implementing alternative fuels and technologies such as liquefied natural gas (LNG), biofuels, hydrogen, ammonia, methanol and electrification (Norwegian Shipowners Association, 2023).

Table 4 illustrates how some of the most significant alternative fuels and technologies vary in terms of their availability, infrastructure investment requirements for production, storage and distribution, and environmental advantages (Mäkitie et al., 2019; Bach et al., 2020). A more detailed table is presented in Appendix 1.

	LNG	BIO fuel	Hydrogen	Ammonia (green)	Methanol (green)	Electric-hybrid	Electric (full)
Reduction of GHG	Moderate	High	Very high	High	High	Moderate-high	Very high
Reduction on NOx	High	Negative	Very high	High	High	Moderate	Very high
Reduction of SOx	Very high	Very high	Very high	High	High	Moderate	Very high
Investment cost	Moderate	Low	High	High	High	Moderate-high	High
Fuel cost	Low	High	High	Moderate	Low	Moderate	Low
Availability (incl. infrastructure)	Moderate	Low	Low	Low	Low	Moderate	Moderate

Table 4. Characteristics and benefits of alternative fuels and technologies for shipping.

LNG with its near absence of SO_X and lower CO_2 and NO_X emissions compared to conventional marine fuels, provides immediate environmental benefits (DNV GL, 2019; Giese et al., 2021). The technology for using LNG as a ship fuel is readily available, enabling enhanced energy efficiency and reduced fuel consumption (Elkafas et al., 2020). However, careful monitoring and management are

necessary to minimize unintentional methane slips during LNG storage and transportation (Balcombe et al., 2019).

Biofuels can contribute to reducing shipping emissions and offer the possibility of diversifying the energy mix in the industry (Balcombe et al., 2019). The compatibility of biofuels with existing ship engines and infrastructure allows for utilization without significant modifications (Sekkesæter et al., 2023; Inal et al., 2022). However, ensuring the availability and scalability of sustainable feedstock is essential for their widespread adoption (Bengtsson, Fridell & Andersson, 2013).

Hydrogen is another fuel that can potentially replace fossil fuels in shipping, particularly in segments where electrification alternatives are challenging (Zincir, 2022). It offers significant reductions in air emissions when used in fuel cells and internal combustion engines (DNV GL, 2019). However, infrastructure development and scaling up hydrogen production from renewable sources are essential for its successful implementation (Bach et al., 2020). The limited knowledge base on hydrogen indicates the need for substantial research and technology development (Steen et al., 2019).

Ammonia offers the advantage of near-zero GHG emissions from ships when produced using renewable energy as a potential zero-emission fuel (Hammer et al., 2023). However, its adoption requires addressing challenges related to safe handling and storage due to its toxicity and flammability. It is crucial to establish sustainable ammonia production and develop legislation governing its use in ships and supply chains (Norwegian Ministry of Climate and Environment, 2019).

Methanol is a cleaner alternative to traditional fuels, which can significantly reduce harmful pollutants (Inal et al., 2022). It has higher current technology readiness levels than ammonia and hydrogen, making it an attractive option for immediate implementation (Norwegian Shipowner Association, 2023). However, safety concerns regarding toxicity and flammability require proper handling and safety measures.

Electrification and hybrid solutions offer the benefits of reduced local air emissions, GHG emissions and fuel consumption (Bach et al., 2020). Ships

operating on electricity have the advantage of improved energy efficiency and fuel savings. However, they require access to charging infrastructure in harbors and rely on the power grid (DNV GL, 2019). Using electric-hybrid propulsion systems can improve response times in safety-critical operations, extend engine lifetime, reduce maintenance, noise and vibrations.

Figure 6 describes the ability of various technologies to reduce greenhouse gas emissions and contribute to decarbonization efforts. Among these technologies, alternative fuels have the extraordinary capacity to reduce consumption by as much as 100%, according to the energy transition outlook report by DNV (2022). Decarbonizing shipping will primarily necessitate the use of new fuels, as well as increased energy efficiency and enhanced logistics (Figure 6). Regardless of efficiency gains, achieving ambitious decarbonization objectives will necessitate a switch to carbon-neutral fuels. Unfortunately, the new fuels are not currently available in sufficient quantities, typically require greater space, and are considerably more expensive. All of these elements strengthen the business case for energy efficiency

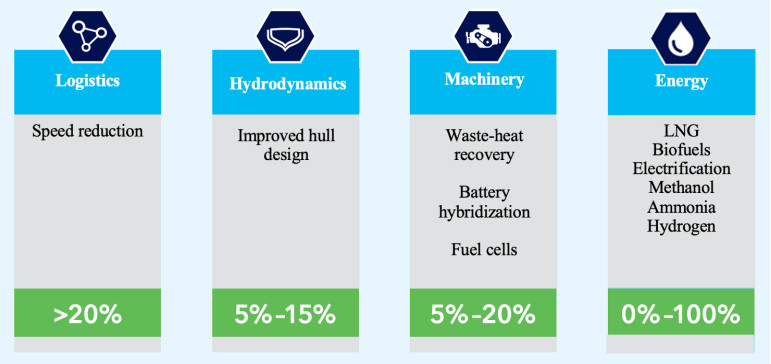


Figure 6. GHG emission-reduction potential of technologies that can contribute to decarbonization (DNV, 2022).

3.2 Energy Efficiency Measures

Energy efficiency is crucial for shipping companies aiming to decarbonize and reduce climate gases (Rehmatulla & Smith, 2015). It provides an effective means to make significant progress without relying on alternative fuels or extensive investments. By focusing on energy efficiency, shipping companies can optimize operations, improve vessel performance and minimize energy waste (DNV, 2022). These initiatives as illustrated in Figure 7, not only benefit the environment but

also lead to economic advantages through reduced fuel consumption and operating costs.

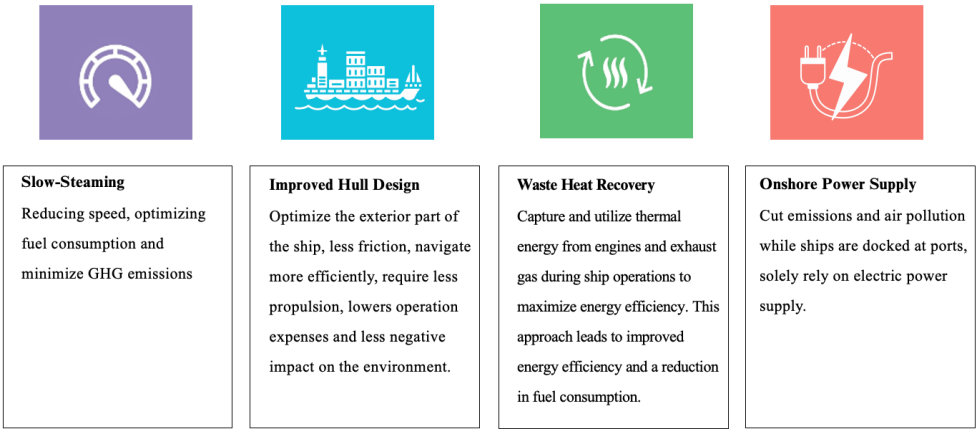


Figure 7. Energy Efficiency Measures

Slow steaming is an effective approach, which involves intentionally reducing ship speeds or derating engines to achieve lower power output (Psaraftis & Kontovas, 2013). Shipping companies can improve their cargo transportation through enhanced logistics and supply chain management. The main goal of slow steaming is to optimize fuel consumption and minimize GHG emissions in the shipping industry by operating vessels at lower speeds. This method efficiently mitigates the environmental impact of shipping operations by conserving fuel resources and reducing emissions. Further, enhanced synchronization of ship arrival in ports ('just-in-time') will permit fuel savings from slow steaming (DNV, 2022).

Hull design refers to the hull of a vessel, which is the exterior portion of the ship's body that makes contact with water. Optimizing the ship's performance and energy efficiency heavily relies on the hull design (Barreiro, Zaragoza & Diaz-Casas, 2022). In order to reduce frictional resistance, this involves using streamlined shapes, improving bow and stern profiles, and using special coatings. Ships can navigate through the water more effectively by improving their hull designs, requiring less propulsion power and fuel to reach the desired speed (DNV, 2022). Ultimately, this lowers operating expenses and has a less negative impact on the environment.

Waste heat recovery is vital in the shipping industry, capturing and utilizing thermal energy from engines and exhaust gases during ship operations

(Rehmatulla & Smith, 2015). These systems recover otherwise lost waste heat, converting it into useful power or heat, maximizing energy efficiency (Barreiro, Zaragoza & Diaz-Casas, 2022). They employ specialized equipment like heat exchangers or recovery units to transfer the captured heat to onboard systems or processes. The recovered heat has multiple applications, such as power generation, space heating and supporting auxiliary systems. By repurposing waste heat, these systems significantly improve energy efficiency and environmental sustainability in shipping (DNV, 2022). They reduce fuel consumption and GHG emissions and enhance operational efficiency while minimizing environmental impact.

Onshore power supply, also known as shore power or cold ironing, reduces emissions and air pollution when ships are docked at ports (Barreiro, Zaragoza & Diaz-Casas, 2022). By connecting the ship to the onshore power grid, it can switch off its engines and rely on the port's electric power supply. This eliminates the need for fossil fuel-powered auxiliary engines or generators, resulting in significant reductions in GHG emissions, particulate matter and other pollutants. Onshore power supply improves air quality in ports and is an effective strategy for reducing the carbon footprint of ship operations (DNV, 2022).

3.3 Transitioning Cargo from Road to Sea

Despite the acknowledged environmental superiority of SSS over road transportation, both road and rail transport remain the primary competitors for shipping services (Hjelle & Fridell, 2012). EU transport policy papers have consistently emphasized the need to shift cargo transportation from road to sea since the 1970s (Hjelle & Fridell, 2012). However, despite the longstanding efforts of Norwegian authorities to promote freight transport via sea, the current trend indicates a continued increase in land-based cargo transportation (Norwegian Port Association, 2023). This shift in trend highlights the persistence of challenges such as noise, accidents, environmental costs, traffic congestion and road wear. To effectively address these challenges, a substantial transfer of goods from land to sea is crucial.

Signals indicate that cargo owners are positive about using more sea transport (Norwegian Port Association, 2023). Short-sea shipping provides a safe and

environmentally friendly flow of goods along the coast and is considered to offer greater ecological and economic competitiveness compared to road transportation. This is primarily due to higher fuel efficiency, reduction of road congestion and reduced air pollution (Medda & Trujillo, 2010; Mulligan and Lombardo, 2006). The use of sea transportation allows access to international markets and connectivity across different regions (Hjelle & Fridell, 2012), thereby facilitating the expansion of trade and business opportunities. Nevertheless, cargo owners can encounter disadvantages when opting for SSS due to the limited connectivity between land modes at the origin and destination of SSS services. This results in a fragmented and slow transport chain, as well as an elevated risk of cargo damage (Paixão & Marlow, 2002).

The challenge lies in convincing cargo owners, satisfied with the existing options of land transportation, to transition to sea transportation (Shortsea Promotion Center & Maritime Forum, 2021). Cargo owners perceive this change as an operational risk, creating a motivational gap between their desire to transition goods and their willingness to explore alternative options (Shortsea Promotion Center & Maritime Forum, 2021). Furthermore, Norway's geographical characteristics, such as its extensive coastline relative to its land area, pose challenges for cargo owners and hinder change (Hjelle & Fridell, 2012). To incentivize the adoption of sea transportation, creating an attractive market environment is crucial. However, securing institutional capital for financing the development of new green maritime infrastructure, including alternative fuels like green hydrogen, green ammonia and biofuel, faces notable risks due to market demand (Grimsby et al., 2023).

The initial investment costs for shipping companies directly impact transportation expenses, resulting in higher prices for cargo owners (Ministry of Trade, Industry and Fisheries, 2013). In addition, the freight income must be high enough over time to cover operational and investment costs. For maximum earnings, the ship's operator will endeavor to sail with the maximum last. However, SSS shipping is characterized by relatively low margins and strong competition, including from land transport. If the ships are to take cargo from road transport, it is crucial that it can be done to last sufficiently larger volumes of goods so that the shipping price per unit will be competitive (Ministry of Trade, Industry and Fisheries, 2013).

Without cargo owners' willingness and capacity to bear this risk through long-term customer contracts to purchase green fuel, Norway may face challenges in achieving swift and extensive implementation of new green maritime infrastructure (Grimsby et al., 2023).

Barriers to transition cargo from road to sea transport from the perspective of cargo owners include lead time, frequency, transit time, flexibility and punctuality (Poulsen et al., 2016). Cargo owners prefer the closest port due to lower transport costs, shorter transport time and reduced cargo damage. In logistics, the duration of transport time holds significance, as cargo owners strive for shorter transit durations from origin to destination (Chang & Thai, 2017). Optimal lead time can be achieved by cargo owners setting a suitable volume threshold for longer transportation durations and participating in government-led mapping initiatives for goods transfer (Frostis et al., 2023). Furthermore, transit time stands as one of the most critical factors in logistics, influencing cargo owners' choice of transport mode.

Chapter 3 – Literature review

This chapter discusses relevant literature and theories that address the research question; *How can the Norwegian maritime industry successfully work toward zero-emission supply chain operations by 2050?* Reviewing and discussing existing literature will serve as the foundation for developing knowledge regarding relevant research conducted in the field. We use sustainability as a conceptual factor in our thesis and elaborate on how the supply chain in the marine sector can contribute to sustainability. Further, we enclose information about stakeholders to understand its contribution to the market of zero-emission shipping. In addition, we look into theoretical market theories for the implementation of zero-emission shipping (Figure 8). Lastly, a conceptual framework will be provided (Figure 12).

Figure 8. Structure of Literature Review

3.1 Sustainability

Sustainability is defined by The Brundtland Commission (1987, p. 42) as "development that meets the needs of the present without compromising the ability of future generations to meet their needs." Sustainability has become an umbrella term encompassing numerous concepts that both practitioners and academics frequently employ. Sustainable operations and supply chains have become well-established subjects, and Geissdoerfer et al., (2017) emphasize that sustainability concerns are increasingly being integrated into the agendas of policymakers and corporate strategies. A sustainable organization is a well-organized entity that can maintain its operations using its own generated income while positively contributing to the socio-ecological environment in which it operates (Parrish, 2010). This concept is closely associated with creating shared value, where all participants in the organization's value chain, including suppliers and customers, are considered essential stakeholders (Lozano, 2011). Alongside the importance of the Brundtland Commission's definition of sustainable development, the value of monitoring and guiding the process of sustainable development has grown over the last two decades (Singh et al., 2012).

According to Frempong et al. (2022), companies embrace sustainability practices to gain access to new markets and consumers (Lloret, 2016). In the era of sustainability, gaining and enhancing consumer loyalty has both short-and long-term effects on the performance and profitability of businesses. Sustainability practices of business organizations are those that address the economic, social and environmental concerns of businesses, and their stakeholders. Customers increasingly demand that the businesses they engage

with demonstrate environmental and social responsibility (Frempong et al., 2020). Most consumers prefer to associate with businesses with positive green-oriented perspectives or images (Orth & Green, 2009, cited in Frempong et al., 2020). Customer interactions with businesses influence their decisions regarding specific products and services and their loyalty. Companies that lead in green innovation may benefit from the first-mover advantage, enabling them to charge relatively higher prices for their green products and gain additional competitive advantages (Frempong et al., 2020).

3.2 Sustainable Supply Chain Management

Supply chain (SC) first appeared in the literature over thirty years ago when Oliver and Webber (1982) presented the initial definition for the administration of such systems (Christopher, 2016, p.3). Since then, supply chain management (SCM) has significantly expanded in research and industry. According to Barbosa-Póvoa, Da Silva and Carvalho (2018), the SC is a collection of processes to fulfill customers' requests, involving various network entities such as suppliers, manufacturers, transporters, warehouses, retailers and customers. It is a foundational system for every organization (Barbosa-Póvoa et al., 2018). The primary objective of the chain is to ensure customer satisfaction while minimizing costs (Regan, 2002).

The paper by Schöggl, Fritz, and Baumgartner (2016) addresses the issue of assessing sustainability issues across the entire SC. Companies are attempting to reduce their exposure to economic, environmental and socio-political risks in their SCs due to stricter regulations and heightened public awareness. This interest extends particularly to the consumer end of the SC (Schöggl et al., 2016). Therefore, significant brand-owning companies attempt to shape their businesses and SCs accordingly (Ayuso et al., 2013). Assessing sustainability behavior and performance of a company is challenging. Extending the assessment to include the SC amplifies the complexity, as it necessitates the development of a certain level of influence, trust, collaboration with supply chain stakeholders and appropriate technical tools (Xia & Tang-P, 2011, cited in Schöggl et al., 2016).

International and national flow of products, globally dispersed production capacities and sourcing parties, and the delivery of related services are all possible

with modern SCs. They operate as networks of organizations engaged in various processes and activities that create value for the consumer in the form of products and services (Christopher, 2016). These organizations interact upstream and downstream (supply and distribution). Typically, interacting organizations include suppliers, manufacturers, wholesalers, retailers and customers (Chopra & Meindl, 2000). When a logistics context is considered, roles such as logistic service providers (LSP), carriers, cargo owners and consignees are included to account for physical cargo and the associated informational and financial flows. As shipping activities entail SC integration with upstream cargo owners and downstream consignees (Lai et al., 2004), green shipping practices (GSP) are integrative, requiring cross-functional cooperation. As opposed to being restricted to a single organizational function with an emphasis on environmental preservation. Given the increasing emphasis on the environment by the international trading community, shipping companies should embrace GSPs as distinct corporate resources for enhanced performance (Lai et al., 2011).

3.2.1 The Maritime Supply Chain

The definition of the maritime supply chain is given by Jasmi and Fernando (2018) as the series of activities related to shipping operations and the flow of cargo from the point of origin to the point of destination (Lam, 2011). Brooks (2004) and Jasmi and Fernando (2018) describe the maritime SC sector as a unique organization that promotes economic growth and combines institutional roles with the typical functions of private organizations at various levels. The objectives of SC have evolved to incorporate activities focusing on economic and environmental factors, compared to a previous focus on cost-reduction strategies and commercial best practices for an optimized SC (Karmaker et al., 2021). Giving rise to the concept of green and sustainable supply chains.

The concept of a green or sustainable supply chain is not new to the marine industry, as it is prevalent and extensively discussed in nearly all industries, especially in the maritime sector, for resolving environmental issues (Davarzani, Fahimnia, Bell, & Sarkis, 2015; Zhu & Sarkis, 2004; Jasmi & Fernando, 2018). It entails shipping companies finding a harmonious balance among their economic, social and environmental performance to meet the interest of stakeholders with a legitimate or significant stake in the company (Tran et al., 2020). As in many

other service industries, shipping companies provide transportation services, but delivering these services requires substantial investments in capital products (Greve, 2009). The existing literature on sustainable SC factors does not address the current climate. It has therefore become a crucial factor for any business striving to achieve sustainability objectives (Rajeev et al., 2017). Pressure from customers, society, and local and global regulatory agencies compels the maritime industry to adopt green business practices (Jasmi & Fernando, 2018). As a response to meet emissions standards, reduce marine pollution and address climate change, the industry has started implementing sustainability strategies and adopting green technology. However, shipping and logistics being highly cyclical, must balance capacity and demand (Lister, 2015; Jasmi & Fernando, 2018) making the sustainable transition more time-consuming.

3.3 Stakeholder Theory

The operations of the maritime supply chain involve a wide range of stakeholders with different nationalities. These stakeholders engage in complex activities influenced by governments at various levels and transnational private entities (Lister, 2015; Jasmi & Fernando, 2018). According to the World Wildlife Fund, stakeholders are individuals, groups, or institutions that can influence or be influenced by the outcomes of a situation or issue (WWF, n.d.). The distribution of interests among different stakeholder groups in resource management varies based on their historical usage and relationship with those resources. Stakeholder theory is relevant to understand the motivations behind firms' sustainability practices, including those in the shipping industry. It involves identifying, analyzing and engaging with key stakeholders to address their interests and concerns. Understanding the expectations, needs and potential impact of each stakeholder group is crucial. By actively involving stakeholders in decision-making processes and fostering collaborative relationships, maritime stakeholders can mitigate conflicts, enhance transparency and promote sustainable practices (Jasmi & Fernando, 2018).

3.3.1 Stakeholder Analysis

In their study, Yuen, Wang, Wong, and Li (2020) conducted research and drew upon the findings of Wagner (2011) to identify four distinct stakeholder groups associated with maritime transport companies. They emphasized the significance

of stakeholder participation in promoting sustainability. These four stakeholder groups are categorized into an internal value chain, external value chain, regulatory, and public stakeholders. Shareholders and employees fall under the internal value chain category, while customers and suppliers belong to the external value chain group. The value chain is a concept developed by Michael Porter that represents the activities and processes through which a company adds value to its products or services. It is a systematic approach to understanding and analyzing the various activities involved in creating, producing and delivering goods or services to customers (Yuen et al., 2020; Wagner, 2011). Regulatory stakeholders engage with government entities, and public stakeholders include local communities and non-governmental organizations. Yuen, Wang, Wong, and Zhou (2017) argued that implementing sustainable shipping practices could foster relationships, enhance stakeholder satisfaction, build trust and promote commitment (Lun et al., 2016). This approach can ultimately lead to stakeholder collaboration.

3.3.3 Stakeholder Collaboration

Stakeholder collaboration involves diverse groups engaging in dialogue and working together to find solutions beyond their individual perspectives (WWF, n.d.). It requires effective communication, cooperation, coordination, trust, inclusion and constructive engagement. Through diverse expertise and resources, collaborative engagement promotes culturally sensitive approaches, partnership models and innovation. It also builds trust and credibility in decision-making, making stakeholder collaboration a powerful approach to addressing complex problems that cannot be solved through isolated efforts. Successful collaboration is more likely when there is room for negotiation, stakeholder interdependence in achieving individual and shared goals, and a willingness to participate (Orr, 2013).

Sustainability in business is now associated with strong collaboration among all SC stakeholders, moving away from the outdated notion of merely sustaining activities (Barbosa-Póvoa et al., 2018). Increased collaboration among SC members can foster improved environmental practices and reduce pollution (Vachon & Klassen, 2006). Integrating technology and environmental collaboration with key suppliers and customers have shown a strong positive correlation (Vachon & Klassen, 2006). However, collaboration may not always be feasible if initiatives lack a cohesive structure or require unrealistic levels of

participation (Orr, 2013). Shin, Thai, and Yuen (2018) emphasize that manufacturers increasingly acknowledge the significance of logistics as a means to gain a competitive advantage. This advantage can be achieved through closer collaboration with their LSPs (Lavie, 2006), which fosters the development of trust and commitment.

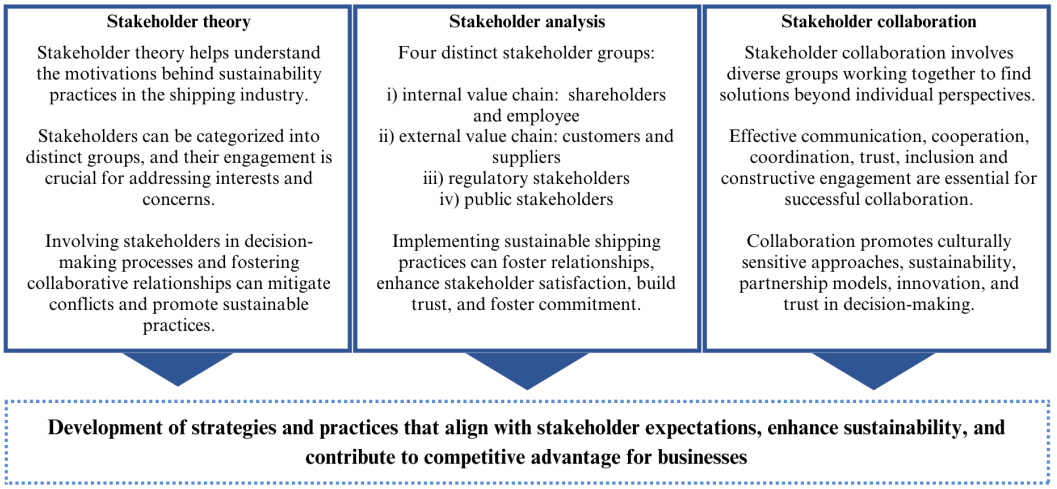


Figure 9. The Importance of Stakeholders

3.4 Market Structure

3.4.1 Emerging Markets

According to Sarasvathy and Dew (2005), the term "market" has been challenging to define because it is used in various ways and thus is difficult to define. However, existing literature on new markets can be divided into three categories: (i) demand, (ii) supply and (iii) institutions. As numerous academics have pointed out, the creation of new markets is fraught with insufficient information (Sarasvathy and Dew, 2005). Furthermore, they frequently deal with the creation of new markets while also surviving in existing markets. Sarasvathy and Dew (2005) assert that new markets can be created through exploration. In contrast, Bala and Goyal (1994) claim that new markets are constantly opening up due to technological, political or regulatory changes, and that the emergence of the new market then depends on the expectations of entrepreneurs and their necessary attempts to enter the market. An emerging market is a sector or industry in its early stages of development and growth, often characterized by new technologies, shifting consumer demands and changing regulations (Amaya, Arellana & Delgado-Lindeman, 2020). In addition, emerging markets evolve into significant consumer markets, while still supplying products to developed markets (Yeoman

& Santos, 2020). Therefore, the transition to zero-emission shipping can be considered a developing market.

3.4.2 Market Structure Theory

Market structure theory is an economic framework that focuses on analyzing the organization and characteristics of markets (Lun, Lai, and Cheng, 2010, p. 66). Shipping companies provide a variety of transportation services to meet the needs of their customers. Ships as their primary asset, vary greatly in size and type, and they provide a full range of services for a variety of goods, whether transported over short or long distances (Stopford, 2009, p. 52). According to Lun et al. (2010, p. 66) to achieve long-term competitiveness, a shipping company must be market-oriented, and its actions must be consistent with the marketing concept, positioning customers at the center of business operations. Getting near to the market and understanding how it is likely to evolve in the future is a key benefit of a company becoming market-oriented (Lun et al., 2010, p. 66). To obtain this knowledge, market intelligence about customers, competitors and the market must be gathered. Firms with a focus on the market must view information from a holistic business perspective, determine how to deliver superior customer value and take action to deliver customer value (Lun et al., 2010, p. 66).

A market-oriented shipping firm is adept at comprehending the preferences and needs of its consumers and deploying the necessary resources and skills to satisfy them profitably (Lun et al., 2010, p. 66). A customer-centric perspective requires determining which services their consumers value, by gathering intelligence on competitors, fostering multidisciplinary coordination and comprehending the performance implications. The decision of a cargo owner to support a shipping line is influenced by the attributes and characteristics of the shipping services they value. The sales representatives of shipping lines must directly contact cargo owners and consignees to obtain information on what and how to improve consumer value (Lun et al., 2010, p. 66).

3.4.3 Innovation Management

Schumpeter (1976) defines innovations as a source of “creative destruction” that alters the competitive strength of a company and the structure of an industry. In the field of business studies, innovation is widely recognized as a vital avenue for

maintaining competitiveness (Acciaro & Sys, 2020). Innovation management, an academic discipline, focuses on the systematic and strategic management of organizational innovation processes (Beltrán-Esteve & Picazo-Tadeo, 2015). In the logistics industry, innovation plays a significant role in creating value propositions encompassing two main aspects. Firstly, it enables providing services at a more competitive price by optimizing asset utilization, reducing fuel consumption and lowering overall unit costs. Secondly, innovation allows for differentiating services, providing unique features or capabilities that set companies apart from their competitors. Additionally, innovation is crucial in driving improvements in environmental performance and promoting sustainability within the logistics sector (Beltrán-Esteve & Picazo-Tadeo, 2015). According to Xie, Huo, and Zou (2019), environmental sustainability is essential and provides an opportunity to improve competitiveness using win-win logic (Porter & Van der Linde, 1995). Pioneers in green innovation strategies can potentially achieve and sustain competitive advantages (Albert-Morant, Leal-Millán, and Cepeda-Carrión, 2016). Innovations in green technology are anticipated to yield a double dividend, reducing environmental impact while contributing to the technological modernization of the economy (Albert-Morant et al., 2016).

Along the maritime logistics chains, innovation is increasingly recognized as a key determinant of success. However, despite the growing number of innovation efforts within the industry, little is known about the processes and mechanisms that drive successful innovation. As a result, many initiatives in the maritime sector are often uncoordinated, lacking focus and poorly managed, ultimately failing to deliver the expected results (Acciaro & Sys, 2020). By promoting innovation and implementing effective innovation management, shipping companies can drive internal sustainability improvements and contribute to the broader goals of sustainable shipping management (Xie et al., 2019).

3.4.4 Supply and Demand

The marine sector in Norway is in the midst of a transition process with technological change and discontinuities, technological change is widely acknowledged as an important driver of corporate and national advantage. The instability inherent in emerging technologies disrupts supply and demand equilibrium, rendering the microeconomic assumption of “all else equal” invalid

(Linton, 2005). As a result, Linton (2005) explains that the microeconomics theory fails to adequately address new product innovation, raising concerns as these disruptions are critical to economic growth for nations and provide profit opportunities for entrepreneurs and firms. The objective of SCM is to align supply and demand (Osobajo, Koliousis & McLaughlin, 2021), however, this can be challenging due to uncertainty. Identifying and addressing supply constraints is critical in a developing market. If a particular technology or product's supply is limited, it can stifle market growth and limit the potential benefits for both consumers and businesses. Recognizing supply constraints early on allows steps to be taken to overcome them, such as investing in R&D, improving production capabilities, or encouraging collaboration among industry players. If it becomes clear that the potential markets of interest are being hampered by a lack of supply, the government can step in to support or incentivize activities aimed at closing the knowledge and production gaps (Osobajo et al., 2021).

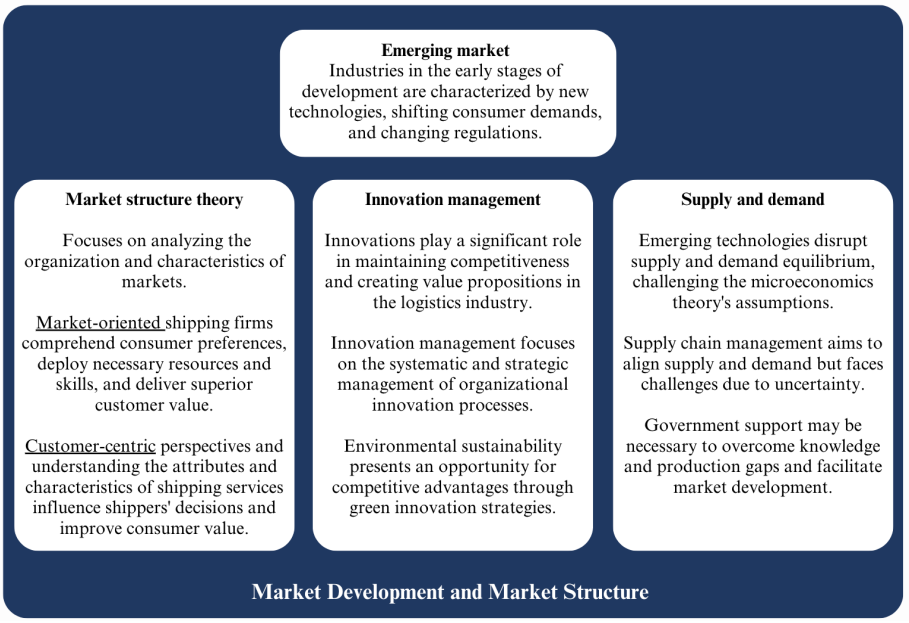


Figure 10. Market development and market structure

3.5 Drivers of the Transition to Sustainability

3.5.1 Institutional Theory

Institutional theory provides a conceptual framework for understanding the drivers and their relationships in adopting green SCM within the marine sector. The theory asserts that the institutional context and environment can significantly influence the development of prescribed organizational structures, often more so than market pressure and competition (Jasmi & Fernando, 2018). Institutional

theory suggests that coercive and normative pressures influence shipping companies and individuals in this industry. Coercive pressures come from legal and regulatory frameworks and the need to maintain relationships with port authorities and regulatory bodies. Normative pressures arise from the desire to conform to industry standards, gain peer acceptance, and maintain a positive reputation. Applying institutional theory to the shipping industry enables a deeper understanding of how formal and informal institutions influence the behavior and practices of shipping companies and how adherence to these institutions is crucial for maintaining legitimacy (Zucker, 1987), reputation and successful operations in the complex and interconnected world of maritime trade. These factors explain why maritime organizations take specific actions or perform in a particular manner in response to pressure.

Furthermore, according to Raza (2020), the institutional theory proposes that stakeholders use institutional pressure to legitimize the environment. Stakeholders are those with a legitimate or latent interest who can exert normative, mimetic, or coercive pressure on a shipping company to improve sustainability (Lai, Wong, Lun & Cheng, 2013). Consequently, such capabilities enable stakeholders to commit or withdraw resources in order to influence the productivity and financial outcomes of shipping companies. According to Lai et al. (2013), a shipping company's stakeholders consist predominantly of its shareholders, customers, employees, suppliers, society and the environment. Scholars have also included regulators as well since shipping companies need to comply with international and other regional regulations. According to Brammer et al. (2012) using paradigms developed from the institutional theory perspective is one method to investigate the challenges such that green SC implementation is frequently difficult to monitor, as is assessing the ecological footprint and practices in the maritime industry. One reason for this difficulty is that activities occur at sea and another is that the maritime industry utilizes networks of multi-tiered SCs (Brammer, Jackson, & Matten, 2012). The institutional theory emphasizes how organizations adopt various social structures as recommended social behaviors (Dacin, Goodstein, & Scott, 2002).

Institutional theory aids in the identification of factors that encourage the adoption of GSPs, such as regulations and trade potential (Lai, Lun, Wong, & Cheng,

2011). As firms strive for legitimacy by serving the interests of institutions in their business environment, this perspective broadens our understanding beyond firm boundaries. Lai et al. (2011) investigate how shipping companies manage institutional forces generated by customers and business partners concerned about environmental and productivity performance. Despite the shipping industry's role in facilitating international trade and economic growth through affordable and dependable shipment services, the study recognizes the neglected pollution from cargo movement. Cargo owners and customers, among others, request or require shipping companies to be more environmentally conscious when managing their shipments (Lai et al., 2011). As transportation accounts for more than 80% of IKEA's total CO_2 emissions, the company has implemented an environmental policy to minimize environmental harm by collaborating with its carriers to reduce CO_2 emissions and improve scheduling and transportation utilization (Lai et al., 2011).

3.5.2 Corporate Social Responsibility

Corporate social responsibility (CSR) is defined by Christensen, Hail, and Leuz (2021) as the corporate activities and policies that assess, manage and govern a company's societal and environmental responsibilities and impacts. The terms "CSR" and "sustainability" are used interchangeably in the literature, with sustainability representing a long-term perspective while CSR is normative and inclusive. In this context, CSR and sustainability refer to the corporate actions and policies aimed at evaluating, managing, and regulating the social and environmental repercussions of businesses. Given the current global and competitive environment, CSR has gained significant interest and importance. As a result, many companies now actively engage in environmental activities to maximize profits (Baron, 2001).

CSR has positively affected corporate evaluations, customer satisfaction and market value leading to increased profitability for shipping firms (Dahalan, Zainol, Yaa'kub, & Kassim, 2012). Yuen, Thai, Wong, and Wang (2018) emphasize the growing importance of CSR efforts in the maritime industry, as they can impact development, profitability and survival. Empirical evidence supports the notion that green shipping practices, including shipping design for compliance, improve shipping firms' financial and service performance, especially

when combined with appropriate standards, procedures and cargo owner collaboration. (Lun, Lai, Wong, & Cheng, 2015). Fjørtoft, Grimstad and Glavee-Geo (2020) defined four frequently cited reasons for engaging in CSR: reputation, moral obligation, sustainability, and license to operate (Figure 11). CSR goes beyond compliance with legal, regulatory and contractual requirements (McWilliams & Siegel, 2001), therefore, CSR activities and policies are typically voluntary, although they can be strategic or induced by markets (Kitzmueller & Shimshack, 2012).

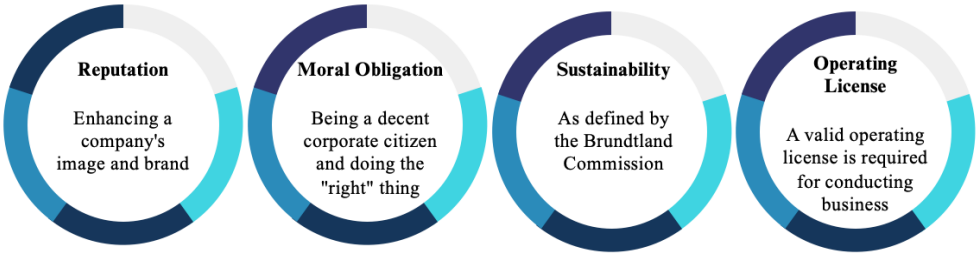


Figure 11. Reasons for engaging in CSR

3.5.3 Technology Adoption Frameworks

Two theoretical frameworks, the Technology Acceptance Model (TAM) and the Theory of Planned Behavior (TPB), serve as the basis for technology adoption research in various contexts. TAM is a widely utilized framework for assessing how individuals make decisions regarding adopting new technologies, the individuals' technological acceptance and adoption (Autry, Grawe, Daugherty & Richey, 2010). TAM has been widely utilized in information systems and other disciplines (Davis, 1989; Autry et al., 2010). TPB is widely known and utilized in marketing research studies (Ajzen, 1991). Therefore, it is a suitable paradigm for addressing consumer acceptance of various technologies. Therefore, both TAM and TPB are beneficial when examining the potential adoption of new technology (Koul & Eydgahi, 2017). TAM has since its introduction over 20 years ago (Davis, 1989) received a great deal of attention in operations management and business literature and aims to predict user acceptance and identify potential design issues before users interact with the system. In contrast, TPB focuses primarily on forecasting human behavior and incorporates the concept of perceived behavioral control. According to the TBP, (Hardeman et al., 2002; Ajzen, 2011), shipping companies may be more inclined to engage in green initiatives if they are convinced it will help them achieve their competitive goals (Wolf, 2014).

Autry et al. (2010) conducted an empirical study on supply chain technology adoption. They broaden the TAM by taking into account the technological turbulence of the environment as well as the organization's existing adoption of other SC technologies. In technologically volatile environments, perceived usefulness and ease of use have a greater influence on the intention to use the technology. However, in firms with greater technological breadth, the relationship between intention and actual implementation is weaker. TAM informs operations managers about firmwide acceptance and adoption of specific SC technologies. The intent of a firm to use SC technology for competitive advantage is influenced by technological turbulence, whereas effective dissemination throughout the SC network enables mutually agreed-upon results. User-friendly SC technologies offer rapid and effective implementation for responsive market demands (Autry et al., 2010). As companies investigate the various SC technology options on the market, they frequently purchase and test ("pilot") a number of them with a variety of partners prior to widespread adoption across all relevant SC relationships. Furthermore, companies frequently choose to upgrade their existing SC technologies in phases or differently based on the versions/platforms currently operated by their partner companies, resulting in multiple versions of a technology being held and operated through multiple overlapping upgrade cycles (Autry et al., 2010).

3.5.4 Resource-Based View

Resource-based view (RBV) theory is a strategic management framework that emphasizes the significance of an organization's internal resources and capabilities in achieving sustained competitive advantage (Tran et al., 2020). According to this theory, the key to obtaining a competitive advantage lies in possessing unique and valuable resources and capabilities that are not readily available in the industry and are difficult for competitors to imitate or replicate (Tran et al., 2020). By effectively leveraging tangible and intangible resources, shipping companies can enhance their sustainable competitive advantage, promote environmental responsibility, and achieve long-term success in the maritime industry (Tran et al., 2020). The resource-based perspective argues that innovations are sources of competitive advantage. Resources provide a competitive advantage if they are challenging to transfer or require significant prior investment (Greve, 2009). Major technological innovations meet these conditions as they spread slowly and

are adopted more rapidly by companies with high technological capabilities (Dewar & Dutton, 1986).

According to RBV, shipping companies allocate resources to the development of GSPs to obtain cost, service and environmental advantages in order to generate economic returns (Barney, 1991). Specifically, implementing a proactive environmental strategy, such as employing GSPs, will allow businesses to increase their resource capacities (Aragon-Correa and Sharma, 2003). As shipping companies face business uncertainty due to evolving regulatory pressures, such as GHG emissions and hazardous waste regulations, it will be advantageous for them to pursue a proactive environmental strategy by developing corporate resources, such as the adoption of GSPs, to deal with the enduring institutional pressures (Lai et al., 2011).

Drivers	Theoretical Hypothesis
Institutional Theory	Shipping companies are influenced by a combination of formal and informal institutions that shape their behavior and practices.
Corporate Social Responsibility (CSR)	CSR compels companies to proactively participate in environmental initiatives.
Technology Adoption Framework	Companies are more likely to increase their engagement in green initiatives when they are convinced that these initiatives will help them achieve their competitive goals.
Resource-Based View	Possessing unique and valuable resources and capabilities that are not readily available in the industry and difficult for competitors to imitate and replicate is key to obtaining a competitive advantage.

Table 5. Theoretical Drivers for net zero-emission

3.6 Barriers of the Transition to Sustainability

3.6.1 Transaction Cost

Transaction cost theory provides a theoretical framework for understanding the expenses incurred during economic transactions. It emphasizes the role of transaction costs, which include various expenses such as information searching, contract negotiation, performance monitoring and agreement enforcement (Yuen, Wang, Wong, & Zhou, 2018). These costs arise due to imperfections and complexities in conducting economic transactions. In the context of green technology implementation, transaction cost theory highlights how transaction costs can impede the adoption of environmentally friendly practices (Yuen et al., 2018).

In their study, Yuen et al. (2018) found that cargo owners perceive sustainable shipping practices of a shipping company as reducing sustainability-related transaction costs. The costs associated with transitioning to green technology, such as acquiring and installing new equipment, retraining personnel and modifying infrastructure, create uncertainties and information asymmetry surrounding green technologies. These costs can create barriers that hinder widespread adoption in the shipping sector. Building upon transaction cost theory, Vachon and Klassen (2006) conducted research and concluded that making asset-specific investments in a transaction raises the level of risk. There is a possibility that valuable knowledge and competitive advantage gained through the investment could be transferred to other suppliers or customers.

The theory of transaction cost suggests the need for governance mechanisms to reduce the cost of trade coordination, mitigate the opportunistic behavior of trading partners and prevent the loss of specific economic exchange investments. Based on the assumption that firms act self-interestedly to maximize financial gains (Smith & Grimm, 1987), these theoretical perspectives disregard environmentally responsible actions of firms that may not be solely motivated by economic gain.

3.6.2 Economies of Scale

Economies of scale refer to the cost advantages that arise when the scale of operations increases (Chaos et al., 2020). In the shipping industry, this concept manifests in the form of larger vessels and consolidated cargo, leading to lower unit costs per transported item. However, it is crucial to recognize that economies of scale can also contribute to higher environmental impacts, as larger ships tend to consume more fuel and emit greater amounts of pollutants. Finding the right balance between economies of scale and sustainability necessitates careful consideration of the trade-offs between efficiency gains and environmental consequences. Numerous studies in the field of maritime transport have examined economies of scale, focusing on various economic activities, with a particular emphasis on understanding the dynamics of container shipping and other shipping markets (Chaos et al., 2020). Shipping is a capital-intensive industry requiring substantial investments in vessels, infrastructure and operational resources, so shipping companies benefit from economies of scale (Cullinane & Khanna, 2000).

However, it is essential to note that barriers to initiating the transition can exist when implementing new technology and infrastructure (Chaos et al., 2020). This is because the full benefits of economies of scale may only materialize after a certain threshold is reached, creating initial obstacles to overcome. The literature requires research on whether the industry benefits from economies of scale or if there is a dis-economies of scale happening (Cullinane & Khanna, 2000).

3.6.3 Change Management Theories

Since its initial publication, status quo bias (SQB) has gained popularity as a subject of study. It has been observed in various industries and research contexts (Godefroid, Plattfaut & Niehaves, 2022). Individuals tend to maintain the status quo because they perceive the potential disadvantages of change to outweigh the benefits (Kahneman, Knetsch & Thaler, 1991). Generally, people are more influenced by the negative aspects of a change rather than the positive aspects, leading to the SQB. SQB refers to an irrational or biased preference for the status quo (Samuelson & Zeckhauser, 1988; Godefroid et al., 2012). Similar to other streamlined decision-making processes, it can save time and increase productivity. However, this bias can still be demonstrated even when maintaining the status quo is not possible. Godefroid et al. (2022) define SQB as an individual's preference to avoid changes and maintain the current situation. In the modern era, where technological advancements necessitate frequent organizational change, SQB can hinder progress (Godefroid et al., 2022).

Godefroid et al. (2022) argue that part of the SQB can be attributed to individuals' desire to avoid uncertainty and transition costs. Uncertainty costs arise when the value of a product or service is unknown in advance. Therefore, individuals tend to remain loyal to brands with which they have had positive experiences. Similarly, it may be prudent to continue working with the same supplier because switching to another would require investing in a due diligence process (Godefroid et al., 2022). However, these expenses have already been incurred for the current option. Consequently, maintaining the status quo could be seen as a prudent choice.

The psychological commitment associated with SQB is often described as the sunk cost effect. This effect refers to the increased tendency to continue a course

of action after an initial expenditure of money, effort or time (Arkes & Blumer, 1985). Furthermore, research on innovation resistance provides additional insights. Innovation resistance is a well-known phenomenon in academic literature, referring to normal consumer reactions when adopting and implementing an innovation. It encompasses any behavior to preserve the status quo and current beliefs. Innovations often bring about change, and individuals may have valid reasons to maintain the status quo, the higher risk perceived by an individual, the higher the resistance to the innovation (Ram, 1989). Status quo satisfaction is a factor that can further heighten resistance. For instance, a consumer who is extremely satisfied with a product is more likely to resist change than a dissatisfied consumer, assuming all other factors remain constant (Heidenreich & Handrich, 2015).

Barriers	Theoretical Hypothesis
Transaction cost	Uncertainty and information asymmetry surrounding green technologies creates cost barriers and hinder widespread adoption
Economies of Scale	The lack of economies of scale makes the technology too expensive and hinder widespread adoption
Change Management Theories	The negative implications of uncertainty and increased costs outweigh the positive aspects.

Table 6. Theoretical barriers for net zero-emission

3.7 Conceptual Framework

To establish a comprehensive foundation for our analysis, an extensive literature review was conducted considering the limited existing research and literature on our specific research topic. The review encompassed various research areas, including sustainability, market dynamics, drivers, barriers and stakeholder perspectives. By synthesizing the insights and theories presented in the literature, we have developed a robust conceptual framework, illustrated in Figure 12, which serves as a guiding framework for our further analysis and investigation.

The conceptual framework provides an overview of the expected relationship between our variables presented in the literature. Depicted below are the key factors and their relationship in influencing the adoption of zero-emission shipping and the transition toward sustainable supply chain operations. We believe the industry can effectively overcome barriers and eventually achieve sustainable supply chain operations and zero-emission shipping by synergistically combining

drivers and fostering collaboration, while also comprehensively understanding the needs and expectations of markets.

The framework comprises key elements we believe are essential to address the research question; *How can the Norwegian maritime industry successfully work toward zero-emission supply chain operations by 2050?* Assisted by the sub-questions, our research focuses on studying current zero-emission strategies in the Norwegian shipping sector to achieve the overall climate and sustainability goals. This by looking into the new arising market of zero-emission shipping, identifying drivers and barriers to this implementation and the collaboration between stakeholders to make this transition faster and easier. Utilizing this framework, enables us to navigate the challenges and capitalize on the opportunities in the collection of primary data through industry expert interviews, providing valuable insights to inform and enhance our understanding of the pathway toward achieving zero-emission supply chain operations in the Norwegian maritime industry by 2050.

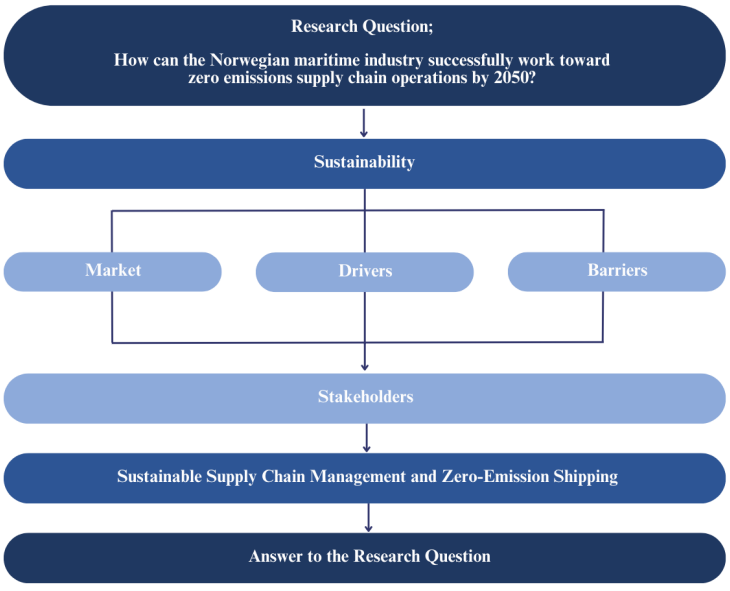


Figure 12. Conceptual framework

Chapter 4 – Research Methodology

This chapter will examine and justify the methodological decisions made to address our research question: *How can the Norwegian maritime industry successfully work toward zero-emission supply chain operations by 2050?* We will provide a detailed explanation of the selected strategy, approach and design, in

addition to outlining the procedure for data collection and analysis. Furthermore, we will assess the scientific quality of our research and discuss the constraints associated with our chosen method, as well as the methodological limitations of our study.

4.1 Research strategy

Properly selecting research methodology is critical for achieving research objectives (Ragab & Arisha, 2018). A research strategy is "a plan for how a researcher will approach answering his or her research question" (Saunders et al., 2016). According to Bell et al. (2019), methods refer to the strategy used by the researchers to collect and analyze the data resulting from the study. The literature distinguishes methods for quantitative and qualitative research.

Quantitative research focuses on collecting and quantifying numerical data, while qualitative research emphasizes using language for data collection and interpretation (Bell et al., 2019). Although qualitative research has been criticized for being subjective, difficult to replicate in different contexts, time-consuming and challenging to generalize (Bell et al., 2019), we believe that a qualitative approach is most suitable for answering our specific research question. Given the novelty of green shipping, zero-emission concepts and the ongoing learning process among marine stakeholders regarding their implications. A qualitative method provides a more in-depth understanding of the underlying dynamics and challenges. While a quantitative approach can provide statistical data on emissions and economic indicators, it may not fully capture the perspectives, motivations and challenges faced by industry stakeholders. Therefore, we opted for a qualitative approach to gain contextual and nuanced insights necessary for comprehending the complexities of leveraging the emerging market of zero-emission shipping within the Norwegian maritime industry.

A qualitative research approach, as described by Bell et al. (2019) is characterized as a more open-ended research strategy that links key concepts in the literature with the collected data. Thus, the strategy will be employed to gain a deeper understanding of the Norwegian maritime industry's SC transformation. This approach involves linking key concepts from the literature with collected data and exploring firsthand experiences, opinions and practices of industry experts. By

utilizing qualitative methods, we aim to uncover valuable insights and identify patterns in the industry, going beyond the limitations of quantitative data alone.

4.1.1 Scientific approach

In our master's thesis, we adopted an abductive research approach, which combines elements of both inductive and deductive methods (Bell et al., 2019). The deductive approach starts with existing knowledge to form a hypothesis and test the theory, while the inductive approach involves specific observations contributing to theory development (Bell et al., 2019). The abductive approach we employed utilizes a "hermeneutic circle," where there is a constant interplay between data and theory throughout the research process (Bell et al., 2019, p. 24).

In line with the literature, our study focuses on the importance of sustainability, opportunities and challenges of the market, as well as stakeholder collaboration within the maritime supply chain. Given the limited research on this topic in the Norwegian maritime sector, we employed an abductive reasoning approach, also known as systematic combining, to eliminate the limitations associated with deductive and inductive research (Bell et al., 2019, p. 24; Dubois & Gadde, 2014). Abductive reasoning allows us to develop explanations frequently by continuously examining theory and data. (Bell et al., 2019; Dubois & Gadde, 2014). This method facilitates the generation of new knowledge through creativity and adaptation of theories based on acquired information (Kovács & Spens, 2005). By employing this approach, we established a theoretical foundation, gathered primary data, and developed insights regarding the transition toward the emerging market of zero-emission in the Norwegian maritime sector. Through an iterative process, we analyzed the drivers, barriers, collaborative efforts and potential opportunities for competitive advantages related to sustainability objectives in the industry. This non-linear approach facilitated a deeper exploration of the topic, enabling us to move back and forth between the theoretical and empirical realms and enhance our understanding of the research area.

We gathered primary data to gain insights into factors influencing sustainability goals related to the emerging markets of zero-emission shipping. We conducted a literature review on maritime supply chains, stakeholder collaboration, market

theory and their connections to sustainability. This review laid the groundwork for our study, identified research gaps and guided the development of our conceptual framework (Figure 12) and investigation. While there has been some research on the environmental impacts on the maritime transportation sector (Shi et al., 2018), there was a lack of theoretical assumptions related to drivers and barriers to incorporating sustainable initiatives. Therefore, we utilized interviews to evaluate and redefine our theoretical foundation, filling this literature gap and showcasing the originality and significance of our research question.

Throughout the primary data collection phase, we made adjustments to ensure consistency between the literature and our evolving theoretical foundation. By incorporating new information from our primary findings, we redefined our initial conceptual framework and contributed to the body of scientific knowledge. This iterative process enhanced the robustness and relevance of our research, ensuring alignment between theoretical insights and empirical observations. Figure 13 illustrates our abductive research design during the study phase, which was influenced by Kovács & Spens' (2005) framework for examining the abductive method.

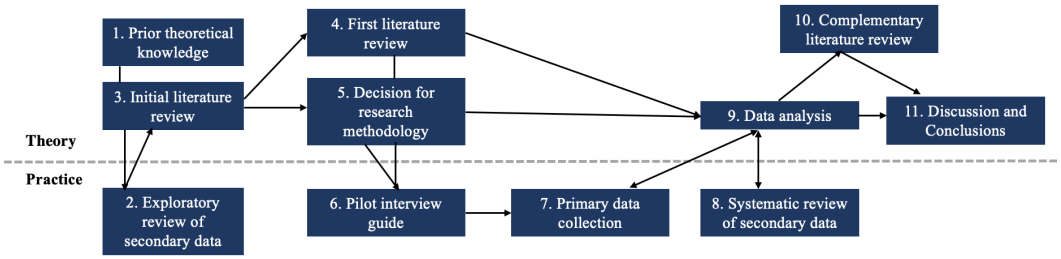


Figure 13. Abductive research design

4.2 Research design

A research design establishes a framework for data gathering and analysis (Bell et al., 2019). In other words, this framework leads researchers through data collection, analysis and interpretation, detailing how the empirical study will be conducted (Sreejesh et al., 2014). Furthermore, it reveals the kind of research and depth of analysis (Ghauri et al., 2020). As the overall research objective was to explore the transition of the Norwegian maritime SC to reach its ambitious goals by 2050, we determined that expert interviews would best serve as the research design for our investigation.

During the research design phase, we considered single and multiple case studies to explore our research topic. Case studies may be favored due to their ability to provide detailed data for in-depth analysis and insights into the implications of implementing GSPs and emission reduction strategies (Ridder, 2017). However, conducting multiple case studies to represent the entire shipping industry was deemed impractical and time-consuming, as businesses within the industry exhibit diverse practices, perspectives and sustainability priorities. This made it challenging to collect comprehensive data, documentation and observations across multiple businesses. Consequently, the findings from case studies would lack external validity and generalizability to the broader industry context.

In our research design, we opted for expert interviews to gain a broader understanding of the topic, particularly when access to the area of interest was challenging (Bell et al., 2019; Bogner et al., 2009). We employed expert interviews to elucidate sustainability concepts, gain insights from industry experts on their perceptions and practical limitations of the transition process to a new market. This method was also chosen due to the limited empirical exploration of the topic. These insights gained from the expert interviews contributed to refining our research question, identified conceptual perspectives and guided future empirical studies in the field of sustainable maritime SCs. Additionally, expert interviews were suitable for our qualitative research as they allowed us to investigate businesses facing similar opportunities and challenges (Bell et al., 2019). Interviewing multiple experts from the industry broadened our understanding. These practitioners are designated as experts due to their extensive knowledge and experience, therefore providing valuable and detailed insights. Expert interviews, as suggested by Bogner et al. (2009), enable the collection of inside knowledge from a larger group, reducing overall data collection time.

We adopted an exploratory approach to gain flexibility and delve deeper into our topic (Sreejesh et al., 2014). This allowed for a comprehensive and open-ended exploration of relevant information. Exploratory research, which focuses on uncovering new ideas and understanding the issue at hand (Sreejesh et al., 2014), often incorporates qualitative methods and has a more unstructured research process. Given the complexity and evolving nature of our research question on *How can the Norwegian maritime industry successfully work toward*

zero-emission supply chain operations by 2050?, an exploratory research design is the most appropriate method.

Our chosen research design enables us to investigate the factors, motivations, and obstacles related to integrating zero-emission shipping in the Norwegian maritime industry. This approach facilitates in-depth data collection and insights from industry experts, fostering a comprehensive understanding of the challenges and opportunities in sustainable shipping practices. As an exploratory study, we maintain flexibility to adapt our research process to emerging themes and insights during data collection and analysis.

4.3 Data Collection

According to Bell et al. (2019), data collection is the most significant part of any research. Our data collection is divided into a literature review, primary data and secondary data. Because we used a systematic combining method, we collected data and interpreted our findings using the model proposed by Dubois and Gadde (2002) (Figure 14).

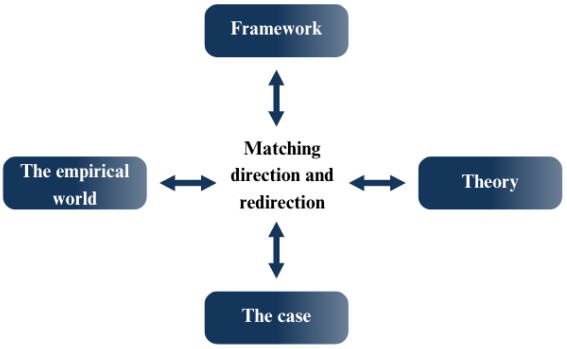


Figure 14. Systematic combining (Dubois & Gadde, 2002, p.555)

We began the data collection process by reviewing the literature to understand relevant concepts and theories related to our issue. The academic databases Google Scholar, Web of Science and Oria were beneficial to find articles and scientific papers within our field of study, we used various variations of the following keywords in our search:

"emerging market", "market", "zero-emission", "supply chain sustainability", "transportation", "sustainability", "IMO", "sustain* shipping", "environment*", "maritime supply chain", "cargo owners", "alternative fuels", "Norwegian

maritime industry", "innovation", "decarbonization", "environmental regulations" "carbon neutrality" "stakeholder collaboration", "green technologies"

The literature review played a crucial role in enhancing our comprehension of the principles of sustainable maritime practices and providing a broader context for our research. Through an extensive literature review, we aimed to establish a solid theoretical foundation and gain insights into existing knowledge in the field. Initially, our approach was misguided, as we overly focused on the technological aspects of the transition while neglecting the essential theoretical understanding of logistics. This realization prompted us to shift towards adopting a more theoretical perspective to address the challenges at hand effectively. Furthermore, to ensure the quality and reliability of our sources, we relied primarily on highly-ranked publications and credible academic journals. In addition, we incorporated industry reports from reputable consulting firms, regulatory agencies, and notable shipping companies. We searched for comprehensive and up-to-date data from various sources to support our analysis and findings.

To ensure the relevance, validity and quality of our study, we focused our literature search on the period between 2000 and 2023. Given the recent development of green shipping research (Wan et al., 2016), this time period was chosen because the demand for sustainability and technological advancements is relatively new and the market is evolving quickly. Therefore, including publications from this particular time frame allowed us to access the most recent and relevant research in the field. While giving priority to more recent articles ensures their relevance, it is essential to note that some of these articles may still be undergoing peer review. Since the concept of green shipping was introduced in the late 1990s and early 2000s (Shi et al., 2018), the focus on technologies, short-sea and Norway has grown in recent years within research. Concurrently, older sources were included to establish industry facts, emphasize the need for reforms and provide historical context. By incorporating a mixture of older and more recent sources, we intended to provide a comprehensive overview of the topic and stay current with the most recent developments.

Using our systematic combining approach, we were able to traverse back and forth between empirical findings, published literature and analysis. The literature

review influenced the development of the conceptual framework and questions for future qualitative interviews. Similarly, empirical findings assisted us in strengthening our research question and revising the theoretical foundation, which was a constantly shifting process.

4.3.1 Primary Data

Primary data is original information collected by researchers for the first time (Kothari, 2004). It includes data obtained through interviews, observations, focus groups and questionnaires (Kothari, 2004). In our qualitative study, we conducted semi-structured interviews to gather in-depth insights into the practical orientations within the industry. This open dialogue approach allowed the interviewees to elaborate on the topic of interest and ensure comparability (Bell et al., 2019).

These interviews facilitated the exploration of new concepts and theories, as their adaptable structure allowed for nuanced findings and perspectives (Kothari, 2004). Personal interviews also provided better control over samples and reduced the likelihood of nonresponse (Kothari, 2004). However, this method has limitations. The time-consuming nature of organizing and conducting interviews constrained the sample size. Additionally, the presence of researchers during physical discussions could introduce bias into the results, potentially influencing the trajectory of the interviews.

Initially, for the first two interviews, we provided an interview guide (Appendix 2) to participants beforehand, allowing them to prepare and discuss technical solutions for achieving zero-emission. However, we found that this approach resulted in rigid and stilted interviews. To improve the flow, we decided not to provide the interview guide in advance for the third interview. We used a different guide (Appendix 3) with questions on industry perspectives, collaboration, stakeholders, current practices and the future outlook. This change allowed for a more natural and conversational interview experience. Based on this, we decided not to share the questions with subsequent interviewees, as they were able to respond well without prior knowledge of the specific questions. In addition, we piloted the interview guides before conducting the actual interviews to familiarize ourselves with the process and identify any problematic questions (Bell et al.,

2019). The pilot phase helped us modify and refine the queries, in addition, provided valuable insights, such as the need to repeat questions and allocate sample time for open discussions and conclusions. The semi-structured interviews greatly contributed to the breadth of our exploratory study by generating new perspectives and additional questions.

Before each interview, a thirty-minute preparation meeting was held to tailor the interview to the individual interviewee. This involved assessing their background, discussing and finalizing interview questions and modifying the interview guide as needed. The semi-structured interviews were conducted in Norwegian and detailed notes were taken to capture important insights and observations. To discuss our findings, we translated the interviews from Norwegian to English while maintaining the essence of the conversations. However, we acknowledge that this may introduce a potential limitation to our research. During the interviews, active listening, probing questions and follow-up inquiries were used to encourage participants to share their perspectives, experiences and ideas freely.

4.3.1.1 Sampling

To investigate the factors and challenges influencing the transition to zero-emission solutions and identify drivers in this process, we conducted interviews with experts in the field. Our research employed purposeful sampling, strategically selecting participants who were relevant to our research question. This approach aligns with qualitative research methodology, where the research question is central to the sampling process (Bell et al., 2019). Rather than random selection, we chose individuals based on their expertise and relevance to our research objectives. While random selection is not always necessary or preferable (Eisenhardt, 1989, p. 537), it is important to acknowledge the potential for human bias in the sampling process.

For our research, we employed purposive sampling, specifically criterion sampling, to select participants who met specific criteria. This approach allowed us to gather comprehensive data and analyze the various stakeholder viewpoints influencing the transition towards zero-emission within the Norwegian maritime sector. Among the different types of purposive sampling (Bell et al., 2019),

snowball sampling was deemed most suitable as it enabled us to contact relevant individuals with whom we had no prior affiliations.

Our initial focus for snowball sampling was on “green shipping” within Norwegian shipping companies. Through a representative from BI, we obtained an interview with an expert in maritime shipping operations who then directed us to other internally and externally relevant individuals. This chain of referrals led us to several Norwegian shipping firms and regulatory authorities. Additionally, one of the participants suggested interviewing two specific regulatory experts, resulting in two additional interviews. Although one recommended company was unavailable for an interview, their suggestion still enriched our research. To ensure sufficient information, we continued the snowball sampling process until we reached a point of perceived saturation, as it was challenging to determine the exact number of interviews required. This collaborative approach, facilitated by snowball sampling, expanded our network of participants and provided a diverse range of perspectives for our study. Snowball sampling involves participants assisting researchers in identifying potential subjects, leading to a deeper understanding of the concept (Bell et al., 2019).

To ensure a diverse range of perspectives, we employed multiple methods to identify interview participants, including email and LinkedIn outreach, website searches, contacting BI representatives, and leveraging our professional and personal networks. These channels allowed us to engage with individuals from various backgrounds and companies, offering a comprehensive viewpoint for our study. We approached a total of 19 representatives to participate in our study. As qualitative research emphasizes in-depth investigation rather than the sample size (Tuckett, 2004), our final sample consisted of 9 interviews. On average, each interview lasted between thirty to sixty minutes, depending on the depth of the discussion and the amount of information shared.

In our data collection process, we categorized three target groups for the semi-structured interviews with participants from diverse backgrounds to obtain comprehensive insights. The first target group focused on experts in maritime shipping operations and port management. This group consisted of four interviewees, including three experts in maritime shipping operations and one

expert in port management and operations. Their direct knowledge and experience provided valuable insights into sustainable maritime practices and the operational aspects of transitioning to sustainability in the maritime sector. In the second target group, we interviewed three experts from government and governance agencies involved in marine policy and regulation. These regulatory and policy experts played influential roles in shaping the regulatory frameworks and policies impacting the maritime industry. Their perspectives shed light on current initiatives, regulatory landscapes and potential future developments related to green shipping in Norway. Lastly, we engaged with two industry experts specializing in green shipping technology and sustainable practices in the final target group. These participants had extensive knowledge and expertise in innovative technologies, alternative fuels and emerging trends contributing to sustainable growth in the Norwegian shipping sector. Their insights deepened our understanding of technological advancements, potential solutions and future prospects for sustainable practices in the industry.

The selection of our sample was based on two key factors: a comprehensive understanding of the sector's green shipping tendencies, and the availability and willingness to participate. This approach ensured an appropriate sample size for achieving our thesis objectives and capturing diverse viewpoints and experiences within the Norwegian marine industry. We received enthusiastic responses from the majority of the participants, who not only provided valuable information themselves but also recommended other suitable individuals for interviews.

We used online communication tools like email, Zoom, and Teams for data collection and communication with companies and participants, which proved to be efficient and productive. While online video calls have limitations according to Bell et al. (2019), such as internet connectivity and sound quality, we did not encounter any difficulties with these tools. During interviews, we faced challenges in maintaining flexibility when topics were repeated or touched upon again. To address this, we adjusted our approach by skipping redundant questions or seeking clarification, ensuring focused and efficient discussions. Two interviews involved two interviewees, which we initially expected to be challenging, but the process went smoothly.

It is important to note that not all participants could answer every question due to their diverse backgrounds and perspectives. We strictly followed BI's anonymity and ethics guidelines during our data collection process. No additional data, voice recordings, images, or identifiable information were collected. To maintain anonymity during interviews, we took detailed notes instead of recording audio, on all except two interviews, or capturing images. We were careful to avoid any questions that could potentially reveal the identity of the interviewees. Furthermore, we ensured ethical practices by upholding honesty, independence, respecting the participants' dignity, and adhering to established ethical standards.

Interview object(s)	Date	Target Group	Position	Interview Length
Object 1	09.03.2023	Maritime Shipping Operations and Port Management Expert	Executive Vice President	45 minutes
Object 2	23.03.2023	Maritime Shipping Operations and Port Management Expert	CEO	60 minutes
Object 3	26.05.2023	Maritime Regulatory and Policy Expert	Section Manager for New Maritime Technology	60 minutes
Object 4	30.05.2023	Maritime Regulatory and Policy Expert	Member of the Committee on Energy and the Environment	60 minutes
Object 5	02.06.2023	Maritime Regulatory and Policy Expert	EU Advisor	60 minutes
Object 6	05.06.2023	Green Shipping Technology and Sustainable Expert	CEO	45 minutes
Object 7	06.06.2023	Maritime Shipping Operations and Port Management Expert	Terminal Advisor	60 minutes
Object 8	09.06.2023	Green Shipping Technology and Sustainable Expert	Two Environment Advisory Consultants	35 minutes
Object 9	14.06.2023	Maritime Shipping Operations and Port Management Expert	Ammonia Commercial Manager & Director Industry and Market Leads	30 minutes

Table 7. Overview of experts

4.3.2 Secondary data

Secondary data, collected by other researchers or organizations, offers advantages in terms of time-saving and access to high-quality data (Bell et al., 2019). We utilized secondary data sources, such as archival data and company reports, to establish a foundation for understanding the complexity connected to the maritime industry. As well as the strategies, challenges and opportunities of transitioning to zero-emission solutions. Our sources included our participating companies' annual reports and climate action, where many of the interview objects generously offered us their annual reports containing sections on sustainability and green shipping solutions. These sources provided us with valuable insights into sustainability commitments, green shipping solutions, regulations and

environmental impact assessments. We also consulted additional online resources, including company websites to broaden our understanding and serve as a springboard for further investigation of the topic of interest. Although the specific findings from these reports may not have been explicitly included in our research findings, they substantially influenced our understanding of the topic.

While secondary data influenced our research design and analysis, it is important to note its limitations. Bell et al. (2019) caution that secondary data may have quality concerns or risk misinterpretation due to a lack of familiarity and control. To ensure data reliability, we cross-checked information with interviews and other primary data sources or additional sources. This iterative process of integrating theory and data allowed us to enhance the credibility of our findings and consider different perspectives.

We utilized secondary data to complement and support our primary data, ensuring the reliability and depth of our findings. By incorporating perspectives from other researchers, we expanded our understanding of the research topic and considered alternative approaches (Bell et al., 2019). This approach was beneficial as it allowed us more time to analyze our primary data. Furthermore, secondary data, often generated by experienced researchers, tend to be of high quality enhancing the reliability of our study (Bell et al., 2019). The inclusion of secondary data sources significantly enriched our research by providing crucial context, background information and existing knowledge related to the transition to zero-emission solutions.

4.4 Data analysis

Data analysis plays a crucial role in our research, involving data organization, reduction and interpretation (Bell et al., 2019). Qualitative research, which relies on unstructured language generates a large and complex dataset (Bell et al., 2019). To analyze our qualitative data, we adopted the grounded theory strategy, which involves systematically collecting and analyzing data throughout the research process (Bell et al., 2019; Strauss & Corbin, 1998). This strategy aligns well with our abductive approach, allowing us to discover new relationships and variables (Dubois & Gadde, 2002). In this method, data collection, analysis and the eventual formulation of a theory are interconnected. Our aim is to identify

strategies, actions and factors that can enable the industry transition toward a zero-emission supply chain.

Our analysis began with a comprehensive literature review on emerging markets, stakeholder collaboration, maritime supply chain investigation, sustainability concepts in the maritime sector and their drivers and barriers. This process allowed us to construct a conceptual framework (Figure 12) and develop a strong understanding of the key concepts. The literature review also informed the creation of two interview guides (Appendix 2 and 3). Throughout the research, we continuously refined our theoretical foundation based on insights gained from semi-structured interviews and reports. Initially, our thesis aimed to assess the feasibility and sustainability of green shipping technologies for Norwegian short-sea shipping. However, as we delved into the literature and engaged with industry experts, we realized the need to broaden our objective to explore the emerging market of zero-emission shipping in the Norwegian maritime industry. This shift in focus highlighted the importance of stakeholder collaboration, technological advancements, and policy frameworks in achieving sustainable and competitive maritime operations. Consequently, we revised our conceptual framework and research question to ensure they aligned with this evolving understanding of the research topic.

During the data analysis phase, raw data from the semi-structured interviews were organized by taking detailed notes capturing key points, essential quotes and noteworthy statements. This data was then coded, which is a central process in grounded theory (Bell et al., 2019). Coding involves treating the data as potential indicators of concepts and continuously comparing these indicators. Given that we used two interview guides for all interviews, it was easy to identify indicators related to the research question.

To start with, we undertook the task of categorizing the notes and answers into distinct themes. Through this process, we successfully identified five overarching themes: new market, drivers for sustainable shipping, barriers for sustainable shipping, collaboration and competitive advantage. We also encountered quotes that resonated with multiple themes, along with an introductory section exploring the current situation and sustainability aspects. Pertinent responses were

highlighted and compared to identify patterns and variations. The coded data were then categorized accordingly. This process was repeated for each theme, laying the foundation for analyzing inter-category relationships and providing a clear understanding of the central themes.

We recorded the first two interviews using interview guide 1 with our participants consent. These recordings were later transcribed, a time-consuming process that added credibility to the interviews. However, to streamline the process and focus on extracting essential information, we decided not to record and transcribe the subsequent interviews. Although this absence of recordings is a limitation, we took detailed notes during these interviews, capturing fundamental information and critical insights from the conversations. While the lack of recorded interviews may introduce potential bias or overlook specific data nuances, we mitigated these concerns by maintaining meticulous documentation and carefully reviewing the interview notes to ensure the analysis's accuracy and validity. Although recording all interviews would have provided a more accurate and detailed account of the conversations, capturing respondents' exact words and ensuring no significant comments were missed (Bell et al., 2019), our thorough note-taking and subsequent analysis still yielded valuable insights for the data analysis stage. We acknowledge the limitation of not having recorded interviews and made efforts to minimize biases through extensive documentation and reflection on the interview notes.

The collected data and analysis were synthesized and organized into a cohesive report. Notes and supplementary materials were reviewed and analyzed to identify themes and key findings, which formed the basis for structuring the report. The report followed a logical flow, including an introduction, description of zero-emission strategies, literature review, methodology, findings, discussion and conclusion. Findings and analysis are presented clearly, supported by relevant quotes and interview examples. The discussion section provides a deeper exploration and interpretation of the findings, connecting them to existing literature. The conclusion summarizes key findings and offers insights for future research. Overall, the report aims to provide a comprehensive and evidence-based account of the research findings. It shed light on regulations, sustainable strategies

and technologies relevant to achieve sustainable shipping goals within the Norwegian marine sector.

4.5 Scientific Quality and Methodological Limitations

A significant challenge for researchers is to collect qualitative data of the highest quality. To assure scientific quality, two prominent criteria must be met: trustworthiness and authenticity (Bell et al, 2019; Lincoln & Guba, 1985). There are four criteria for evaluating the trustworthiness of a study: confirmability, dependability, transferability and credibility. This section will discuss these criteria and the authenticity of the data collected for this research paper.

4.5.1 Trustworthiness

Confirmability regards the objectivity of the research, or whether the researcher's values and opinions influenced the study's findings (Bell et al., 2019, p. 48; Stahl & King, 2020). Despite Bell et al. (2019) stating that achieving complete objectivity is impossible, even if unintentionally, the researchers' meanings and interests will influence the study in some way. To ensure confirmability, we will make every effort to be objective. By maintaining detailed documentation of the research process and employing rigorous data analysis techniques, we enhanced the confirmability of our study, promoting transparency and trustworthiness (Stahl & King, 2020). This systematic approach is intended to ensure consistency and replicability, thereby increasing the study's confirmability. Reflexivity was essential for preserving confirmability. We routinely engaged in critical self-reflection and ongoing discussions regarding our values, assumptions and potential biases. This method reduced the influence of our biases on the interpretation of the data, ensuring that the findings remained objective. To further improve confirmability, we utilized peer debriefing and member checking. As we are two researchers that contributed to the data analysis, providing a variety of perspectives and reducing individual biases. Consistent discussions and debriefings validated and refined emerging themes, developing consensus. We were able to evaluate and provide feedback on the findings as a result of member checking, enhancing credibility and confirmability.

Dependability refers to measures of reliability that guarantee the study is consistent and trustworthy (Bell et al., 2019). The criteria require that

comprehensive records of all phases of the research process be maintained in an accessible manner (Bell et al., 2019; Guba & Lincoln, 1985). Quantitative researchers (Bell et al., 2019) criticized unclear descriptions of how and why participants were selected for interviews and how researchers chose to analyze the gathered data. To ensure the dependability of our research, we have maintained a methodical and well-documented research design of data on our research process, including problem formulation, participant selection and notes, so that a third party may easily review, audit and critique our process (Bell et al., 2019). The methodology chapter extensively details the decisions made to ensure the trustworthiness and robustness of our findings. We acknowledged methodological constraints, biases and obstacles. Peer review was sought to enhance the reliability of our research, and our supervisor provided valuable input and feedback on the research design, data collection and analysis techniques. Although the interviews were conducted in Norwegian, we allocated sufficient time to take detailed notes and ensured accurate translations to minimize imprecise wording. Additionally, each sentence was thoroughly proofread for quality assurance

Transferability refers to the extent to which the findings of a study can be applied or generalized to other contexts or settings (Bell et al., 2019; Stahl & King, 2020). Williams (2000) emphasized potential issues associated with generalization in qualitative research. Obviously, the proposed transferability of a research study with a relatively small sample size could be questioned. Bell et al. (2019) argue that it is nearly impossible to know how findings can be generalized to other contexts when conducting interviews that are primarily connected to a small number of organizations within a single industry. Thus, we attempted to conduct as many interviews as possible while also interviewing individuals from a variety of organizational backgrounds. We conducted nine interviews with eleven individuals from nine distinct organizations to ensure a diverse range of perspectives within the unique and complex context of the Norwegian maritime industry. While our findings may not be fully generalizable to all maritime industries or regions worldwide, they provide valuable insights and potential strategies specifically applicable to organizations within the Norwegian context. Some findings are firm-specific, reflecting the unique circumstances of the participating organizations, but they can still serve as inspiration and reference for others.

Our interview participants do not represent the entire population (Bell et al., 2019). The dynamic nature of the field of zero-emission shipping and sustainable SC operations means that the strategies, challenges and opportunities discussed in this thesis are subject to change. However, our research provides a solid foundation for future exploration and inquiry in this field. Future research can build upon our findings and delve deeper into specific aspects, considering the evolving landscape of technologies, regulations and industry practices.

Credibility refers to the believability and trustworthiness of the research findings. It involves establishing the accuracy and authenticity of the data collected and the analysis conducted (Stahl & King, 2020). To achieve a high level of credibility, we gathered primary data through qualitative semi-structured interviews with individuals possessing essential expertise, as well as secondary data through internal documents, reports and existing research. As this study drew from multiple data sources, it was determined that an abductive strategy was necessary to ensure its credibility. Multiple perspectives and viewpoints enhanced the credibility of our findings by capturing a broader spectrum of insights and reducing the likelihood of individual bias (Stahl & King, 2020). To increase the likelihood of truthful responses and increase the credibility of our research, we informed and emphasized to participants that their participation in the interviews was voluntary and that they could disengage at any time.

4.5.2 Authenticity

In addition to the four trustworthiness criteria, Guba and Lincoln (1985) emphasize the authenticity criteria, which raises concerns about the broader social and political implications of the research (Bell et al., 2019, p. 365). The criterion requires the researchers to represent different points of view within the focal situation adequately (Bell et al., 2019). On account of the importance and complexity of our topic, we deemed it necessary to seek out a variety of viewpoints. In order to obtain multiple perspectives on *how can the Norwegian maritime industry successfully work toward zero-emission supply chain operations by 2050?,* a diverse sample of actors including industry stakeholders, policymakers and experts, was interviewed. To ensure fair circumstances for all participants, two interview guides were utilized. Furthermore, we aim for this thesis to raise awareness and prioritize zero-emission shipping and supply chain

sustainability among a wider range of industry stakeholders. By thoroughly examining the current state and potential of the Norwegian maritime industry, presenting diverse viewpoints, and fostering discussion and collaboration, we aspire to contribute to the social and political discourse on sustainable practices in this sector. Our research seeks to inspire positive transformations, advancing an environmentally friendly and competitive maritime industry.

Chapter 5 – Empirical Findings

In this chapter, we present the findings derived from our qualitative research and expert interviews, aligning them with the emerging themes identified during the coding and analysis of the gathered data. Our primary objective was to gain valuable perspectives from stakeholders within the emerging market of zero-emission shipping while identifying enablers and barriers encountered during this transition process. The chapter is organized into five key themes: new market, drivers for sustainable shipping, barriers for sustainable shipping, collaboration and competitive advantage. These themes offer a comprehensive understanding of stakeholders' perspectives, challenges, and pathways toward establishing a sustainable and zero-emission maritime supply chain by 2050. Additionally, we have included a section that provides an overview of the current situation and summarizes the most important findings.

Throughout the presentation of our empirical findings, relevant quotes from the interviews are included to support and enhance the clarity and coherence of our findings. The focus of our empirical findings is on transforming the market of zero-emission shipping in the Norwegian maritime industry to reach the ambitious sustainability goals by 2050. By presenting these findings, we aim to provide a holistic view of stakeholder perspectives and shed light on the complexities of transitioning to a sustainable and zero-emission maritime industry.

5.1 Current Industry Situation

This section offers an overview of the Norwegian shipping sector's current state, informed by expert interviews. As shown in Figure 15, key findings reveal a shared goal of achieving zero-emission and the importance of reducing consumption alongside technological advancements. Promising approaches include energy efficiency measures and alternative fuels. Collaboration,

innovation, and individual responsibility are deemed crucial for environmentally friendly and economically viable practices.

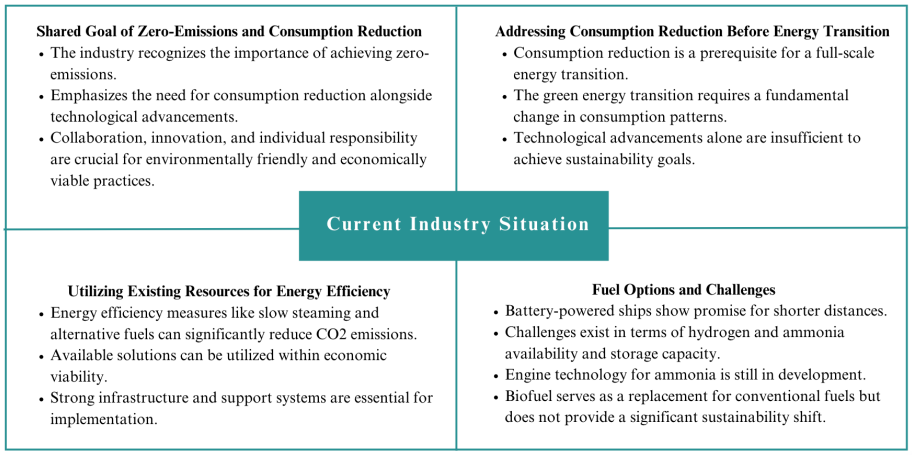


Figure 15. Key takeaways from the current situation

Diverse perspectives and voices converge in the field of climate action and sustainability to shape the conversation and drive change. One significant aspect recognized by object 6 is the importance of sea transport in the sustainability discussion. Due to the significance of maritime transport for both global trade and emissions, object 2 establishes a shared goal among the industry to *"complete the circle and return to our starting point of zero-emission."* Object 5 acknowledges, in the pursuit of sustainability, the emergence of new energy carriers presents both opportunities and challenges. The concept of zero-emission requires new technological advancements, however, consumption can be reduced without a full-scale change in technology. As pointed out by object 1 *"The goal of embracing green energy faces resource scarcity, necessitating a reduction in consumption before a full-speed energy transition can be achieved"* and object 7 *"the climate aspect is currently addressed, essential to recognize that climate issues are intertwined with resource management."* These findings suggest that the issues of consumption reduction must be addressed before a full-scale energy transition can be achieved. Implying a shift towards green energy cannot solely rely on technological advancements, but also requires a fundamental change in consumption patterns.

This is further validated by object 6, which indicates that with today's fleet of ships, a reduction of 60% in CO_2 can be achieved. Implementing energy efficiency measures such as slow steaming and possibly alternative fuels *"you can*

get a reduction of 72%," emphasizing the crucial point *"the solutions are here, we can use what we have" - object 6*. Echoing similar sentiments object 2 expresses *"What we have experienced is that propulsion systems and technology systems are easier than getting hold of fuels. It is these value chains that need to be in place to make it happen."* This stresses the importance of utilizing the resources at hand that are proven to be within the scope of economic viability. In addition, to develop strong infrastructure and support systems in order to make these sustainable practices a reality.

The use of batteries to power ships shows great promise in the Norwegian sector. However, object 2 acknowledges their limitations, as *"battery-powered ships are better suited for shorter distances."* Object 1 expresses that increasing the range of battery-powered ships appears to be more environmentally friendly and energy efficient than relying on hydrogen and ammonia as fuel sources. Discussing the different fuel options available in the sector, object 2 provides insights into their respective characteristics. *"There is no hydrogen production today, so availability is limited"* while also stating that hydrogen is difficult to carry at large volumes as it takes up a large amount of space. Object 8 recognizes that the infrastructure and development of LNG are in place after 20 years. Moving forward the industry needs to accelerate this process *"We would like to have the same green development, but it must happen a lot quicker" - object 8*. *"Ammonia can go a long way, but engine technology is not finished there" - object 2,* this is also emphasized by object 9. Further object 2 states that biofuel presents itself as a long-distance sailing alternative, however, it merely replaces the conventional fuels currently in use without providing a significant shift in terms of sustainability.

Norway, as highlighted by object 5, holds a prominent position in maritime affairs, often serving as a pilot country for innovative solutions. Despite the leading position of Norway, meeting sustainability targets remains a significant challenge, as object 6 points out that only *"one in seven"* people believe the targets set for 2030 will be reached. This highlights the need for proactive measures and concerted efforts to overcome hurdles and achieve ambitious sustainability objectives. The maritime industry in Norway, as revealed by object 2, exhibits a diversity of approaches toward sustainability. While some

stakeholders actively invest resources in green and innovative initiatives, others adopt a more cautious approach. The current situation in the shipping sector calls for coordinated efforts to navigate the path toward sustainability. Most of the interviewees believe that through collaboration, innovation and individual responsibility, stakeholders can work together to develop environmentally friendly, economically viable and socially equitable practices in the marine industry.

5.2 New Market

This section explores the early stages of the zero-emission market in the maritime industry while capturing the dynamics and challenges of shaping a sustainable market. Prioritizing market development is crucial, with authorities and larger actors playing key roles. Pioneers, complexities, and bridging the gap between expertise and market understanding are discussed as illustrated in Figure 16. Financial profitability, stimulating market demand and creating green workplaces are highlighted.

Figure 16. Key takeaways from market development.

Our findings suggest that the market for zero-emission shipping is absent. Object 6 states, *"It is the market that needs to come to life, and it is the market that we must focus on first before moving forward. This is key."* This aligns with the perspective of object 7 "*Build up markets before you build up supply chains*."

Transitioning to a new market necessitates a new set of habits and thought patterns, which object 6 emphasizes as difficult for all those involved in emerging markets. Authorities are highlighted by multiple interviewees as an important factor in this transition, as new markets require structure, guidelines and support to overcome economic hurdles, share risk and stimulate supply and demand. The interviewees share similar thoughts about the role of authorities, *"In a transition phase, the authorities have an extremely important role in making this happen [...] the authorities must take part of the risk and not let the private business sector take it all" - object 6. "The Norwegian authorities should step in as a market maker" - object 2.* Authorities can contribute substantially by shaping the market landscape and fostering the necessary conditions for sustainable market development.

For the market to grow someone has to take the first step and be a pioneer, however, in such complex markets determining who should take the lead can be difficult. Object 3 asserts, *"We cannot push anyone to be first in a market. Fortunately, it is often the slightly larger players who take that role, with the desire to take the risk of building a new market and bearing its costs."* This suggests a natural tendency for slightly larger players to assume the pioneering role, as they are driven by ambition and willingness to take calculated risks. In addition, often more capable of shouldering the costs and uncertainties of building a new market. Object 9 shares similar perspectives on the complexities surrounding the establishment of a zero-emission market, *"No established market where we talk about supply and demand but more about stimulating a demand that gives us zero-emission solutions."* This viewpoint acknowledges that transitioning to zero-emission solutions necessitates a proactive approach to creating market demand. Furthermore, object 9 expresses, *"difficult to test the market before a commercial market exists,"* implying that traditional market testing and validation methods may not be readily applicable in the absence of a commercial market. As there is no established customer base or market dynamics to assess and analyze, the situation presents unique challenges. Our findings highlight Norway's position in creating and fostering this new market by being a vital player in pilot projects, as mentioned by object 3. There is some disagreement among the interviewees, as object 1 states, *"The German market has made greater progress compared to the Norwegian market. They are more*

concerned about it and willingness to pay is something we see, the Norwegian market is quite immature."

Our findings revealed multiple obstacles in consideration of the new market. Object 6 suggests that all actors must contribute to developing the market as *"the market does not understand all the environmentally proven measures - it becomes too complex."* The complexity surrounding environmental measures often leads to a lack of understanding among market participants, with a need to bridge the gap between environmental expertise and market understanding. A comprehensive approach is valued by object 2, "*The entire value chain must be in place – comprehending value chains and understanding how they function is important.*" This supports the identification of opportunities for improvement and developing more sustainable practices by contemplating the entire lifecycle of products and services. Furthermore, object 3 remarks on the importance of financial profitability, as actors in the industry seek to maximize profit and sustainable solutions are more costly, *"We must be aware [...] that finances wield significant control. Shipowners, understandably, prioritize financial profitability."* Object 5 highlights the importance of stimulating market demand for actors to survive while also creating employment opportunities, "*Scale and growth to create green workplaces*." This finding highlights the potential ripple effect, as organizations scale and adopt sustainable practices, they can inspire and influence other companies within their sector or supply chain to follow.

5.3 Perceptions of Drivers for Sustainable Shipping

The transition towards a sustainable maritime market is driven by key factors, including the influential role of cargo owners and the regulatory frameworks established by authorities. Cargo owners drive change through their investments in sustainability, while authorities provide guidance and enforce industry practices. Incentives and funding mechanisms further contribute to this transformation. A comprehensive understanding of these drivers is essential for fostering sustainability and driving positive change within the maritime industry.

	Object 1	Object 2	Object 3	Object 4	Object 5	Object 6	Object 7	Object 8	Object 9
Position	Executive Vice President	CEO	Section Manager for New Maritime Technology	Member of the Committee on Energy and the Environment	EU Advisor	CEO	Terminal Advisor	Two Environment Advisory Consultants	Ammonia Commercial Manager & Director Industry and Market Leads
Type of expert	Maritime Shipping Operations and Port Management Expert	Maritime Shipping Operations and Port Management Expert	Maritime Regulatory and Policy Expert	Maritime Regulatory and Policy Expert	Maritime Regulatory and Policy Expert	Green Shipping Technology and Sustainable Expert	Maritime Shipping Operations and Port Management Expert	Green Shipping Technology and Sustainable Expert	Maritime Shipping Operations and Port Management Expert
Drivers	Incentives for new technology	Cargo is king — consumers is always the driver	Incentives from the government	Authorities and interaction with all actors in the market	The authorities	Interaction with all actors in the market and risk capital	Industry actors	Regulations and cargo owners	Regulations and consumers/cargo owners

Table 8. The most important drivers highlighted by the interviewees

We encountered different attitudes and perceptions regarding who should bear the responsibility of being the driving force. Some respondents provided clear responses, such as object 6, which stated "*Cargo owners are the driving force behind the transition and the ones who have to pay for it."* Cargo owners are also highlighted by object 8 which states *"cargo owners take more initiative."* Their decisions and willingness to invest in sustainable practices significantly impact the drive for change. Object 2 shares similar sentiments, stating, *"our focus is on what the customer sets as requirements,"* while also stating *"cargo is king"* highlighting a profit-oriented and customer-centric approach. Object 6 also mentions, *"More of our customers' customers are beginning to demand more sustainable solutions."* Object 9 states *"consumers are key."* These findings imply that businesses are motivated to adopt greener practices to meet consumer demands as sustainability expectations flow down the supply chain. According to object 5, shipping is at the core of driving change and the shipping industry itself plays a pivotal role in global trade and has the potential to make a significant impact on sustainability efforts.

The majority of participants underscored the importance of authorities and regulations as crucial players. Object 5 remarked, *"The authorities set requirements, then the industry follows,"* while object 2 stated, *"The common denominator is the authorities and what they actively use, purchasing power, to challenge and implement technology development."* Object 6 also supported this view, stating that it is essential for authorities being major purchasers to, *"use their purchasing power to set tougher sustainability requirements in their procurement contracts to establish longer purchasing contracts."* The authorities

are therefore emphasized as critical to help the industry *"considering the significant investments involved"* - *object 6. "Important with the authorities and that they enter the field to start a new zero-emission market"* - *object 9.* Authorities provide a framework within which businesses can operate and innovate. Furthermore, their purchasing power can act as a catalyst for change and create market demand by demanding sustainability in their procurement contracts and making long term-contracts and commitments. However, object 7 strongly disagrees and perceives the authorities as a barrier to sustainable development, stating, *"Held back by the authorities."* Suggesting that while the government demands change, it is challenging for businesses to meet the necessary conditions for implementation when the government fails to keep the progress and pace of the industry.

The interviewees also highlighted the importance of incentives and funding as significant contributors to the transition. Object 1 mentioned, *"Support schemes for new technology [...] and regulations are another important driver*," while object 3 emphasized, "*Absolutely the most important arrangement."* Object 2 described incentives as "*a positive driver and a prerequisite for success."* Clear and robust regulations establish a regulatory framework that promotes sustainability and ensures a level playing field for businesses. These mechanisms incentivize businesses to invest in and develop innovative solutions by offering financial support for the adoption of sustainable technologies and practices. Without failure, all the interviewees commented on the balance between punishment and reward. Emphasizing the need to suggest both carbon tax incentives and funding opportunities.

5.4 Perceptions of Barriers to Sustainable Shipping

This section explores challenges hindering the adoption of sustainable practices in the maritime industry. Key barriers include risk assessments, lack of clear standards, economic viability, resistance to change, infrastructure development, and regulatory requirements. Understanding and addressing these barriers is crucial for promoting the adoption of sustainable shipping practices and achieving the industry's environmental objectives.

	Object 1	Object 2	Object 3	Object 4	Object 5	Object 6	Object 7	Object 8	Object 9
Position	Executive Vice President	CEO	Section Manager for New Maritime Technology	Member of the Committee on Energy and the Environment	EU Advisor	CEO	Terminal Advisor	Two Environment Advisory Consultants	Ammonia Commercial Manager & Director Industry and Market Leads
Type of expert	Maritime Shipping Operations and Port Management Expert	Maritime Shipping Operations and Port Management Expert	Maritime Regulatory and Policy Expert	Maritime Regulatory and Policy Expert	Maritime Regulatory and Policy Expert	Green Shipping Technology and Sustainable Expert	Maritime Shipping Operations and Port Management Expert	Green Shipping Technology and Sustainable Expert	Maritime Shipping Operations and Port Management Expert
Barriers	High cost	High cost	Finding the best solution transitioning to green	Sticking to the goals and keeping the will	Supply and demand, build a market that does not exist	Someone must be the first-mover and lack of supply and demand	The authorities, exiting habits and resistance to change	High cost and the supply and demand	The difficulty to test a market that is not commercial and get a good business case

Table 9. The most important barriers highlighted by the interviewees

One interviewee, object 1, highlighted the importance of risk assessments in determining the maturity and financial feasibility of sustainable initiatives, stating, "*Everything is based on risk assessments and whether there is a risk to the technology, maturity of the technology, risk around the financial part of it."* By conducting thorough risk assessments, businesses can ensure the ethical and successful implementation of sustainable initiatives, as well as make informed decisions to enhance safety, as expressed by object 3, *"The understanding of how to reduce risk and why certain measures must be taken."* The absence of clear standards was identified as a significant risk by object 6, who cautioned against adopting solutions that may not gain traction, stating, "*No standards - locking yourself into something that will not really become anything is a huge risk."* Establishing robust standards not only fosters investor and consumer confidence but also facilitates the compatibility, dependability and scalability of sustainable solutions.

In light of our research, we have come to reassess our initial assumption regarding the technology barriers to the implementation of zero-emission solutions. Contrary to our expectations, the insights provided by industry actors indicate that technology itself is not the primary obstacle. Instead, the focus shifts to the economic aspect and the need for a compelling business case. Object 9 confidently asserts, *"No technology barriers, know how to make it and transport it, boils down to getting a good business case."* Echoing this sentiment, object 8 concurs, stating, *"Technology can be done, it is economics that is a barrier."* While remarkable progress has been made in developing sustainable technologies, the economic dimension presents a formidable challenge. This underscores the crucial importance of ensuring that sustainable initiatives are not only

environmentally sound but also economically viable and financially attractive to stakeholders. Without a strong business case, widespread adoption becomes an uphill battle. To address these economic barriers, it becomes imperative to establish robust business models and economic frameworks that incentivize and support the integration of sustainable practices. The economic challenges often stem from factors such as substantial upfront costs, uncertainty surrounding returns on investment, and the need to compete with existing, more established and potentially less expensive alternatives.

Another crucial barrier we analyzed through our interviews is the resistance to change and the aversion to new ideas, which can hamper progress. As object 5 aptly put it, *"Aversion to anything new,"* while also emphasizing that *"no one wants to change."* Similar sentiments were expressed by object 2, who noted the challenge of social acceptance, stating, *"social acceptance, difficult to be accepted by customers and surroundings."* This reluctance to embrace uncertainty and willingness to pay for uncertain outcomes were also identified as barriers by object 4 and object 6, with object 4 stating, *"Keep the will, be willing to use the entire apparatus even when it is not popular."* Commitment and a steadfast focus on sustainability objectives are crucial for long-term success.

To stimulate the market and expedite the transition, it is imperative to recognize the value of sustainable practices and encourage investments in green technologies. Additionally, the development of necessary infrastructure, such as fueling stations or manufacturing facilities, is critical to support the widespread adoption of new technologies. However, building a market for non-existent technologies and infrastructure presents significant challenges, as noted by object 5, *"Supply and demand. The technology and solutions are validated, show that it works, building a market that does not exist, that is the biggest barrier."* The lack of demand is further exacerbated by insufficient production, as highlighted by object 4, *"Lack of production. It is hardly produced, at least not within a reasonable cost. Must bring up the demand."* Object 2 also emphasized the need for coordinated planning and infrastructure development, stating, *"The main challenge is that you need simultaneity in building ships, but at the same time someone has to build a factory that can make the new fuel."* Addressing these infrastructure challenges often comes at a higher cost, as acknowledged by object 1, "*That it costs, it is more expensive to run green."* Object 8 provides an

interesting perspective on the interplay between supply, demand and regulatory requirements. They emphasize that the lack of supply and demand should not be seen as a barrier in itself. According to object 8, *"supply and demand come with time because you have to follow requirements from regulations."* This viewpoint underscores the significance of regulatory frameworks in driving the transition toward sustainable practices. Regulations play a crucial role in shaping market dynamics and creating the necessary conditions for the emergence of supply and demand for sustainable solutions. By establishing stringent environmental regulations and setting clear sustainability targets, governments can create a regulatory environment that encourages the adoption of zero-emission technologies and practices.

5.5 Collaboration

Collaboration is vital for sustainable practices in the maritime industry. Our findings on the topic reveal, as illustrated in Figure 17, its significance in fostering environmentally friendly, economically viable and socially equitable solutions. Shipping companies exhibit a tradition of cooperation, emphasizing common goals and open dialogues. The influence of cargo owners, evolving collaboration methods and risk-sharing are crucial. Despite challenges, a collaborative mindset accelerates innovation, propelling the industry toward sustainability.

Figure 17. Key takeaways from collaboration

Our findings conclude that collaboration is both important and aspired in the industry. According to object 4, the industry does not have a *"formalized collaboration",* however, as object 2 points out *"shipping companies have a fine tradition of cooperating as much as possible. You also compete when you have to, but the main essence is to cooperate."* Object 3 also acknowledges this stating *"Cooperate on the things that are not beneficial to compete on."* These findings highlight the notion that shipping companies have a long-standing tradition of

both cooperating and competing, with a primary emphasis on collaboration. Implying that the industry recognizes the value and benefits of working together. This is further validated by object 8 stating *"Norway is good at getting competitors, interest organizations and customers in the same room, so all parties in the value chain collaborate."* This fosters a dynamic environment where all stakeholders can actively learn from each other and facilitate the process for all stakeholders involved to come to an agreement. Object 8 expressed this crucial point further by exemplifying *"if you don't meet in the same room, you don't know if you may have the same problems."* Furthermore, a good balance between healthy competition and necessary collaboration is required to allow companies to differentiate themselves in competitive areas while also finding common ground for cooperation in non-competitive areas. Object 6 emphasized, *"Interaction and cooperation in this value chain will eventually become extremely important." "Cooperation is essential to achieve sustainability and zero-emission" - object 8.* A collaborative mindset promotes knowledge sharing, innovation and group problem-solving, which can accelerate the process of building a market and promote mutual growth.

Object 3 highlights the importance of common goals and objectives and classifies them as the foundation for cooperation. According to object 9, achieving sustainable and zero-emission solutions necessitates collaborative efforts from industries, emphasizing the importance of agreement, communication and cooperation. Object 8 shares similar sentiments, *"discuss issues and agree on the message you want to signal to the politicians and authorities - what you actually need to achieve zero-emission."* They emphasize the importance of industries working together to develop solutions. This highlights the importance of collaborative decision-making processes and open dialogues between stakeholders. When industry players work together, they can focus on common goals and find long-term solutions. It is critical to identify areas where cooperation over competition is preferable. Furthermore, object 3 states *"actors who make demand"*, this concept recognizes that stakeholders play a proactive role in shaping the direction of the industry. By vocalizing their demands, they exert pressure or influence on other actors, thereby impacting the decision-making landscape. This further helps organizations or policymakers better align their actions and strategies with the needs and expectations of key stakeholders. As

emphasized by object 6, cargo owners have a significant influence on the shipping industry as they pay for transportation services. Object 5's perspective, *"if shipping companies and cargo owners agree, it usually succeeds"* suggests that there is a mutual understanding and alignment of interests between these key stakeholders. Object 8 emphasizes the importance of operational measures that can be taken, such as being more flexible when cargo is delivered, and states *"Think of how many vessels sail without cargo because they failed to cooperate with others" - object 8.* This collaboration could include negotiating favorable terms, ensuring efficient transportation and delivery, optimizing logistics processes, and addressing specific cargo requirements or challenges.

While object 3 expresses that collaboration has been a norm in the Norwegian maritime cluster, object 1 suggests that the manner in which they collaborate must evolve. *"We have to collaborate in a completely new way going forward. As I see it, between the energy supplier, technology supplier, and shipping company, they have to work together in a completely different way going forward to bring about the green shift and new technologies"- object 1.* The observation implies that traditional modes of collaboration may no longer be sufficient to address the challenges and complexities associated with the green shift and technological advancements. This finding also emphasizes the interdependence and interconnectedness of these stakeholders in driving sustainable change. They can overcome barriers, foster innovation, and accelerate the adoption of green technologies in the shipping industry by collaborating in a new way, as endorsed by object 3. *"When working with new fuels, it is extremely important that you cooperate so that you help develop a set of regulations and ensure safety"* - object *2.* Object 9 emphasizes the importance of risk-sharing in this context. While they express a willingness to bear some of the risks in a rising market, they also recognize that carrying the entire burden is impractical. This highlights the importance of stakeholder collaboration, including industry actors, governments and financial institutions, in managing and mitigating the risks associated with the development and deployment of zero-emission solutions.

Our findings indicate that collaboration is not always simple. *"Some friction, some have different goals and opinions about things" - object 5. "Technology ownership, and now we give up a little more than we wish" - object 3.* These findings highlight the reality that not all actors share the same objectives and

viewpoints, leading to potential challenges in collaboration and decision-making. As object 3 stated, technology ownership could be a factor that influences collaboration dynamics, as there can be a reluctance to share knowledge on technology, hindering progress or cooperation. Object 1 gives an interesting take on Norway's advanced regulatory framework for collaborating internationally. It suggests that while Norway has a robust regulatory framework, it is essential to avoid excessive regulations specific to Norway that could hinder international collaboration and efficiency in the shipping industry.

5.6 Competitive Advantage

Norway's shipping industry holds a prominent international position and is recognized as a pioneer in transitioning to sustainable technology. Figure 18 demonstrates the findings which indicate a strong desire within the industry to adopt innovative solutions, reflecting a tradition of innovation and competitiveness. Norway's success in the green shift attracts global attention, positioning it as a knowledge hub. However, challenges, such as maintaining a business perspective and navigating global regulations, must be addressed to sustain the competitive advantage. An evolutionary approach is recommended to enhance the cluster's position.

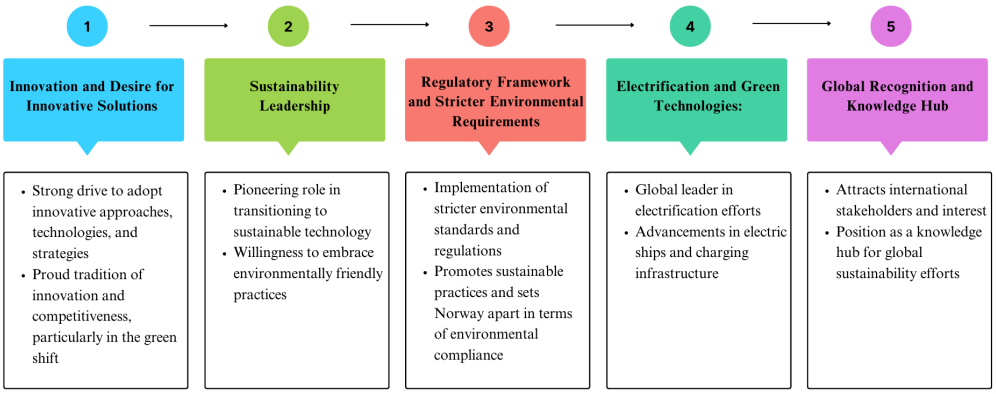


Figure 18. Factors Contributing to Norway's Competitive Advantage in the Shipping Industry

Our findings present an intriguing perspective on Norway's reputation for seeking innovative solutions. *"Norwegian players want the most innovative solutions," - object 5* and *"Norway has a proud tradition of being innovative and competitive, and this now applies to the green shift" - object 2.* These findings suggest that Norwegian players strongly desire to adopt the most advanced and cutting-edge approaches, reflecting a proud tradition of innovation and competitiveness. It indicates a proactive mindset of seeking out novel approaches, technologies and

strategies that can contribute to environmental progress. This pursuit of innovation can fuel competitiveness, foster industry advancements and position Norwegian companies as leaders in sustainable solutions. *"Looking to Norway to learn"- object 6.* Norway's success in adopting innovative approaches to the green shift attracts the attention and interest of international stakeholders who seek to imitate its achievements. Which further positions Norway as a knowledge hub and a valuable resource for global sustainability efforts. This is further validated by object 4 confidently addressing, *"When it comes to green shipping, we are ahead. We have been ahead. So, we are still leading there. But they need to pick up the pace to remain in the lead."* Object 1 acknowledges a positive contributing factor to Norway's leading position, *"Norway is quite richly equipped, which is not the case worldwide."*

To substantiate these claims, object 1 mentions the early adoption of shore power in Norway stating, *"In 2011 we started with shore power (...) in 2019, there was a greater focus on it, and by then, we have already been doing it for eight years."* Additionally, object 1 highlights Norway's status as the global leader in electrification, *"Norway is the absolute world leader in electrification (...) Norway is impatient and wants regulations that progress faster."* The competitive advantage is further validated by object 5, who states, *"The more Norway manages to raise the ceiling, the more challenging it will be for the others, as they will need to take action with their ships. Therefore, they will strive to have the regulations as lenient as possible."* While object 4 mentions, *"The Norwegian shipyard has the advantage that we are going to change that we set stricter environmental requirements."* Object 8 presents an interesting take on Norway's competitive advantage, *"we are ahead of others, which will lead us to have knowledge that will eventually be demanded."*

Object 2 acknowledges the first-mover dilemma, stating, *"There are some advantages to being a first-mover, but it also involves significant risks and an expectation that scaling up will have cost implications, which can penalize the first-mover."* However, it is essential to bear in mind the statement by object 5, *"What can be a showstopper can also be an opportunity."* Object 9 raises an interesting perspective regarding the notion of being a first mover. They argue that being at the forefront of innovation and sustainability initiatives can sometimes

result in a disadvantage. Object 9 states, *"not talking about first mover advantage, but first mover disadvantage, it costs to be first."* This viewpoint acknowledges the potential risks and costs associated with being an early adopter of sustainable technologies and practices. It emphasizes the need for careful consideration of the challenges and uncertainties that come with pioneering efforts. However, despite the potential disadvantages, object 8 recognizes the benefits of being a first mover in the industry. They highlight advantages such as partnership opportunities, trust within the industry and competitive advantage.

Norway does face challenges that need to be addressed to maintain its leading position. Recognizing the business aspect of the transition is crucial, as supported by object 5 which states, *"No shipowners are operating on charity; they aim to make money. There must be a competitive advantage to switching to new technology."* Furthermore, achieving a sustainable transition requires systematic and enduring approaches, as emphasized by object 4, which mentions, *"We need to shift from ad-hoc measures to something more systematic and enduring."* Object 9 brings attention to the challenges faced by Norwegian players in the global market due to the creation of regulations that hinder their competitiveness abroad. They express concern, stating, *"problematic when a set of regulations is created that makes it difficult for Norwegian players to compete abroad."* This highlights the potential drawbacks of regulations that inadvertently create barriers for Norwegian industries seeking to expand their presence and offer sustainable solutions on a global scale. Finally, to enhance the leading position and gain a stronger competitive advantage, a vital statement from object 6 suggests, *"evolution rather than a revolution"* for the actors in the Norwegian maritime cluster.

Table 10 demonstrates a summary of the top three findings of each topic which is chosen based on our research subject and topics for further discussion. The significance of coordinated efforts among stakeholders to overcome barriers, foster collaboration, and develop the market for sustainable and zero-emission solutions in the maritime industry is highlighted by these key findings. Drivers such as cargo owners, consumers, and authorities play a crucial role in influencing the landscape of the industry. In addition, the competitive advantage of Norwegian companies, combined with their openness to innovation, positions them as leaders in the transition to a sustainable and environmentally conscious maritime sector.

	New Market	Drivers	Barriers	Collaboration	Competitive Advantage
Top three findings	Building a new market is complex and the entire value chain must be considered.	Cargo owners and consumers are highlighted as crucial drivers.	Cost and make it economically viable.	Important and aspired resulting in a fine tradition of cooperating as much as possible.	Norwegian players want the most innovative solutions, showing a willingness to change.
	Authorities are crucial in a transition phase and should act as market-maker.	Authorities, regulations, and a good balance between positive and negative incentives	Build a market and generate supply and demand.	Common goals and objectives, and the importance of communication, cooperation, and agreement.	Norway has access to resources and needs to utilize them.
	Stimulating a demand that gives zero-emission solutions	Good interaction between all actors in the industry	Resistance to change and difficult to change habits	Stakeholders play a proactive role in shaping the industry	Norway has the advantage of stricter regulations.

Table 10. Summary of the top three findings under each topic.

Chapter 6 – Discussion

This chapter presents empirical findings on the factors affecting the transition to zero-emission shipping in the Norwegian maritime industry. Findings obtained through expert interviews will be discussed in relation to the presented literature and conceptual framework. To answer the research question: *How can the Norwegian maritime industry successfully work toward zero-emission supply chain operations by 2050?,* we will first discuss the sub-questions presented in Chapter 1. Section 6.1 will look into sub-question 1 and discuss collaboration in relation to theory and its significance, followed by the findings on barriers and drivers, illustrating how collaboration aids the transition to a new market. Section 6.2 addresses the second sub-question and discusses how cargo owners contribute to the industry's sustainability, collaborative logistics, and synergy opportunities to reduce emissions and enhance sustainability. Section 6.3 will present the final discussion in relation to the research question. We combine our empirical findings and theoretical background, covering sustainable market development, Norway's competitive advantage, and include key points from sections 6.1 and 6.2. This provides a well-informed and conclusive answer. In addition, we will present a final conclusion, implications and future research.

6.1 Collaborative Partnerships for Zero-Emission

Collaboration and partnerships are essential in our interconnected world to achieve results and drive change. This section explores sub-question 1; *What collaborative efforts and partnerships are needed for achieving zero-emission in the Norwegian maritime sector?* We look into their significance, motivations, benefits and challenges, to provide a discussion of what collaborative efforts and

partnerships are needed to support the achievement of zero-emission in the Norwegian maritime sector. We will examine stakeholder engagement and their collaborative efforts to overcome the barriers and draw advantage of the enablers to the implementation of zero-emission practices.

6.1.1 Collaboration for Sustainable and Competitive Shipping

This section emphasizes the significance of collaboration in the maritime industry for attaining competitive advantage and sustainability. It highlights the need for new ways of thinking and cooperation to respond to changing market dynamics. Collaboration fosters innovation, the sharing of goals, knowledge and collective success, which influences the adoption of sustainable solutions. The relationship between shipping companies and cargo owners is vital, despite obstacles such as a lack of formal organizational structure and a potential lack of trust. These insights enhance the comprehension of industry collaboration.

Figure 19 illustrates that collaboration in the maritime industry, governed by requirements, provides substantial advantages for achieving sustainability and competitive advantage. By collaborating, stakeholders in an industry can drive innovation, shape the market, mitigate risks, improve their reputation, and gain access to new growth opportunities. Collaboration is essential to developing a competitive and sustainable shipping ecosystem.

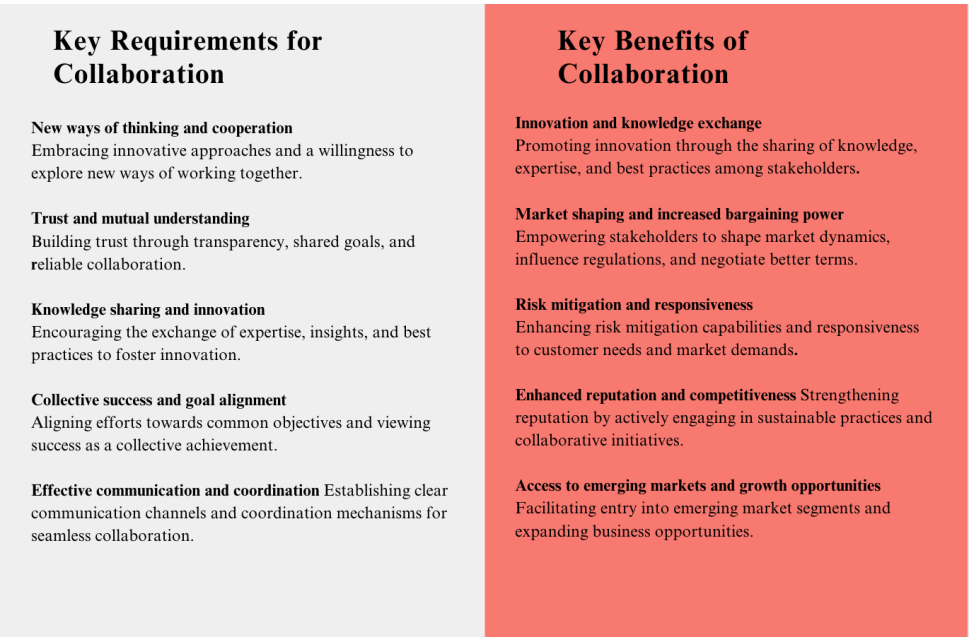


Figure 19. The key requirements and benefits of collaboration in the maritime industry for achieving sustainability and competitive advantage.

The findings highlight the importance and desirability of collaboration in the industry, and accentuate the fact that new innovative solutions necessitates new ways of thinking and cooperating. This generates the significance of collaboration to effectively adapt to changes in this evolving market with rising new technologies (Vachon & Klassen, 2006). It is clear that the transition needs to happen a lot faster than it has been, therefore to accelerate the adoption of zero-emission shipping and transform supply chain operations, there is a need to cultivate a collaborative mindset. A collaborative mindset promotes innovation, growth and collective success, harnessing the power of shared knowledge, teamwork and diverse perspective. The transition towards zero-emission necessitates creative thinking and creation of novel organizational structures, which applies to all parties involved. Therefore, beginning the transition collectively with other actors in its early stages would yield significant benefits for stakeholders involved. In line with theory, collaboration is more likely to happen when there is a willingness to participate (Orr, 2013). Despite the lack of mandatory or formalized collaboration in the industry, the sectros fine tradition and desire to cooperate when possible and compete when necessary is an important competitive advantage within the international sector. The findings highlight the willingness of Norwegian actors to come together, engage in meaningful dialogue and actively seek common ground.

The theory behind collaboration enables professionals in the industry to combine their competencies, knowledge and resources to solve problems more creatively and efficiently (Orr, 2013). Consistent with our findings, where practitioners recognize collaboration as a driving force for innovation and encourage knowledge sharing. This exchange of knowledge can facilitate the industry in understanding and embracing new technological solutions, thereby propelling innovation and punching the frontiers of sustainable maritime operations. This highlights the crucial role of stakeholder collaboration in attaining shared goals and objectives pertaining to sustainability and competitiveness.

The findings propose a specific reason for stakeholders to be interested in collaborating, as it increases their collective ability to shape the market in their desired direction. Incorporating this with the concept of sustainability, which is closely associated with creating shared value for all essential stakeholders (Lozano, 2011). This highlights the role of collaboration in driving positive

change and creating mutual value in both market shaping and sustainability efforts. Thus, by aligning their demands, needs, goals and intentions, industry players can influence market dynamics, including the availability and adoption of zero-emission shipping solutions. When industry players align their demands, they gain a stronger collective bargaining power. This allows them to bargain for better terms, prices and conditions with authorities, as pointed out in the findings.

We examine the relationship between shipping companies and cargo owners to demonstrate some of the benefits of stakeholder collaboration. Cargo owners are noted as a crucial actor to collaborate with, as this collaborative relationship can generate benefits such as risk mitigation, responsiveness and market expansion. Findings emphasize this relationship as crucial and frequently results in success. Establishing a proactive mindset and exerting pressure on demand, shipping companies are compelled to take decisive action and meet the specific requirements of cargo owners. This dual focus on meeting customer needs and advancing sustainability goals mutually benefits both parties involved and contributes to the overarching societal goals. This customer-centric approach (Lun et al., 2010, p. 66), is persistent in our findings, and highlighted as extremely important. Focusing on customer needs can enhance shipping companies' reputation among consumers, industry actors and governments, enabling them as trustworthy and reliable partners to collaborate with. As they acknowledge and respond to the pressure of various stakeholders and compel to adopt GSPs (Jamsi & Fernando, 2018).

According to Frampong et al. (2020), a reliable reputation gives access to new markets and consumers, opening avenues for growth and expanding business opportunities, particularly relevant in emerging markets. Adopting a collaborative approach, stakeholders in the industry secure an influential role in shaping the market and facilitating the transition to sustainability. These collective efforts bring forth multiple advantages such as increased visibility, enhanced credibility and access to emerging market segments. Consequently, solidify their positions as industry leaders within sustainability, strengthening their reputation and competitive advantage (Jamsi & Fernando, 2018). These findings are significant and consistent with theory, implying a link between technological integration and environmental collaboration (Vachon & Klassen, 2006).

Collaboration can be difficult when working in a sector that is global, complex, and full of strong players and supply chains. Theoretically, collaboration can be particularly challenging when there is no strong organizational framework (Orr, 2013). This challenge becomes more pronounced in the emergence of a new market without a proper structure and the complex network of supply chains associated with it (Barbosa-Póvoa et al., 2018). However, as the emphasis on logistics as a means of gaining a competitive advantage grows (Lavie, 2006), a closer relationship with LSPs becomes more advantageous. This subsequently improves the market position of cargo owners, empowering them with a competitive advantage. Our findings substantiate the concept that collaboration becomes challenging in the absence of mutual understanding. This can give rise to friction, inflexibility, and a reluctance to share technological knowledge, driven by concerns that competitors may gain a greater competitive advantage by accessing such information. Trust becomes a critical factor in this regard, highlighting the important effect of collaboration, as stakeholders may be hesitant to share valuable knowledge and resources without assurance that their interests will be protected. This can result in initiatives in the marine sector being uncoordinated, lacking focus and poorly managed, ultimately failing to deliver the expected results as presented by Acciaro & Sys (2020).

The findings presented above contribute to the understanding of the current collaboration practices and perspectives among industry practitioners. Illuminating the real-life experiences, challenges, and aspirations of the industry in achieving sustainable and competitive collaborative outcomes. This empirical data enriches the existing literature by providing a deeper understanding of the practical aspects of collaboration within the emerging market of zero-emission shipping. Despite the lack of concrete examples of how actors in the industry collaborate, these findings provide empirical evidence that aligns with the existing understanding of the importance of collaboration in attaining sustainability and competitive advantage in the maritime industry (Barbosa-Póvoa et al., 2018). This strengthens the validity of the findings and supports the existing knowledge base.

6.1.2 Barriers to Adopting Zero-Emission Technologies

This section discusses the obstacles hindering the widespread adoption of zero-emission solutions in the maritime industry. The identified barriers are

categorized into physical and psychological barriers. First group includes the risks and uncertainties associated with new technologies, the increased costs and the absence of economies of scale, and lack of demand and infrastructure. Psychological barriers consist of resistance to change and the potential influence of reputation on interview responses. This discussion shed light on the complexities and challenges faced by industry actors, emphasizing the need for collaboration, strategic planning, and determination to overcome these barriers and achieve sustainable practices in zero-emission shipping.

Table 11 contrasts theoretical and empirical findings regarding barriers to the adoption of zero-emission technologies in the maritime industry. Risks and uncertainties, increased costs, a lack of economies of scale, and resistance to change are the theoretical obstacles. The practical barriers align with the theoretical ones, emphasizing the risks and uncertainties associated with new technologies, the increased costs and the resistance to change established ways of thinking. The lack of supply and demand for zero-emission technologies is a significant obstacle from both a theoretical and a practical standpoint. Consequently, there is no market equilibrium and no competitive pricing. In addition, both perspectives acknowledge the unfamiliarity and uncertainty of a new market as a barrier to adoption.

The lack of infrastructure can hinder the adoption of zero-emission technologies in the maritime industry and is a significant practical finding that was not explicitly mentioned in the theoretical context. Another practical distinction is the potential impact of reputation on interview responses, highlighting the need for objective research methods. In conclusion, the practical perspective identifies the absence of support and incentives from authorities as a unique obstacle. This indicates that the widespread adoption of zero-emission technologies is hindered by the lack of support from regulatory bodies and regulating authorities.

	Theoretical Findings	Empirical Findings
Risks and uncertainties associated with new technologies	✓	✓
Increased costs and absence of economies of scale	✓	✓
Lack of supply and demand	✓	✓
Lack of infrastructure	−	✓
Resistance to change	✓	✓
Potential influence of reputation on interview responses	−	✓
Fear on the unknown and need to change established ways of thinking	✓	✓
Unfamiliarity and uncertainty of an unestablished market	✓	✓
Psychological discomfort and resistance to transition	✓	✓
Lack of support and incentives from the authorities	−	✓

Table 11. Comparison of theoretical and empirical barriers to adopting net zero-emission technologies in the maritime industry

In the first category, our findings highlight the risks and uncertainties associated with adopting new technologies, as well as the additional costs and challenges posed by a lack of demand and production of infrastructure. The increased cost in the shipping sector for transitioning to zero-emission is consistent with the transaction cost theory. The hypothesis highlighted under the literature review, *uncertainty and information asymmetry surrounding green technologies creates cost barriers and hinder widespread adoption*, is consistent with our findings and the perceptions of industry actors. These zero-emission technologies and strategies are more expensive compared to conventional fuels as there are more complexities and imperfections (Yuen et al., 2018), which is acknowledged by every interviewee. Nevertheless, sustainable operations are more expensive and industry actors need to take these higher costs into account moving forward, as the environment has a higher priority. The increased cost is seen as a barrier from both a theoretical and practical viewpoint as the shipping industry seeks to maximize profits (Regan, 2002). Investment in sustainable technologies has the potential to transfer valuable knowledge and increase the competitive advantage to other suppliers or customers (Vachon & Klasen, 2006). Our findings correlate to this as the uncertainty and level of risk involved magnify the barrier to increased expenses. This emphasizes the importance of collaboration in lowering transaction costs, as trust, transparency and dependability are critical in overcoming this barrier.

Despite a gap in the literature on the impact of emerging markets in the marine sector, the concept of economies of scale has received attention in emerging markets in other sectors, which can be transferred and compared to the market of zero-emission shipping. The theoretical hypothesis highlighted in the literature review, *the lack of economies of scale makes the technology too expensive. It hinders widespread adoption.* This aligns with our findings indicating a market that is still in the process of establishment, as evidenced by several key factors. One significant aspect is the current state of technology products, which are perceived as being too expensive. This cost barrier creates a challenge for widespread adoption and, consequently, leads to a lack of demand in the market. The lack of sufficient demand, in turn, affects the supply side of the equation. This mutual lack in supply and demand, results in an absence of market equilibrium and competitive prices.

The findings suggest a close relationship between the theory of economies of scale and being a first mover in the industry, providing a nuanced perspective on the role of the first mover in the industry. It becomes evident that what can be perceived as a barrier or showstopper for some can also present multiple benefits for others. However, based on our research, some industry players adopt a cautious approach and prefer to sit on the fence, awaiting the moves of their counterparts. This hesitancy stems from a desire to avoid unnecessary risks and uncertainties that may arise from being the first to embrace new technologies or practices (Frempong et al., 2020). As a result, this cautious stance can slow down the overall progress and implementation of innovative solutions within the industry. Consequently, the lack of economies of scale increases the barrier to being a first mover. These findings and understanding of the dynamics of economies of scale are critical for maritime industry decision-making and strategic planning to navigate the uncertainties that come with being an early adopter in the zero-emission shipping market.

Furthermore, our research delves into the psychological barriers that prevent the adoption of zero-emission shipping. We discovered factors such as resistance to change, fear of the unknown, and the need to change established ways of thinking, which aligns with the hypothesis highlighted in the literature, *the negative implications of uncertainty and increased costs outweigh the positive aspects.*

These psychological barriers must be recognized and addressed as they have a significant impact on the willingness of industry players to embrace new ideas and approaches. The status quo and the psychological discomfort and resistance associated with the transition to zero-emission technologies is exacerbated by the unfamiliarity and uncertainty of an unestablished market. Based on the research, this barrier and unwillingness to change can be connected to individuals' perceptions and not the industry. Considering our research indicates a strong willingness within the Norwegian maritime industry to embrace change and transition towards zero-emission solutions. This finding contradicts the earlier statements and reveals a potential gap in the previous findings, which can be explained by industry experts' desire to appear to have a good reputation while answering questions. However, our findings highlight the determination and perseverance required to overcome the challenges and barriers associated with zero-emission shipping. In addition, the importance of keeping momentum and commitment to sustainability, even in the face of adversity or when the popular choice may not be in line with long-term environmental goals.

The idea that reputation may play a role in shaping responses is an intriguing finding. It suggests that interviewees might be inclined to align their answers with the tone and expectations of the questioner, consciously or subconsciously. This aligning of responses with perceived expectations can introduce a bias that influences the outcomes of studies or surveys. This discovery underscores the importance of conducting rigorous and unbiased research methodologies to obtain accurate insights. Nevertheless, the discovery of both a willingness and unwillingness to change serves as an inspiration and reminder to policymakers, industry leaders, and researchers to keep pushing for sustainable practices and seeking innovative solutions in the face of potential obstacles. It helps policymakers and industry stakeholders develop targeted strategies to overcome the practical challenges that the marine industry faces in embracing the market of zero-emission shipping.

6.1.3 Driving Forces for Overcoming Barriers in Zero-Emission Shipping

The section examines the motivations behind the maritime industry's shift to zero-emission solutions. Key drivers include demand from cargo owners and consumers, regulatory involvement, collaboration theory and market demand.

Corporate social responsibility and technology adoption frameworks also play a role in understanding the dynamics of transitioning to sustainable supply chains and zero-emission. These findings not only shed light on the transition process, but also emphasize the importance of stakeholder collaboration.

The analysis of driving forces in zero-emission shipping revealed both similarities and differences between theoretical and empirical findings, as illustrated in Table 12. Demand from cargo owners and consumers, the involvement of authorities and regulations, collaboration theory, resource availability and capabilities. In addition, technological innovation, a willingness to change, the ease of technology adoption and user-friendliness, and CSR have been identified as the key market drivers. This highlights the complexity and multifaceted character of the transition to sustainable shipping practices. Despite the fact that some drivers aligned with both theoretical and practical perspectives, such as demand from cargo owners and collaboration theory, the importance and impact of various drivers varied. The ease of technology adoption and user-friendliness, as well as the role of CSR, were highlighted in theoretical findings but did not emerge strongly in the empirical findings.

	Theoretical Findings	Empirical Findings
Demand from cargo owners and consumers	✓	✓
Involvement of authorities and regulations	✓	✓
Corporate social responsibility (CSR)	✓	−
Ease of technology adoption and user-friendliness	✓	−
Collaboration theory	✓	✓
Market demand	✓	−
Resource availability and capabilities	✓	✓
Technological Innovation	✓	✓
Willingness to change	✓	✓

Table 12. Comparison of theoretical and empirical driving forces for adopting net zero-emission technologies in the maritime industry

The findings accentuate the significance of cargo owners and consumers as key drivers, as their demand for sustainable shipping solutions can create market pull and incentivize industry participants to invest in zero-emission technologies. This is consistent with the fundamental principle of meeting the needs and preferences of customers (Lozano, 2011; Frempong et al., 2020).

The involvement of authorities and regulations from international and national organizations is deemed crucial for facilitating that transition to zero-emission solutions. This is consistent with the hypothesis acknowledged in the literature where *formal and informal institutions influence the behavior and practices of shipping companies.* Regulatory frameworks provide the necessary structure within which businesses can operate and innovate. The findings emphasize the dependence of governmental or public actors on risk-sharing mechanisms, funding programs, and incentives from governments or other institutions. Industry stakeholders recognize that government interventions such as supportive policies, incentives and penalties can help reduce barriers, and create an environment conducive to the adoption of sustainable practices. Nevertheless, the findings suggest a lack of commitment from the government side, as stakeholders put pressure and demands on the authorities, they encounter a lack of receptiveness or indifference. This is an interesting and important find and one contributing factor to the slow progress in the market.

A fundamental and theoretical enabler highlighted in the study is CSR as *CSR makes companies actively engage in environmental activities*. Companies that embrace CSR principles can proactively align their operations with long-term goals and social values. Including CSR practices in their strategies and operations can help them improve their reputation, stakeholder relationships and competitiveness (Dahalan, Zainol, Yaa'kub & Kassim, 2012). Beyond profit maximization, emphasizing CSR as an enabler emphasizes the importance of considering the broader societal and environmental impact of business practices. However, the concept of CSR is not highlighted in our findings nor emphasized by the interviewees as CSR has become a basis for all actors within every industry and is therefore not a compelling driver.

The market of zero-emission is highly dependent on the adoption of new technology, with the technology adoption framework as a theoretical enabler to drive this transition. Theoretical frameworks such as TAM and TPB become relevant in understanding the factors that enable this transition, with the hypothesis that these frameworks *increase engagement in green initiatives if they are convinced they will help them reach their competitive goals?* The perceptions in the industry recognize zero-emission technologies as a competitive advantage

as they will reduce emissions, comply with regulations, and achieve sustainability goals. Even though these factors contribute to stakeholders in a beneficial way, they do not make up for the barriers connected to economic viability. Additionally, if the adoption process and integration of these technologies are perceived as straightforward and user-friendly (Autry et al., 2010), it further encourages their acceptance and implementation. On the contrary, these processes are not straightforward which aligns with the perceptions of stakeholders. The application of these theoretical frameworks provides a systematic and structured approach to understanding the factors that enable or hinder the transition to zero-emission solutions in the maritime industry. However, they are not recognized nor emphasized by industry actors as a crucial driver for this transition. These findings highlight a gap between theory and practice. Demonstrating that while theoretical contributions are critical for the recognition and foundation of this transition, they are insufficient to bring about change and get stakeholders to commit. The last driver highlighted in the literature will be discussed later.

Collaboration theory combined with the driving force of market demand, can be instrumental in overcoming barriers and entering a new market. By aligning efforts with market demand and anticipating customer needs, collaborating companies can respond to the pull for sustainable solutions. Collaborative efforts ensure that the collective offering meets customer expectations, enhances market competitiveness and increases the likelihood of successful market entry. Collaboration also leverages synergistic capabilities. By combining their unique strengths and expertise, collaborating companies create synergies that enhance their competitive advantage. This collaborative synergy helps overcome individual limitations and accelerates the development and deployment of innovative solutions in the new market. Collaborative problem-solving draws on a broader range of perspectives and expertise, increasing the likelihood of finding effective solutions to complex barriers and challenges. Collaboration theory, in conjunction with the driving force of market demand, provides a robust framework for overcoming barriers and entering a new market. This relationship is in line with the conceptual framework (figure 12), where stakeholder collaboration within the industry can utilize the drivers to overcome the barriers, to generate a sustainable supply chain and zero-emission shipping.

6.2 The Role of Cargo Owners in Sustainability and Collaboration

Cargo owners play a crucial role in the integration of zero-emission shipping and driving sustainable supply chain solutions. This section discusses sub-question 2; *How do cargo owners perceive the integration of zero-emission shipping, and how does it impact their supply chain operations?* By pressuring shipping companies to provide sustainable transportation options, cargo owners contribute to the industry's sustainability efforts. Collaborative logistics and synergy opportunities enable them to reduce emissions and enhance sustainability. Additionally, zero-emission shipping aligns with cargo owners' sustainability goals, improves their market positioning and attracts environmentally conscious customers. Understanding the influence and collaboration between cargo owners and shipping companies is essential for achieving environmentally friendly transportation options.

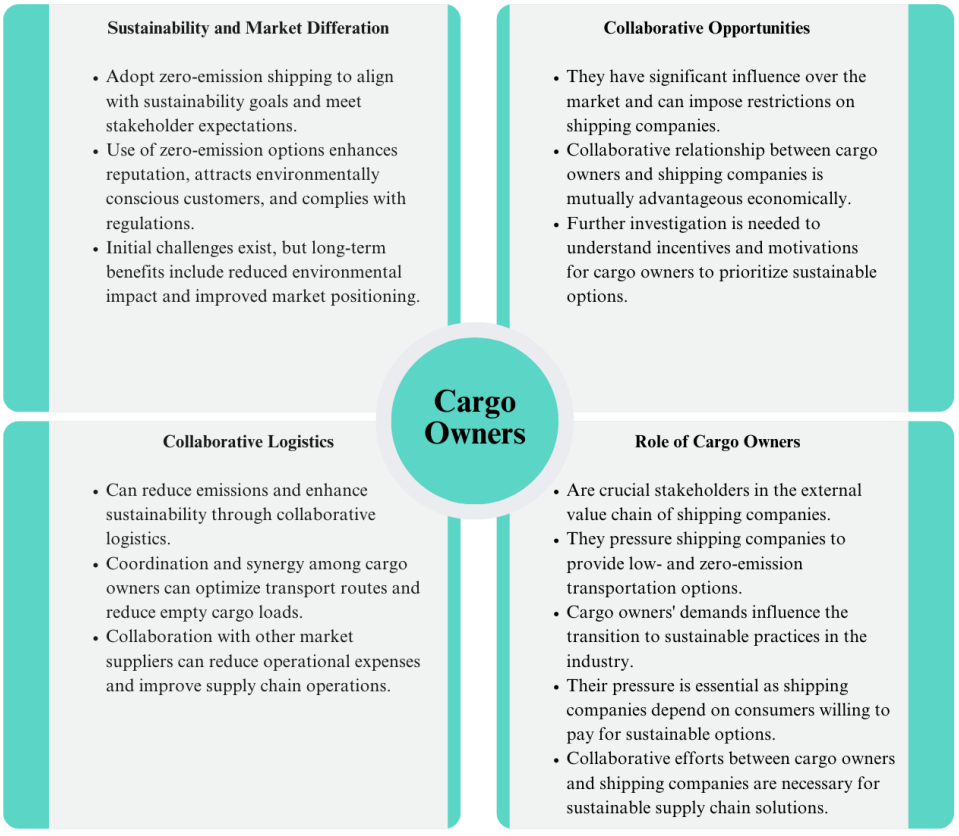


Figure 20. The role of cargo owners

Figure 20 provides an organized summary of the main points and interesting findings regarding the role of the cargo owners in sustainability and collaboration. It emphasizes the significance of cargo owners as stakeholders, the advantages of collaborative logistics, the effect of sustainability on market differentiation, and

the collaborative opportunities cargo owners have for promoting sustainable practices and will be discussed further in this section.

6.2.1 Key Stakeholders Driving Sustainable Supply Chain Solutions

The literature shows a lack of studies regarding sustainability in the maritime shipping sector in relation to different actors in the value chain (Poulsen et al., 2016). However, utilizing the basic concept of supply chains, stakeholders and comments from industry experts, it should be possible to draw up some conclusions. Nevertheless, formulating a perfect answer to the question is doubtful. The primary objective of a supply chain is to ensure customer satisfaction while minimizing cost (Regan, 2002). Within the supply chain today, profit and cost is frequently discussed in relation to sustainability, where the sustainable solutions are more expensive, increasing cost and decreasing profit, thereby less customer satisfaction. Cargo owners are within the supply chain of shipping companies regarded as essential stakeholders categorized within the external value chain (Yuen et al., 2020; Wagner, 2011). Understanding the activities for shipping companies involved in creating, producing, and delivering goods or services to customers, in this example cargo owners is crucial. Cargo owners are the ones paying for transportation from point of origin to point of destination, and therefore, they are characterized as crucial stakeholders. This is because cargo owners put pressure on shipping companies by requiring transportation options that include low- and zero-emission. This is consistent with the perception of industry experts. Without this pressure, shipping companies do not have the same incentives to transition, as this is costly, and they are dependent on consumers who are willing to pay for this.

6.2.2 Collaborative Logistics Driving Sustainability

Assessing if the supply chain operations of cargo owners are affected is difficult, as it necessitates the development of a certain level of trust, influence, and appropriate technical tools (Xia & Tang-P, 2011, cited in Frempong et al., 2020), which based on previous discussion again emphasizes the importance of collaboration. Our findings suggest that by collaborating and understanding the basic concept of logistics, considering shipping is highly cyclical (Lister, 2015; Jasmi & Fernando, 2018), cargo owners can, without the need for zero-emission

transport routes, reduce their consumption towards climate. By actively engaging with logistics and examining their respective transport routes, cargo owners can identify opportunities for synergy. For instance, one cargo owner may require transportation from point A to point B, while another requires transportation in the opposite direction. Through coordination, emissions can be reduced, and sustainability can be enhanced by ensuring that ships are not sailing without a full cargo load. By leveraging such collaborative efforts and adopting environmentally conscious practices, the industry can make substantial progress toward achieving emission reduction targets and promoting sustainability. Furthermore, by collaborating with other market suppliers, not only will their operational expenses be reduced, but it can be assumed that this will have a positive impact on their supply chain operations, resulting in cost reduction and subsequent profit increase. These findings provide insight into the dynamics of the shipping industry, emphasizing the potential for collaboration and the role of cargo owners in driving sustainability.

6.2.3 Sustainability and Market Differentiation

The incorporation of zero-emission shipping is viewed by cargo owners as a strategic move to align with their sustainability goals, meet stakeholder expectations, improve supply chain resilience and differentiate themselves in the market. Cargo owners align their operations with their sustainability goals and contribute to global efforts to combat climate change by selecting zero-emission options. Despite the acknowledged environmental benefits of utilizing sea transportation, both road and rail transport are the primary options for cargo owners (Hjelle & Fridell, 2010) and the trend within the Norwegian sector seems to continue to increase for the use of road and rail. Signals indicate that cargo owners are positive about using more sea transportation (Norwegian Port Association, 2023), as there is increasing pressure on cargo owners to adopt sustainable practices from customers, investors and regulators. This demonstrates their commitment to environmental responsibility. By doing this, it assists them in maintaining a positive reputation, attracting environmentally conscious customers, and complying with ever-changing environmental regulations. While initial challenges such as cost and infrastructure requirements exist, cargo transportation along the coast is considered to offer greater economic competitiveness compared to road transportation (Medda & Trujillo, 2010; Mulligan and Lombardo, 2006).

Therefore, the long-term benefits of reduced environmental impact and improved market positioning make zero-emission shipping an appealing prospect for cargo owners committed to sustainable practices.

6.2.4 Collaborative Opportunities for Cargo Owners

The findings indicate that cargo owners wield significant influence over the market as they are in closer proximity to the end customers, who ultimately bear the costs. Consequently, they possess the greater potential to sway market dynamics. Furthermore, cargo owners play a pivotal role in determining demand and imposing restrictions on shipping companies regarding zero-emission transportation routes. This collaborative relationship between cargo owners and shipping companies is mutually advantageous from an economic standpoint. Our findings are important for our research, as the literature on cargo owners is scarce and their influence is critical to the discussion of zero-emission. It shows that this is a subject that needs further investigation, so cargo owners might get more incentives or penalties from the government or funding organizations, as this is highlighted as an important and necessary driver. By exploring opportunities for fostering sustainable practices within the industry by recognizing the economic benefits of collaboration between cargo owners and shipping companies, will enable knowledge to identify potential incentives and motivations for cargo owners to prioritize environmentally friendly transportation options.

6.3 The Market of Zero-Emission Shipping

Based on a comprehensive examination of the findings and relevant literature pertaining to the sub-questions, we can effectively leverage this valuable information to provide a well-informed and conclusive answer to the overarching research question. By synthesizing the insights gained from the findings and literature review, we are equipped with a robust foundation to address the research question: *How can the Norwegian maritime industry successfully work toward zero-emission supply chain operations by 2050?* The findings serve as empirical evidence and provide valuable insights into the subject matter, allowing us to draw meaningful conclusions and make informed judgments. Additionally, the literature review provides a broader context and theoretical framework that supports our analysis and strengthens the validity of our research findings. Integrating the information derived from both the findings and literature, we

ensure a holistic and well-rounded approach to answering the research question. This approach enables us to present a nuanced and comprehensive perspective, taking into account various viewpoints, empirical evidence and theoretical underpinnings.

6.3.1 Driving Sustainable Market Development

A thriving market requires the presence of supply, demand, and supportive institutions (Sarasvathy & Dew, 2005). Our findings reveal a deficiency in demand, leading to a shortfall in production and supply. As a result, the market lacks independence, requiring industry participants to navigate the inherent uncertainties and risk associated with emerging markets. The resulting uncertainty poses a challenge in aligning supply and demand to achieve the objectives in SCM. Leading to multiple consequences such as inefficiency in transportation, reduced profitability, operational disruptions and increased cost. The limited supply of technology can impede market growth and restrict the benefits for both consumers and businesses. To overcome these supply constraints, industry players are engaging in collaborative efforts. Collaboration offers numerous advantages, as discussed above, including resource pooling, enhanced market responsiveness, synergistic capabilities, risk sharing and collective problem-solving. Utilizing each other's strength through collaboration can enhance their market position and improve their chances of successful market entry. Our findings suggest that industry practitioners recognize the imperfect nature of supply and demand dynamics, but they emphasize that the establishment of supply and demand within the market will be primarily driven by regulatory measures and requirements mandated by organizations such as IMO and national regulations. That over time, supply and demand will naturally find equilibrium.

Governments, in line with economic theory (Osobajo et al., 2021), can play a crucial role by intervening when needed, aligning with the expectations of businesses that advocate for sustainable incentives beyond simple funding. Incentives highlighted by the industry to assist in the establishment of the market include contracts for difference in which the government covers the loss from zero-emission transportation contracts, thus for the government to assume the role of a market-maker. This is feasible due to the government’s significant purchasing power, which can be effectively utilized to stimulate demand. Leveraging their

purchasing power, governments play a vital role in driving adoption and market growth for sustainable solutions, thereby encouraging businesses to prioritize environmentally friendly practices. Which align with the perception of the industry experts stating government and authorities to be a crucial driver.

The government has the power to create an enabling environment for sustainable businesses to thrive. Implementing supportive policies, regulations and frameworks, the government can instill confidence in investors and encourage the growth of sustainable industries. This proactive stance from the government holds the potential to bring about transformative changes in market dynamics, paving the way for the establishment of a sustainable economy. The findings emphasize the criticality of government intervention in addressing the demand and production gaps within sustainable markets, reaffirming its significance as a key driving force. By implementing contracts for difference , the government can effectively encourage businesses to embrace environmentally friendly practices, consequently driving up the demand for sustainable solutions. This dual benefit not only fosters the expansion of sustainable industries but also lays the groundwork for a resilient market for green products and services. As a result, the government's substantial efforts can contribute to a more sustainable and thriving economy. However, the authorities attract criticism from industry experts, stating that the authorities fail to reciprocate the same level of commitment as the industry, impeding progress in the market.

While improving supply chains and value chains is critical for all stakeholders to generate value (Lozano, 2011), the findings emphasize the importance of first developing a market for zero-emission solutions before considering supply chain development. In other words, the existence of supply chains becomes uncertain in the absence of a viable market. To build up a market it is important to understand how it works. According to theoretical perspectives, being closely connected to the market and anticipating its future evolution is a significant advantage for market-oriented companies (Lun et al., 2010, p.66). However, with the lack of certainty and development in the zero-emission market, it becomes a challenge for companies to analyze the market structure. Nevertheless, obtaining market intelligence regarding customers, competitors and the potential market, is possible for market-oriented companies and can provide a competitive advantage. As Lun

et al. (2010, p.66) suggest, a market-oriented shipping firm excels at understanding the preferences and needs of its consumers and possesses the necessary resources and skills to meet them profitably. Companies that actively engage with market dynamics and customer demands can position themselves strategically and capitalize on emerging opportunities in the zero-emission sector. Efficient collaboration, drawing upon the synergy of theoretical and empirical insights, streamlines the process, and makes it more seamless and effective.

These findings contribute significantly to the existing literature on the maritime industry's transition to zero-emission solutions. They emphasize the need for market orientation and intelligence gathering, especially in uncertain and underdeveloped markets. The research highlights the importance of companies understanding customer preferences and adapting their resources and capabilities to meet these demands profitably. Furthermore, the findings underscore the positive impact of innovation in green technology, emphasizing its potential to drive environmental sustainability and promote economic advancement.

The findings indicate that the Norwegian cluster is at the forefront of innovation and implementation. This aligns with existing literature, which suggests the advancement in green technology has the potential to yield double dividend (Albert-Morant et al., 2016). The Norwegian cluster contributes to a reduction of environmental impact and to the technological modernization of the economy.

Leading the way in sustainable technology innovation, the Norwegian cluster demonstrates that with a proactive approach, it is possible to achieve sustainability goals while driving economic growth. This stems from a proud tradition of collaboration and wanting to be the best in the market, claiming their share as pioneers and sustainability leaders. The global shipping industry operates under the regulations set by IMO, which must take into account the diverse range of actors in the sector, including their varying levels of technology, progress, resources and capabilities, when establishing ambitious goals. In this context, Norway stands out as a frontrunner, equipped with advanced technology or the ability to develop it, abundant resources, funding opportunities, and a national government that enforces stricter regulations. Consequently, Norway stands to benefit significantly from IMO's drive to minimize emissions within the shortest

possible time frame. This highlights the industry's robust foundation and position, ultimately resulting in a compelling competitive advantage for Norway.

6.3.2 Overcoming Uncertainty in Markets

The findings highlight the relevance of the first-mover dilemma in the context of the Norwegian cluster's leading position in the transition to zero-emission solutions. This topic becomes a natural focus of discussion in both academic literature and practical implementation. The research reveals varying opinions on this dilemma, with most acknowledging the theoretical aspects behind it, as discussed above. According to theory, first-mover advantage results in companies to charge higher prices for their products and gain competitive advantage (Frempong et al., 2020). However, due to the market's incomplete development and the prevailing economic uncertainties, putting the dilemma into practice may not necessarily confer advantages. Although the necessary technology for zero-emission solutions exists, the demand for such solutions does not align with market equilibrium. As a result, early adopters face substantial costs, as they bear the burden of pioneering efforts. Furthermore, since the market is relatively new, even the second, third, or tenth movers will experience high costs, creating a significant barrier to entry. Consequently, it takes a considerable amount of time for economies of scale to benefit the market as a whole. This further complicates the initial step, as the expense of being an early mover is often too high for many actors in the sector.

6.3.3 Obtaining Competitive Advantage

Despite the challenges, being among the first to embrace zero-emission solutions should offer advantages. It allows companies to establish a reputation as sustainability leaders, build valuable partnerships, foster trust among stakeholders and should give a competitive edge. This resonates with both the characteristics of collaboration and the RBV theory. The hypothesis generated from the literature states, *possessing unique and valuable resources and capabilities that are not readily available in the industry and difficult for competitors to imitate and replicate is key to obtaining a competitive advantage.* This underscores the importance of an organization's internal resources and capabilities in achieving long-term competitive advantage (Tran et al., 2020). Companies that proactively invest in innovative solutions from the outset and during the early stages not only

acquire valuable knowledge but also gain expertise through a process of learning and experimentation. As a result, when other companies eventually follow suit, these early adopters possess a significant competitive advantage. They have already navigated the learning curve, identified what works, and fine-tuned their approaches, positioning themselves ahead of the curve in terms of successful implementation and market readiness. The research brings attention to the pivotal role played by reputation, partnerships and competitive advantage in propelling sustainable practices. This valuable insight holds relevance for both academic research and industry practitioners, underscoring the significance of internal resources and capabilities as critical drivers of long-term success in the adoption of zero-emission technologies. The findings deepen our understanding of the first-mover dilemma, its implications for the maritime industry, and the strategic considerations involved in embracing zero-emission solutions. By addressing the challenges, recognizing the advantages and adopting a resource-based perspective, this research contributes insightful knowledge that informs future studies, policymaking efforts and guides strategic decision-making within the industry.

These findings hold significant importance for research in several ways. Firstly, they contribute to the understanding of the first-mover dilemma specifically within the context of the maritime industry's transition to zero-emission solutions. By exploring different perspectives and addressing the practical challenges associated with being an early mover, the research enriches the existing literature. It facilitates a more comprehensive analysis of this complex issue. Secondly, the findings shed light on the cost implications and barriers that hinder market development in the early stages of sustainability adoption. This understanding is crucial for policymakers, industry stakeholders and researchers to design effective strategies, policies, and support mechanisms that mitigate these barriers and promote a smooth transition to zero-emission solutions. By combining the research findings with the conceptual framework presented in Figure 12, we gain valuable insights that allow us to examine the results in a broader context. This holistic approach enables us to effectively address the challenges, seize opportunities and leverage the competitive advantage inherent in the robust innovation witnessed within the Norwegian maritime sector. By capitalizing on these strengths, the industry can strategically position itself to enter the emerging

market of zero-emission shipping. By doing so, the industry can work towards its overarching goal of achieving zero-emission supply chain operations by 2050.

The successful development of a thriving market necessitates the presence of demand, supply and supportive institutions. Governments, by leveraging their financial power, possess the ability to stimulate demand for sustainable products and services effectively. Furthermore, as market-makers, governments can provide stability and create an enabling environment for sustainable businesses to flourish. The research findings emphasize a crucial aspect, establishing a sustainable supply chain necessitates the prior establishment of a robust market for zero-emission solutions. However, the lack of certainty and development in the zero-emission market presents challenges for companies operating in the maritime industry. Notably, the findings highlight the Norwegian cluster's position as a frontrunner in innovation. Through its proactive approach to green technology innovation, the Norwegian cluster showcases its commitment to achieving sustainability objectives while concurrently driving economic growth. The research findings underscore the significance of the first-mover dilemma within the context of the Norwegian cluster's leading role in the transition to zero-emission solutions. This status enables companies to establish themselves as leaders in sustainability, forge valuable partnerships, instill trust among stakeholders and gain a competitive advantage.

Chapter 7 – Conclusion

The global transition towards net zero-emission is inevitable and driven by increased pollution and climate change. Governments worldwide are committed to achieving this by 2050. The Norwegian short-sea shipping industry, with tens of million tons of cargo every year, embraces the goal and has taken significant initial steps in testing sustainable practices to reach it. However, the industry is wide and fragmented and needs guidance to ensure successful work in the transition. The Norwegian government is aligned with international goals, and has established clear medium- and long-term emission reduction targets. By 2030, a significant reduction in emissions is expected, with the goal of achieving zero-emission operations by 2050.

The existing state of urgency and preparedness within the Norwegian short-sea shipping industry varies. Some companies have made significant strides in adopting to and preparing for a zero-emission future, including testing and implementing energy efficiency measures, exploring alternative fuels and investing in zero-emission technologies. These are pioneers in the field and need to be recognized, praised and forwarded as role models. However, it is important to acknowledge the potential first-mover dilemma. It is still not clear that there is a first-mover advantage in the industry. Pioneers bear the initial costs and risks, while others wait to learn and benefit from their experiences. Progress is being made by some companies, but many others are still cautious or even resistant to change. There is still a need for a more comprehensive and widespread effort across the entire industry.

The industry is faced with several different initiatives with different needs for infrastructure. The industry needs to continue to invest in research and development to develop and enhance sustainable alternatives to current practices in order to be able to establish the preferred solutions for the technology involved, including fuel. Innovation in green technology is seen as a driving force in achieving zero-emission supply chain operations. The research demonstrates that companies that actively invest in innovative solutions, engage in pilot programs, focus on learning and experimentation, and adapt their resources and capabilities to satisfy customer demands set themselves in the position for significant competitive advantage. These early adopters establish themselves as sustainability leaders, and they acquire valuable experience and knowledge that should put them ahead of the curve as the market develops.

Collaboration and knowledge-sharing among the industry stakeholders are vital in accelerating the transition. Establishing partnerships with governmental agencies, research institutions, and other businesses can facilitate the exchange of ideas and expertise. Such collaborations can lead to the further development of shared standards, best practices, and technological advancements, ultimately driving the industry forward collectively. This presents an opportunity of overcoming the first-mover dilemma and fostering comprehensive industry-wide efforts. Further establishing partnerships, coalitions and a collaborative mindset will aid the maritime industry meet the 2050 goals.

Recognizing the need for substantial commitment and financial support, the Norwegian government aims to involve stakeholders in achieving the desired objectives. While some industry players have made notable progress, there is a varying state of urgency and preparedness within the sector. Cargo owners have so far played a relatively passive role, with customers failing to recognize zero-emission shipping as a separate market from the existing one. It is critical that cargo owners be actively involved and engaged in this transformative process.

Encouraging all industry players to prioritize long-term planning aligned with sustainability principles is crucial. Companies should integrate environmental considerations into their strategies, set ambitious emission reduction targets, adopt transparent reporting practices, and foster a culture of accountability. Effective communication and stakeholder engagement are vital in conveying the industry's vision and future model. To foster long-term commitments, short-term gains that offset the higher costs of the transition should be developed. These gains could include recognized emissions reductions, securing new contracts, or accessing government incentives. The successes of frontrunners within the established coalition should be utilized as examples for others to follow.

On the path to zero-emission supply chains, market growth and uncertainty are significant difficulties that must be overcome. The research emphasizes the importance of market orientation and intelligence gathering to comprehend customer preferences, predict market dynamics, and capitalize on emergent opportunities. Companies that proactively engage with the market and adjust their strategies consequently will be well-positioned for success in an environment that is constantly changing.

Further work could, as this paper focuses on the industry´s processes involved in reaching the zero-emission targets, investigate the alternative preferred systems and technologies, as well as how the suggested coalition of leading players and government agencies could interplay and function effectively. Partners in the established coalition could be used firsthand before other players follow. Norwegian short-sea shipping should constantly build on successes as the industry is moving towards zero-emissions. As we see the challenges of making wide industry collaboration, future work could investigate if the work could be more

efficient if led by establishing an elevated, strong coalition of a few leading industry players and regulatory bodies who could be at the forefront of the transition on behalf of the whole industry. Forming such a coalition could secure public understanding and legitimacy and involve cargo owners as deemed necessary. The coalition could lead the development of a clear vision, overall strategy, and model for how the industry would look when zero-emission is in place. The coalition could also be used as a sounding board for where substantial government funding should be allocated during the transition, as well as recommendations for technologies such as hull design, fuel, slow steaming, and onshore power supply.

This research paper has provided insightful information and learning opportunities in a variety of areas. We have learned about the industry itself, including its historical background, size, technological advancements, ongoing development, and potential future trajectory. Furthermore, the paper has examined the level of pollution, greenhouse gas emissions, global and national environmental initiatives, and the impact of these initiatives on the industry. Another important learning point stems from the process of writing a thesis, which has allowed for a more in-depth understanding of research methodology and academic writing conventions. The most important takeaway from this research, however, is recognizing and better understanding the complex process of setting goals and fostering collaboration between governments and private industries to achieve these goals. It emphasizes the significance of extensive knowledge and expertise required to lead such a monumental transition. Managing this change process effectively becomes a critical component, similar to a large change-management effort.

There is no turning back from the transition towards zero-emission operations. The Norwegian maritime industry must continue to prioritize sustainability, collaboration, and innovation in order to achieve zero-emission supply chain operations by 2050. Companies should actively engage, collaborate, and learn from both successes and failures. Only through concerted efforts can the industry unlock the rewards of zero-emission practices, contribute to mitigating pollution and climate change, and ensure a sustainable future. By utilizing these strategies and approaches, the industry can effectively work toward achieving their

ambitious goal of climate neutrality by 2050. A sustainable future is a better future for all.

7.1 Implications

7.1.1 Theoretical Implications

This research contributes to our comprehension of fundamental theoretical concepts within the context of the maritime industry's transition to zero-emission supply chain operations. First, it highlights the complexities and repercussions of the first-mover dilemma, illuminating the practical challenges faced by early adopters. The study underlines the importance of a nuanced comprehension of the first-mover advantage in uncertain and underdeveloped markets.

The research is consistent with the RBV theory, emphasizing the importance of internal resources and capabilities for achieving sustainable competitive advantage. By proactively investing in innovative solutions and accumulating valuable knowledge, businesses can position themselves as leaders in the zero-emissions sector. The study enhances our knowledge of RBV theory and its application to the transition of the maritime industry. Another significant theoretical implication is market orientation. The research emphasizes the significance of market intelligence in volatile and underdeveloped markets. Companies can capitalize on emerging opportunities in the zero-emission sector if they engage strategically with market dynamics and customer demands. The emphasis placed on comprehending customer preferences, adapting resources and capabilities, and analyzing market structure contributes to our understanding of market orientation theory.

Collaboration is essential for a successful transition to emission-free supply chain operations. The study highlights the advantages of collaboration, such as enhanced market responsiveness, synergistic capabilities, risk sharing and collective problem-solving. Businesses can streamline and enhance their transition processes by integrating theoretical and empirical insights. Additionally, the study emphasizes the positive effects of green technology innovation on environmental sustainability and economic development. Technological advancements can reduce environmental impact and hasten economic modernization. Companies that embrace innovative solutions and lead in the development of sustainable

technologies can establish themselves as sustainability leaders and acquire a competitive edge. In addition, the study emphasizes the role of CSR in the transition of the shipping industry to zero-emission supply chain operations. Adopting and implementing CSR practices can assist businesses in achieving emission-free supply chain operations by 2050. Additionally, CSR creates a competitive advantage by enhancing the brand, fostering trust among stakeholders, and attracting environmentally conscious consumers.

These theoretical implications improve our understanding of key concepts, including the first-mover dilemma, RBV theory, market orientation, collaboration, innovation, and corporate social responsibility, in the context of the maritime industry's transition to zero-emission supply chain operations. The findings contribute to the existing body of knowledge by offering theoretical insights that can inform future research, policymaking initiatives, and strategic industry decisions.

7.1.2 Practical Implications

This master's thesis has substantial practical implications for the Norwegian maritime industry's journey towards zero-emission supply chain operations by 2050. These ramifications direct industry practitioners, policymakers, and relevant stakeholders in the implementation of strategies and actions that facilitate the transition to sustainable practices.

Collaboration between industry participants, governments and regulatory agencies is essential. Establishing partnerships and collaborative initiatives can consolidate resources, improve market responsiveness and facilitate the exchange of knowledge. Through collaborative efforts, the market development for zero-emission solutions can be accelerated, operational disruptions can be mitigated, and costs can be lowered. Governments play a crucial role in facilitating the development of sustainable enterprises. It is necessary to implement policies, regulations and frameworks that encourage the adoption of zero-emission technologies. Incentives like contracts for difference stimulate demand and propel market expansion. Governments can prioritize environmentally favorable practices and contribute to a more sustainable economy by leveraging their purchasing power.

Prioritize the collection of market intelligence and consumer preferences and requirements knowledge. It is essential to maintain a direct connection with the market and anticipate its future development. Companies can position themselves strategically and capitalize on emerging opportunities in the zero-emission sector if they invest in understanding consumer demands and adjust their resources and capabilities accordingly. Early adoption of zero-emission solutions offers advantages. Companies that adopt sustainability from the inception have the potential to become market leaders. Early adopters can gain a competitive advantage by investing in innovative solutions, acquiring valuable knowledge, and navigating the learning curve. Companies can position themselves ahead of the direction in terms of successful implementation and market readiness through proactive investment in sustainable solutions, valuable partnerships, and stakeholder trust.

Taking into account these practical implications enables the Norwegian maritime industry to navigate obstacles, seize opportunities, and work toward zero-emission supply chain operations by 2050. These repercussions provide actionable insights, guide decision-making, facilitate collaboration, and promote the required changes for a sustainable future. Collaboration, government support, market intelligence and early adoption are essential elements for the transition to zero-emission shipping.

7.1.3 Future research

Despite the fact that this master's thesis provides valuable insights into the Norwegian maritime industry's journey towards zero-emission supply chain operations, there are several avenues for future research that can contribute to the advancement of sustainable practices in the maritime sector and further enhance our understanding.

Future researchers need to further investigate the importance of collaboration, as this can improve the theoretical foundations of their work and contribute to the development of robust frameworks that capture the complexities of collaboration in the maritime industry. Evaluating the effect of international agreements and collaborations on the formation of regulatory frameworks and examining opportunities for harmonization would also be beneficial. Another prospective

area of study is the investigation of methods for optimizing supply chains with zero emissions. This may involve analyzing the integration of renewable energy sources, employing advanced analytics and artificial intelligence in logistics planning, and creating innovative supply chain models. It would be advantageous to comprehend the potential obstacles and opportunities associated with the redesign of supply chain networks to facilitate zero-emission operations.

The regulatory frameworks and policy interventions required to facilitate the transition to sustainable maritime practices can be the subject of additional research. Further, researchers need to investigate the findings that suggest a lack of commitment from the government side, as stakeholders put pressure and demands on the authorities and receive a lack of receptiveness or indifference. This includes analyzing the efficacy of existing regulations and identifying policy enhancement opportunities that can encourage industry participants to employ zero-emission solutions. Investigating the effectiveness of financial incentives and support mechanisms in accelerating the adoption of zero-emission solutions would provide policymakers and industry stakeholders with useful information.

Future research can investigate and evaluate the technological innovations and infrastructure required to support zero-emission supply chains in greater depth. This includes investigating the viability and scalability of emerging technologies like hydrogen fuel cells, battery-electric propulsion systems and alternative fuels. It would be beneficial to investigate the infrastructure requirements, such as charging and refueling networks, and their impact on the overall adoption and implementation of zero-emission solutions. It is essential to examine the economic viability of transitioning to zero-emission supply chain operations. Future research may examine the costs and benefits of sustainable technologies, infrastructure investments and operational adjustments.

Evaluating the environmental impact of zero-emission supply chain operations and conducting life cycle assessments can provide a thorough understanding of their sustainability advantages. Future research can concentrate on quantifying the reduction in greenhouse gas emissions, analyzing the life-cycle environmental impacts of various zero-emission technologies, and evaluating their potential contributions to climate change mitigation. By investigating these areas of

prospective research, we can advance our knowledge and comprehension of sustainable maritime industry practices. The filling of these research gaps will assist industry stakeholders, policymakers, and researchers in devising effective strategies and policies for achieving zero-emission supply chain operations and developing a more sustainable future.

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Appendices

Appendix 1 – Overview of green shipping technologies.

Overview	Characteristics
Electrification and hybrid solutions	Electrification and hybrid solutions in the context of shipping refer to the utilization of electric propulsion systems and a combination of different power sources, such as batteries, fuel cells, and conventional engines, to reduce emissions and improve the sustainability of ships and vessels (Daniel, Trovo & Williams, 2022). Makes electric propulsion a viable option for lesser distances.
Ammonia	Ammonia (NH_3) is a colorless, toxic gas with a sharp and penetrating odour. It is currently produced primarily from natural gas through energy- and emission-intensive procedures. However, electrolysis can be used to produce ammonia from renewable sources (Norwegian Ministry of Climate and Environment, 2019). It is a hydrogen energy carrier that is easier to store at higher temperatures or lower pressures than hydrogen and has a higher energy density (Zincir, 2022).
Biofuel	Biofuel is the collective category for a variety of liquid or gaseous fuels produced by converting primary biomass or biomass residues into fuels. Although other options are available, the most promising biofuels for ships are hydrotreated vegetable oil (HVO), fatty acid methyl ester (FAME), and liquefied biogas (LBG) (DNV GL, 2019).
Methanol	Methanol is the simplest alcohol and liquid fuel with the lowest carbon content and maximum hydrogen content. Methanol is a liquid fuel derived from natural gas, biomass, and carbon dioxide, and it is most frequently used in internal combustion engines and fuel cells (Ammar, 2019).
LNG	LNG is a colorless mixture of gases, mainly methane (CH_4), that has been cooled to liquidity. It originates from natural gas extracted from gas reserves. CH_4 has the lowest carbon content and has great potential to reduce CO2 emissions (DNV GL, 2019).
Hydrogen	Hydrogen (H_2) is a non-toxic, odorless, and colorless gas. It can be stored as a cryogenic liquid, compressed gas, or chemically bonded for ship use (DNV GL, 2019). The cleanest zero-emission marine fuel is green hydrogen, which is generated using renewable energy. It can be produced in various methods, including the electrolysis of renewable matter and the reformation of natural gas (Giese et al., 2021).

Appendix 2 – Interview guide 1

Theme	Questions
Setting the scene	Consent to record audio of the interview Short introduction of you and the company
Current practices and technologies	What is your company's stance on green shipping technologies, and how do you prioritize environmental considerations in your operations? What are the main drivers and barriers that your company has encountered in adopting green shipping technologies in Norwegian short-sea shipping? What are some of the most promising green shipping technologies or practices that your company has adopted or considered adopting, and what are the challenges and opportunities associated with these approaches?
Regulations and policies	How do you perceive the role of government policies and incentives in promoting green shipping technologies in the Norwegian short-sea shipping sector, and how effective do you think these measures have been?
Future outlook	What are your company's future plans and goals for sustainable upgrading in Norwegian short-sea shipping, and how do you see these practices evolving in the coming years? How does your company collaborate with other stakeholders, such as shippers, ports, and regulators, to promote sustainable upgrading in Norwegian short-sea shipping, and what are the challenges and opportunities associated with such collaborations? How do you assess the economic and environmental benefits of sustainable upgrading in Norwegian short-sea shipping, and what metrics or indicators do you use to measure these benefits? What are the most significant risks or uncertainties that your company faces in adopting green shipping technologies in Norwegian short-sea shipping, and how do you mitigate these risks?
Closing Remarks	Is there anything else you would like to add or discuss that has not been covered in this interview? Thank you for your time

Appendix 3 – Interview guide 2

Theme	Questions
Introduction and background	Introduce yourself, your role, and your experience in the maritime industry The role, goals and position in the Norwegian market How familiar are you with the concept of zero-emission and its implications for the industry?
Challenges and Opportunities in Achieving Zero Emissions	From your perspective, what are the key challenges/ opportunities that the Norwegian short-sea maritime supply chain faces in transitioning to zero emissions? What are the potential opportunities for the industry in terms of zero-emission technologies, alternative fuels, or innovative practices? What is the current status of the Norwegian maritime industry in terms of transitioning to zero-emission?
Stakeholder Collaboration and Engagement	How important is collaboration among different stakeholders in driving the transition to zero emissions in the short-sea maritime industry? In your opinion, which stakeholders should play a crucial role in driving the transition to zero emissions in the Norwegian short-sea maritime supply chain? How can stakeholders in the supply chain, including shipping companies, ports, and cargo owners, collaborate effectively to drive the transition toward zero emissions?
Regulatory Framework and Incentives / Policies, Regulations, and Incentives	What kind of policy framework and regulations do you believe are necessary to facilitate the transition to zero emissions in the maritime supply chain? Are there any existing policies or regulations in Norway or internationally that have positively impacted emission reduction in the maritime sector? In your opinion, what incentives or financial mechanisms could encourage maritime stakeholders to invest in sustainable technologies and practices?
Role of Green Shipping Technologies / Technological Innovation and Research	How important is technological innovation in achieving the transition to zero emissions in the maritime supply chain? Are there any specific research areas or technological advancements that you believe are crucial for the industry's sustainable development?

	What strategies or actions has your company/organization implemented or considered to reduce emissions in the supply chain?
Future Outlook and Recommendations	What do you envision as the most significant milestones or goals for the Norwegian short-sea maritime supply chain in terms of achieving zero emissions and sustainability? Are there any emerging trends or initiatives that you believe will shape the future of sustainable maritime supply chains? What are the long-term sustainability goals for the maritime supply chain in Norway, particularly regarding zero emissions and environmental sustainability? Based on your experience, what do you think are the key factors or actions necessary for the Norwegian maritime industry to successfully achieve sustainability by 2050?
Closing Remarks	Is there anything else you would like to add or discuss that has not been covered in this interview? Thank you for your time