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Green Ammonia as a Marine Fuel in the Offshore Shipping Industry

Which Barriers and Strategies for Implementation can be Identified?

Bachelor's thesis in Shipping Management
Supervisor: Tore Relling
December 2023

Bachelor's thesis

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Preface

This thesis marks a substantial milestone of my academic journey at the Norwegian University of Science and Technology. Through this work, I have integrated theoretical principles from my Bachelor of Science in Shipping Management with empirical insights gained within the maritime sector. I am fortunate to have had the opportunity to research a topic that was concurrently developing extensively, specifically the implementation of green ammonia as a marine fuel in the offshore shipping industry.

The thesis' broad and exploratory design has given me insights into various levels of the maritime sector, from regulatory authorities to technology suppliers. This comprehensive perspective has enhanced my understanding with practical insights, going beyond theoretical knowledge from an academic setting. However, the extensive data collection in the exploratory design posed occasional challenges.

Engaging in tasks and closely observing chartering operations during the internship has given me a deep comprehension of this segment within the offshore shipping industry. I extend my sincere gratitude for the privilege of undertaking my internship at Seabrokers Chartering, where I was warmly welcomed by all colleagues who generously shared their knowledge and support. Special appreciation goes to my colleagues in the Renewables, Subsea, and Projects department, Aleksander Kjønnerød and Simon Skjoldevik. Learning from their expertise and work has been invaluable. Additionally, associate professor Tore Relling provided insightful guidance throughout the writing process, aiding me in navigating the complexities of the academic composition.

Stavanger,

December 2023

Vegard Bråtveit Torgersen

Abstract

This thesis explores the ongoing green transformation in Norway's offshore shipping industry as part of the broader global shift in the maritime sector towards environmental sustainability. The empirical motivation stems from the assumed significant influence of regulations and incentives in driving the adoption of low-emission technologies, particularly focusing on green ammonia for propulsion, a rapidly evolving technology.

The theoretical framework includes three main concepts: the multi-level perspective (MLP) theory, organizational change theory according to Jacobsen and Thorsvik, and the diffusion of innovations (DOI) theory. These theories support the thesis' argument that the transformation in the offshore shipping industry is a complex interaction involving actors, technologies, policies, and institutions. The comprehensive background chapter covering regulatory initiatives, in addition to organizational change theory, and the DOI theory compliment the MLP theory.

To address the research question within this theoretical framework, a methodology derived from Larsen's qualitative research phases, complemented by Busch's and Tjora's theories, is employed. The empirical evidence draws from the analysis of eleven interviews with stakeholders in the offshore shipping industry, operating at different levels within the industry.

The research highlights that the shift towards green ammonia as a marine fuel is not solely a technological transition; rather, it involves a dynamic interplay among stakeholders. The main findings show that factors such as the green change, EU policies, and IMO, inherent driving forces, contribute to ambiguity in the maritime system, impeding ammonia engagement. Charterers, influential in driving implementation, display varying commitment levels. Organization proactivity is observed but also unpreparedness due to safety concerns. Additionally, incentives and safety are seen as critical drivers in similar technologies. Overcoming barriers involve leveraging industry collaboration, regulatory support, charterer responsibility, and organizational structures for sustainability assessment.

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Abbreviations

AHTS	Anchor Handling Tug Supply
CCS	Carbon, Capture and Storage
CFD	Contract for Difference
CAPEX	Capital Expenditures
CO_2	Carbon Dioxide
DOI	Diffusion of Innovations
EU	European Union
ETS	Emissions Trading Systems
GHG	Greenhouse Gas
GT	Gross Tonnes
IMO	International Maritime Organization
MGO	Marine Gas Oil
MLP	Multi-Level Perspective
NOx	Nitrogen Oxide
OPEX	Operational Expenses
OSV	Offshore Support Vessel
PSV	Platform Supply Vessel

1 Introduction

The offshore shipping industry in Norway is facing continuous and increasing pressure from various stakeholders in relation to decreasing its carbon footprint. Collectively, the maritime sector accounts for approximately 2.9 per cent of human-caused greenhouse gas (GHG) emissions (European Commission, 2023). In Norway, emissions from maritime offshore activities account for approximately 37 per cent of the emissions from domestic shipping and fishing. The Norwegian petroleum industry has set an ambitious target to decrease greenhouse gas emissions from the oil and gas sector by 50 per cent by 2030 compared to 2005 levels (Norwegian Environment Agency, 2023). As of recently, ammonia (NH_3) has taken much of the spotlight in the alternative maritime fuel debate. In particular, green ammonia, being CO_2 emission free, is of great interest. The Norwegian Environment Agency anticipates a potential decrease of 0.232 million tonnes of CO_2 emissions by 2030 through the utilization of ammonia and biofuels for offshore vessels (Norwegian Environment Agency, 2023).

1.1 Research question, limitations and assumptions

Studies on sustainability concering maritime transport largely cover emissions reduction technologies, decision-making in technology choices, and governance's role in fostering sustainable shipping (Wells et al., 2018; Bacha et al., 2020). Despite the urgency to cut greenhouse gas emissions from maritime activities globally, sustainability transitions research has somewhat neglected the maritime sector empirically (Bacha et al., 2020; Bergek et al., 2018). There has been conducted research on electrification of Norwegian shipping utilizing socio-technical analysis (Nykamp et al., 2023), and on the broader landscape of sustainable transformations of the maritime industry in Western Norway (Sjøtun, 2020; Steen, 2019). However, no such research has been identified specifically related to green ammonia adoption, and neither any research combining theories of the multi-level perspective (MLP), organizational change, and the diffusion of innovations (DOI) theory. The MLP theory was utilized to describe a green transition in the construction industry (Grøv, 2019), and was combined with DOI theory in a case study of technologies in Norwegian municipalities (Haugen, T., Kristensen, G. P. G., 2016). By investigating the multifaceted dynamics of integrating green ammonia, this research aims to contribute nuanced insights into the challenges, opportunities, and transformative processes associated with sustainable fuel adoption in the maritime sector. This thesis aims to highlight the importance of different stakeholders within the offshore shipping industry aligning their efforts towards a common goal, a reduction of emissions, in light of new regulatory efforts to drive the green transformation in shipping.

Considering this context, I aim to respond to the following research question:

Green Ammonia as a Marine Fuel in the Offshore Shipping Industry: Which Barriers and Strategies for Implementation can be Identified?

The sub-research questions discuss the driving forces and barriers, innovation adoption, and strategies to remove the barriers.

The sub-research questions are:

1. What are the main driving forces supporting the implementation of green ammonia as a marine fuel in the offshore shipping industry?
2. What specific barriers impede the implementation of green ammonia as a marine fuel in the offshore shipping industry?
3. What affects the adoption of new innovations such as green ammonia?
4. How can partnerships, collaborations, or government initiatives be leveraged to overcome identified barriers and facilitate the practical implementation of green ammonia as a marine fuel in offshore shipping?

Assumptions

It is necessary to clarify assumptions to further shape the research's direction.

- Shipping is a highly commercial industry, where cashflows are the main priority. Considering the cost of green ammonia as per now, I assume government support and incentives are crucial factors for the success of green ammonia as a marine fuel.
- Implementing new technologies is not often done singlehandedly. Therefore, I assume that the development and usage of green ammonia relies on stakeholder engagement and collaboration.
- It is assumed that the technical solutions for ammonia implementation, such as ammonia combustion engines, bunkering of ships, and development of infrastructure, are all fast approaching and employable.

- Lastly, it is assumed that Norway's climate politics are closely linked to the European Union's (EU). Historically, Norway has never rejected any laws or regulations suggested by the European Economic Area committee.

Limitations

In addition to the assumptions, there are also some limitations which need to be addressed.

- A comprehensive technical analysis of ammonia will not be performed, nor a comparison of other emerging fuels or marine gas oil (MGO). This thesis focuses on the commercial and regulatory aspects of green ammonia implementation, and not the technical side.
- Economic factors, such as the cost-effectiveness of green ammonia, will not be extensively analysed. As per the assumption previously described, ammonia is presently not cost effective.
- The research does not include empirical insights from the charterers' point of view.
- Lastly, the research is limited to the Norwegian offshore shipping market, excluding other large offshore markets, such as the Brazilian and American ones.

Thesis structure

The thesis is divided into six chapters. In Chapter 1, the research questions, assumptions, and limitations are outlined. Chapter 2 provides recent developments and the regulatory background for green ammonia implementation. The theoretical framework is presented in Chapter 3. Chapter 4 describes the methodology utilized. The thesis' results are presented in Chapter 5, and discussed in Chapter 6, with suggestions for future work and criticism of the thesis. Lastly, Chapter 7 presents the conclusions.

2 Background

The goal of the background chapter is to give the reader a understanding of recent broad developments affecting the development of green ammonia implementation, building a basis for the theoretical framework. Firstly, an introduction will be given to the maritime landscape. I have chosen to showcase the ShipFC project in the maritime landscape, as this is the largest, and first, ammonia project in the offshore shipping industry. Then, a time charter for an offshore support vessel (OSV) will be described to exemplify the fuel costs associated with typical operations in the offshore shipping industry. Next, the background chapter will address factors which have been identified as influencing the adoption of green ammonia from a regulatory view, starting from the most local influences to the broadest. Thus, national strategies will be described first, followed by EU strategies and lastly IMO strategies. Literature for this chapter has been identified mostly outside of academic publications, such as sites including the International Maritime Organization (IMO), the Norwegian Environment Agency, the (Norwegian) Government, the European Commission and classification- and advisory organization DNV.

2.1 Offshore Shipping

Offshore shipping refers to the transportation of goods, substances, personnel, or equipment specifically in the context of offshore activities such as oil and gas exploration and production on the sea (North Sea) of the Norwegian continental shelf.

ShipFC project

The ShipFC project illustrates collaboration from different stakeholders in the offshore shipping value chain, from technology suppliers such as Alma Clean Power and Wärtsila to the Sustainable Energy Catapult Centre, governed by Siva, a state-owned agency. The project will showcase an ammonia fuel cell on ship owning company Eidesvik’s plattform supply vessel (PSV) “Viking Energy”, set to operate commercially for the energy company Equinor (Ship FC, 2020). Green ammonia produced by Yara’s green hydrogen plant at Herøya in Eastern Norway, which started production in 2023, will be utilized for energy in a 2 megawatt (MW) fuel cell. Furthermore, land fuel systems for ammonia, and the integration of the full system will also be tried on a offshore subsea construction vessel

(OSCV), a bunker vessel and a cargo vessel, including studies of 20+ MW systems. A PSV typically requires 5 – 8 MW in total for propulsion (Seabrokers, 2023).

Figure 1: The Viking Energy PSV with its history of technological solutions (Eidesvik, n.d.)

The Ship FC project secured funding from the Clean Hydrogen Partnership, a collaborative effort backed by the European Union's (EU) Horizon 2020 research and innovation program, as well as Hydrogen Europe, an organization representing European based companies and stakeholders. In the funding application, reaching IMO's goals of halving maritime emissions by 2050 were referenced. Maritime CleanTech, representing the Norwegian maritime cluster, served as the coordinator for the project, while many other organizations supported with funding (CORDIS, 2023).

A "typical" time charter

In the offshore maritime domain, the four main "players" are the charterer, shipowner, shipbuilders/suppliers and the broker (Stopford, 2009). The charterer, typically upstream oil companies, e.g., Equinor and Aker BP, need vessels for offshore assignments such as rig moves and supply duties. Charterers generally use shipbrokers, acting as intermediaries. The shipbrokers contact shipowners to investigate available vessels for hire, also known as vessels for charter. Although technical capabilities, such as the modernity of deck machinery for anchor handling tug supply vessels (AHTS), are of great importance to the charterer, the cost aspect is often deciding (Panayides, 2018). To showcase the cost relationship between a "typical" time charter (operations lasting under 30 days) of an AHTS vessel and the cost of fuel, data will be presented from the rig move of the semi-submersible rig Stena Don, a 7.7-day workscope from the 18th to 26th of July 2023. The total cost of the charter, payable by the charterer, amounted to £ 516 779, of which fuel costs made up £ 99 171, or about 20 per cent of the total cost (before Norwegian fuel taxes are applied) (Seabrokers, 2023). Marine gas oil (MGO) fuel costs, the most common fuel used for offshore support vessels (OSV) typically amount to around 15 – 25 per cent of the total cost of the time charter (Seabrokers, 2023). In instances, when the day rate (vessel earnings) is high, the fuel cost will be lower relative to the total cost, and vice versa. It is expected that the cost of clean ammonia will be on average approximately 200 – 400 per cent more expensive than conventional fuel during the vessel's early years of operation (Nordic Innovation, 2023). As fuel is payable by the charterer in time charters, they would hypothetically have to pay a high price for green ammonia fuelled vessels as of 2023.

2.1.2 A brief summary of ammonia

The following paragraph is based on The Norwegian Environment Agency's "Climate measures in Norway towards 2030" publication published on the 2nd of June 2023, reviewing, amongst many other aspects, potential barriers and means necessary for the implementation of renewable fuels for offshore shipping.

Ammonia can be used in a customized combustion engine or fuel cell and is produced from green (renewable based), brown (fossil based) or blue (fossil based with carbon, capture, and storage (CCS) technologies) hydrogen and nitrogen. There is however a significant energy loss in the production process. Both ammonia and hydrogen have fuel properties that make ships more challenging to design, build, and operate, which is reflected in the cost of ships using these technologies. For instance, it is assumed that ammonia-powered ships have 10 – 100 per cent higher capital expenditures (CAPEX) and operational expenditures (OPEX) than conventional newbuilds. Testing and development of dual-fuel engines for ammonia are underway, and these engines are expected to be on the market around 2024 – 2025. A quantity of MGO is typically required as "pilot fuel" for ammonia combustion. With relatively low distribution costs compared to production costs, fuels like ammonia can also be imported into Norway. There is a lack of experience with the use and handling of ammonia and hydrogen as ship fuels, both in onboard technology and land-based bunkering infrastructure. It is assumed that the onboard technology will be technologically mature for hydrogen and ammonia around the mid-2020s through ongoing technology development and piloting. Charterers are collaborating with shipping companies in development projects for potential conversion to ammonia propulsion on at least five existing offshore vessels, though some of these are not official. Neither blue nor green ammonia is currently available, but there are plans for production that could provide sufficient volumes in Norway. The amount of ammonia which will be allocated to maritime transport depends on demand in various sectors and price dynamics. A market for transport and distribution in Europe is also anticipated, with suppliers outlining plans for ammonia bunkering facilities for ships, including at offshore bases (The Norwegian Environment Agency, 2023).

2.2 National Strategies

"National" strategies are meant by strategic plans designed by the government at the highest level to the state owned agencies at the lowest level, influencing the adoption of green ammonia in the offshore shipping industry through different policies, regulations and incentives.

Hurdalsplattformen

Hurdalsplattformen refers to the government platform by prime minister Støre's administration, consisting of the Labour Party and the Centre Party. The platform was presented in 2021, and lay strategies for the government's reigning period up until 2025. It includes requirements for low-emission solutions from 2025 and zero-emission from 2030 for OSVs (The Government, 2021). No specific demands from the government have currently been materialized regarding emissions from the offshore shipping sector.

Incentives

The main national agencies delegating funds to alternative fuel projects are Innovation Norway, dedicated to fostering economic growth and innovation, The Research Council of Norway, responsible for funding and promoting research and innovation and Enova, focused on promoting the transition to a more sustainable energy system. These agencies came together in 2018, creating the PILOT-E scheme. The goal of the scheme was to accelerate the development and adoption of new products and services within environmentally friendly energy technology to contribute to emissions reductions both in Norway and internationally. The scheme has targeted areas such as zero-emissions maritime transport and zero-emissions hydrogen value chains (Enova, n.d.). On a national scale, there is substantial attention directed towards the transition to hydrogen technology, exemplified by the allocation of approximately NOK 500 million in research project funding spanning the decade from 2010 to 2020 (Høyland et al. 2023). Furthermore, Enova is intensifying efforts to advance the development of economically viable hydrogen and ammonia solutions within the maritime industry. As a result, Enova has introduced two new support initiatives in the final quarter of 2023: "Marine Hydrogen" and "Marine Ammonia." These initiatives will adopt a competitive bidding framework, allowing shipowners and other stakeholders to seek financial assistance for vessels intended for hydrogen or ammonia propulsion (Enova, 2023). The stated agencies and projects are in accordance with the Norwegian government's action plan for green shipping (The Government, 2019).

Contracts for differences

The contract for difference (CFD) serves as a subsidy tool for promoting green alternatives, aiming to incentivize investments in energy production assets with substantial initial costs. This mechanism provides price stability over an extended period, allowing governments to bridge the cost gap between fossil and green fuels during the transition to a more sustainable economy (Norwegian Shipowners' Association, n.d.). While not yet implemented in Norway, stakeholders such as the Norwegian Shipowners' Association, ammonia producer Yara, hydropower producer Statkraft, and non-profit lobbyist group ZERO have actively advocated for CFD implementation, emphasizing its significance (Zero, 2022). CFDs were not mentioned in the suggested Norwegian state budget for 2024, to the dismay of stakeholders (Norwegian Hydrogen Forum, 2023; Norwegian Shipowners' Association, 2023). The government is instead looking to commit Norway to the European Hydrogen Bank, aiming to subsidize renewable hydrogen production. The Hydrogen Bank may introduce "Carbon Contracts for Differences" (CCfD), but these auctions are anticipated by commercial stakeholders to be large and complex, possibly requiring a large time to launch (The Confederation of Norwegian Enterprise, 2023).

Mineral product tax

There is a carbon dioxide (CO_2) tax payable on mineral oil such as MGO imported or produced in Norway. The tax is set at 2,53 NOK per litre as of 2023. If the mineral oils contain more than 0.05 per cent suplhur, a tax of 0,146 per litre is added (The Norwegian Tax Administration, 2023. The mineral product tax is suggested in the state budget of 2024 to be increased to 3.17 NOK per litre, marking a considerable increase from 2023 (The Government, 2023).

NOx tax

There is a tax on nitrogen oxide (NOx) emissions from ship engines above 750 kilowatts (kW), affecting most OSVs, set at NOK 24.46 NOK per kilogram (The Norwegian Tax Administration, 2023). The tax applies within Norwegian territorial waters, with exemptions for international traffic and vessels in direct traffic between Norway and foreign ports. 15 Norwegian business organizations formed the NOx Fund through an Environmental Agreement with the Ministry of the Environment in 2008. The NOx Fund replaced the government's NOx tax for participant companies, encouraging investments in green technology. A new agreement for 2018 – 2025 aims to further reduce NOx emissions, contributing to Norway's international commitments and promoting environmental technology (The NOx Fund, n.d.). The NOx tax is set to increase to 25.59 NOK in 2024 (The Government, 2023).

2.3 European Union Strategies

Through the European Economic Area Agreement (EEA), Norway is an equal partner in the "internal market", on the same terms as EU member states. Therefore, it is heavily influenced by rules and regulations imposed by the EU. The Norwegian Environment Agency asserts that the EU ETS is the EU's most important tool for cutting greenhouse gas emissions and remains the globe's largest carbon market (The Norwegian Environment Agency, 2023).

European Union Emissions Trading System

The Norwegian Environment Agency manages the EU ETS in Norway. The EU ETS operates based on a "cap and trade" principle. A limit is set on the total GHG emissions allowed for covered operators, and this cap decreases over time to reduce emissions. Operators are allocated emissions allowances within this cap, which they can trade among themselves. This creates value for allowances and encourages emission reductions and investments in low-carbon technologies. Operators must surrender enough allowances to cover their emissions each year, or they face significant fines. Surplus allowances can be saved or sold to others in need (European Commission, 2023). From 2027, OSVs exceeding 5000 gross tonnes (GT) will be included. GT is a measurement of a ship's volume from keel to the outside of the hull framing. Most PSVs operating in the North Sea do not exceed 5000 GT, because of their large open deck. However, the large majority of AHTS vessels, survey and inspections vessels, heavy lift vessels, service operation support vessels (SOV), OSCVs, oil exploration and drilling vessels, and offshore production vessels (et cetera) exceed 5000 GT, largely due to their large accommodation spaces aboard (DNV, 2023).

Fit for 55

The "Fit for 55" package, introduced in 2021, aims to enhance and extend the EU ETS for a minimum 55 per cent emissions reduction by 2030, compared to 1990, with a further goal of 62 per cent reduction from the inaugural year, 2005. Emission allowances, currently decreasing by 2.2 per cent annually, will see a steeper reduction to 4.3 per cent by 2024 and 4.4 per cent per year by 2028 (Emissierechten, 2023). Figure 2 illustrates the annual decrease in CO_2 emission allowances. The figure indicates that no more emissions allowances will be available in 2039. To prevent companies from moving carbon-intensive production outside the EU and to promote cleaner industrial practices, the EU has introduced the Carbon Border Adjustment Mechanism (CBAM). This mechanism places a price on carbon emissions associated with carbon-intensive products entering the EU, and it aligns with the phase-out of free allowances for emissions in the EU ETS, as seen in the figure. This helps ensure fair competition and encourages cleaner production worldwide. Norway reviews CBAM's relevance to the EEA, asserting non-binding adoption as of 2023 (The Government, 2023).

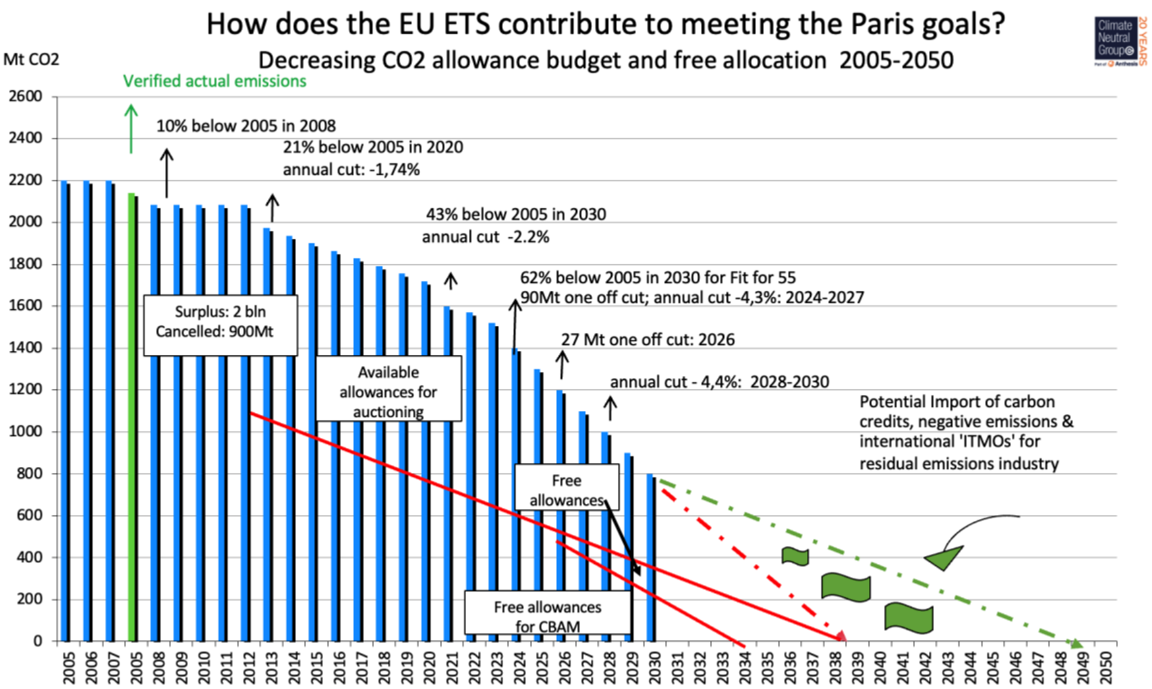

Figure 2: Implications of the revised EU ETS through the Fit for 55 package (Emissierechten, 2023)

In forecasted pricing scenarios, various models predict EU ETS prices to range from 130 to 160 Euros in 2030, while current prices stand at approximately 84 Euros per metric ton of CO_2 emitted (Tradingeconomics, 2023; egologic, 2022). In October 2023, MGO, emitting about 3 tonnes of CO_2 per ton used in ship engine combustion, was priced at 800 Euros per ton. This indicates a projected cost of 1435 Euros for vessels using 1 ton of MGO in 2030 in the EU (ship&bunker, 2023). In comparison, the price per ton of green ammonia varies from 700 to 1400 Euros. Because of MGO's over twice higher energy content per metric ton used in combustion as compared to ammonia, the latter remains notably more expensive in 2030, without factoring in additional CO_2 taxes and potential ammonia price reductions from increased production (Barelli et al., 2020).

Fuel EU Maritime

Following the adoption of the "FuelEU Maritime" initiative from January the 1st 2025, vessels will be subject to gradual emission intensity reductions (European Commission, 2023). Its core objective is the reduction of emissions through utilization of sustainable fuels within the shipping industry (European Council, 2023). The initiative does not include offshore vessels at the time of writing. Although OSVs under 5000 GT are not included in the EU ETS or the FuelEU Maritime in 2024 or 2025, as long as the vessels are between 400 and 5000 GT, their owners will be included in the monitoring, reporting, and verification (MRV) regulation from 2025. Furthermore, their potential early inclusion in the EU ETS will be reviewed in 2026 (Hagberg, 2022).

2.4 International Maritime Organization Strategies

International shipping is regulated worldwide by the IMO, which was established in 1948 through a UN treaty in Geneva. With 175 member nations as of 2023, the IMO aims to take the lead in marine affairs. Its main focus is on creating and maintaining a comprehensive set of laws for the maritime industry, covering areas such as safety, environmental considerations, legal matters, sea optimization techniques, and technical applications (IMO, 2023).

In the summer of 2023, IMO significantly enhanced its greenhouse gas (GHG) strategy. Member states have committed to achieving net zero GHG emissions around 2050, in alignment with the European Green Deal, with interim targets to reduce total GHG emissions by 20 – 30 per cent by 2030 and 70 – 80 per cent by 2040, relative to 2008 levels. This marks a substantial difference from the initial 2018 strategy, which aimed for a 50 per cent reduction by 2050 with no interim targets (IMO, 2023).

IMO & ammonia

The International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code), the IMO's standard for the use of gases as a fuel in maritime transport, lacks specific provisions for ammonia fuel. When designing ammonia fuelled vessels, this gap necessitates the Alternative Design Approach through the International Convention for the Safety of Life at Sea (SOLAS, under the IMO), which involves a complex risk-based process outlined in a Maritime Safety Committee (MSC, under the IMO) framework. A simplified process is feasible if the flag (country in which a ship is registered) accepts classification rules or interim guidelines, ensuring safety equivalent to the IGF Code's functional requirements. Safety assessments by classification societies, such as DNV, are mandatory (Harnes, 2023).

Norway and Japan, among other, Nordic, countries, submitted draft interim guidelines to the Sub-Committee on Carriage of Cargoes and Containers (CCC9) in September 2023. The discussions were focused on hydrogen and ammonia. CCC9 resulted in an agreement for an intersessional working group before the Sub-Committee on Carriage of Cargoes and Containers (CCC10), specifically focusing on ammonia. The goal is the finalization of interim guidelines for ammonia fuel by CCC10 in September 2024, so that approval of ammonia fuelled ships will be an easier process (Harnes, 2023).

3 Theoretical Framework

The "green transition" in shipping aims to shift from fossil-fuelled vessels to eco-friendly technologies, such as using green ammonia as a marine fuel. While it is s a technological shift, focusing solely on technology does not fully explain the complex and time-consuming nature of such transitions. This is because technology is intertwined with social processes, institutions, practices, and contextual factors, making technological shifts socio-technical processes of change (Steen, 2018, p. 2 – 3). Sustainability transitions refer to long-term, multi-faceted processes of profound change in which established socio-technical systems transition toward more sustainable patterns of production and consumption. Notably, guidance and governance often play a crucial role in steering these transitions (Smith et al., 2005). It is essential to recognize that the concept of sustainability is open to interpretation and can evolve over time (Garud & Gehman, 2010). Therefore, theories and perspectives aimed at explaining societal sustainability transformations must emphasize the complexity of these transitions, involving dynamic structural changes at various levels (Markard et al., 2012). The theoretical framework will encompass the multi-level perspective (MLP), a socio-technical model, change in organizations to highlight the role of organizations in the transformation, as described by Jacobsen and Thorsvik (2013), and the diffusion of innovations (DOI) to look at ammonia as an innovation isolated.

3.1 Transition Studies

Transition studies define a particular interdisciplinary field exploring societal systems as complex, adaptive entities, investigating non-linear, long-term change processes. This holistic viewpoint acknowledges the interplay' between human and non-human elements (Avelino & Rotmans, 2009). In discussing transitions towards sustainability, Geels (2011) highlights several distinctive features.

Firstly, these transitions are "goal oriented", with private actors often having limited incentives to engage in them due to the collective nature of the sustainability goal, resulting in free rider issues. Free riders may enjoy positive outcomes of changes while others drive the change. Addressing sustainability transitions requires the active involvement of public authorities and civil society to address public goods, internalize negative externalities, alter economic conditions, and support eco-friendly initiatives

(Geels, 2011, p. 25). Secondly, sustainability solutions may not always offer immediate user benefits and can be less economically competitive than established technologies, necessitating changes in economic conditions, policy adjustments, and power struggles as vested interests resist such changes (Geels, 2011, p. 25). Kivimaa and Kern (2015) argue that better facilitation of niche innovations through policy is necessary. Lastly, the domains in which sustainability transitions are most crucial, like transport, energy, and agri-food, are dominated by large firms with complementary assets, giving them a competitive advantage. While these firms may not initially lead sustainability transitions, their support can expedite the adoption of environmental innovations, but only if they undergo a strategic reorientation. Consequently, sustainability transitions encompass interactions among technology, policy, economics, and culture (Geels, 2011, p. 25).

3.2 Multi-level Perspective

I have chosen the MLP, developed by Geels, to gain a broad view on the transition that is a shift to green ammonia, although other models are also used in transition studies, such as technological innovation systems (TIS) (Smith et al., 2010; Bergek et al., 2018). The most influential concept in transition studies revolves around the multi-level interaction among regimes, niches, and landscapes (Avelino & Rotmans, 2009). The MLP structures the analysis within a sociotechnical framework. The perspective has had a significant impact on the fields of sustainability studies, innovation studies and socio-technical transitions research. Socio-technical transitions refers to the fundamental and often disruptive changes that occur when new technologies and practices challenge existing norms and systems. This transition involves shifts in both the technological and social dimensions, ultimately reshaping how societies function and how industries operate (Avelino & Rotmans, 2009).

Figure 3 provides a simplified representation of how the three levels interact in the progression of socio-technical transitions. Although each transition is unique, a common pattern emerges characterized by interactions across different levels: (a) niche innovations gradually gain momentum internally, (b) shifts occurring at the landscape level put pressure on the existing regime, and (c) when the regime destabilizes, it creates opportunities for niche innovations to breakthrough. These interactions can be further categorized into distinct phases like emergence, take-off, acceleration, and stabilization. Each of these phases can be associated with specific mechanisms (Geels, 2010).

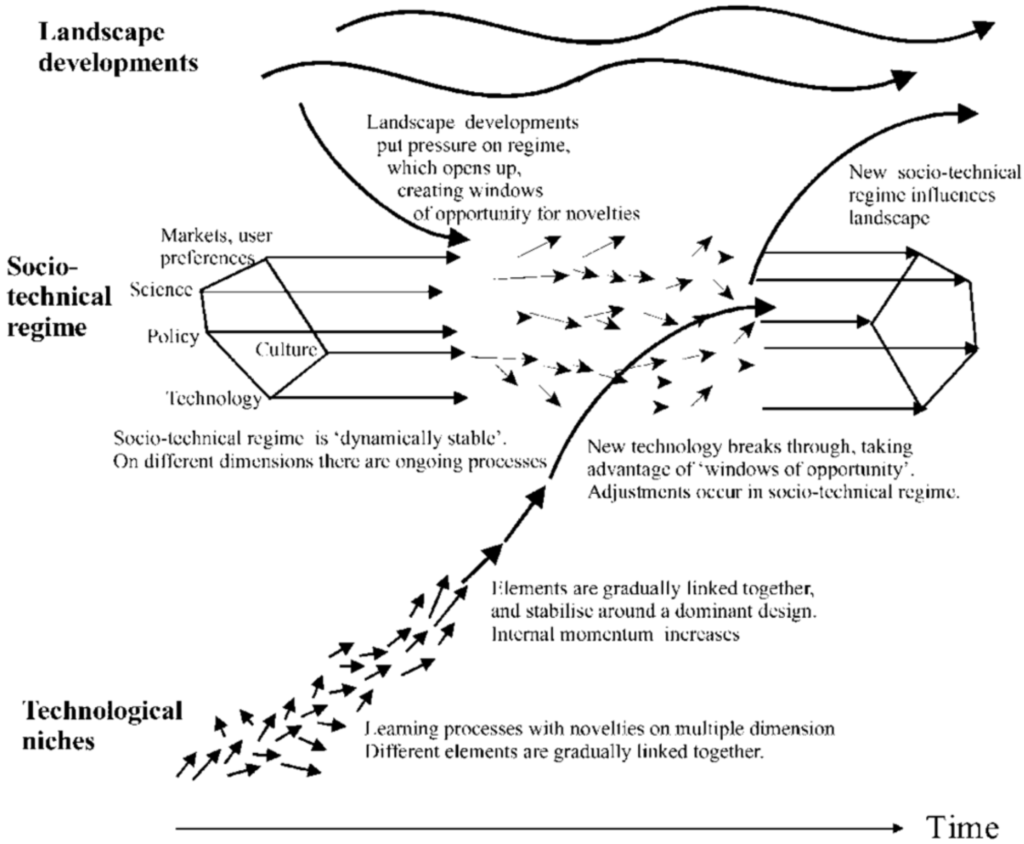

Figure 3: A dynamic perspective on the Multi-Level Perspective (Geels, 2011)

3.2.1 The regime level

The socio-technical regime level describes a stable combination of organizations, technologies, legal frameworks, societal norms, and associated elements that collectively describe the world as we know it (Wells et al., 2018). Change can happen at this level but is often weakened by feedback mechanisms that slow the speed and extent of transformation. Regimes tend to be self-sustaining structures, influenced from higher levels by factors in the landscape (Wells et al., 2018). It therefore serves as the underlying framework responsible for maintaining the stability of an established socio-technical system (Geels, 2004; Geels, 2011). A socio-technical framework might encompass domains such as the maritime industry and construction industry (Markard et al., 2012). Sustainable niches, which aim to disrupt existing regimes and initiate transitions, face challenges in overcoming the regime's inactivity. Dynamism within the regime can originate from both internal factors such as research and development, and external factors such as government regulations or interactions with related regimes. These dynamic elements introduce tension and uncertainty within the regime, creating windows of opportunity for niche alternatives (Smith et al., 2010, s. 441). Sustainable niches can leverage these moments to compete for influence and potentially trigger a transition away from the established regime. Within the Norwegian maritime industry, examples of organizations within the regime level include representative organisations such as the Norwegian Shipowners' Association, the Norwegian Seafarers Union, ship owners, ship charterers (e.g. petroleum companies), naval architects, shipbuilders and suppliers, flag states, finance and investment organisations, and the customers of the shipping sector (both on the supply side and the demand side) (Wells et al., 2018).

3.2.2 The landscape level

The socio-technical landscape serves as the broader context that exerts an influence on the dynamics of the underlying niches and regimes. It underscores not just the technical and material aspects supporting society, but also includes factors such as population changes, political beliefs, social values, macro-economic patterns (Geels, 2011). These factors represent areas where individual actors have relatively minimal direct impact. Nevertheless, indirect influence at the landscape level can manifest itself, for example through the engagement of governmental entities or organizations such as the Shipowners' Association in the development of international emission regulations and standards (Steen, 2018, p. 3). As per Bilali (2019, p. 10), the landscape level plays a dual role in sustainable transformations. It not only pushes the regime level to adapt but also facilitates the emergence and growth of niche developments. The landscape-level elements generally change slowly and have a broad and systemic influence (Wells et al., 2018). A broad example is China's "One-Belt One-Road" (OBOR) initiative, a vast infrastructure project aiming to connect Asia, Europe, and Africa via land and maritime routes. If successful, the OBOR project could significantly impact global shipping trade by shifting cargo from sea routes to land routes, (Wells et al., 2018). Examples of other developments at the landscape level particularly affecting the adoption of ammonia in the maritime sector are the Paris Agreement, the UN's Sustainable Development Goals (SDGs), and increased societal attention to climate change.

3.2.3 The niche level

The niche level represents the localized dimension of the innovation process and typically thrives in sheltered environments, including business and knowledge clusters, subsidized demonstration projects, and laboratories (Steen, 2019, p. 25). In the Norwegian maritime sector, such clusters and networks are not uncommon. Niches are often thought of as emerging quickly and, conversely, fading away just as swiftly. This dynamic can lead to niches expanding and eventually supplanting an existing regime, as exemplified by the way steam technology replaced sail in the field of shipping (Geels, 2002; Wells et al., 2018). Within this level, technologies and innovative sociotechnical practices develop independently from the mainstream market. Examples of niche activities within shipping are rigid sails, ammonia for propulsion and battery systems. Nonetheless, as per Bilali (2019, p. 5), a niche can encompass a wide array of elements. According to Bilali (2019, p. 5), a niche can include recent technology, novel regulations and legislation, emerging entities, innovative projects, concepts, or notions. Market niches are characterized by users with distinct needs who are receptive to embracing emerging innovations. Key aspects of niche management encompass setting expectations, facilitating learning, and fostering networks (Geels, 2011, p. 28). Niche environments, in contrast to well-established systems, tend to have less well-defined rules and more unpredictability. Over time, the emerging technology may become a prevailing trend, with a growing number of participants embracing the advanced technology. These broader trends at the landscape level exert pressure on the existing socio-technical system, creating an opening for niche developers to disturb and convince fellow entrepreneurs of the benefits of their technology. This interplay of dynamics across these various levels leads to a transition. Consequently, there's a transformation within the sector's structure, as described by Geels (2011). Radical socio-technical systems may encounter challenges in gaining acceptance, primarily due to mismatches with existing established regimes. Such misalignments may include the absence of necessary infrastructure, regulatory frameworks, and consumer behaviours (Geels, 2011, p. 27).

In the figure below, aspects in relation to the maritime industry are placed in landscape, regime, and niche levels of the MLP.

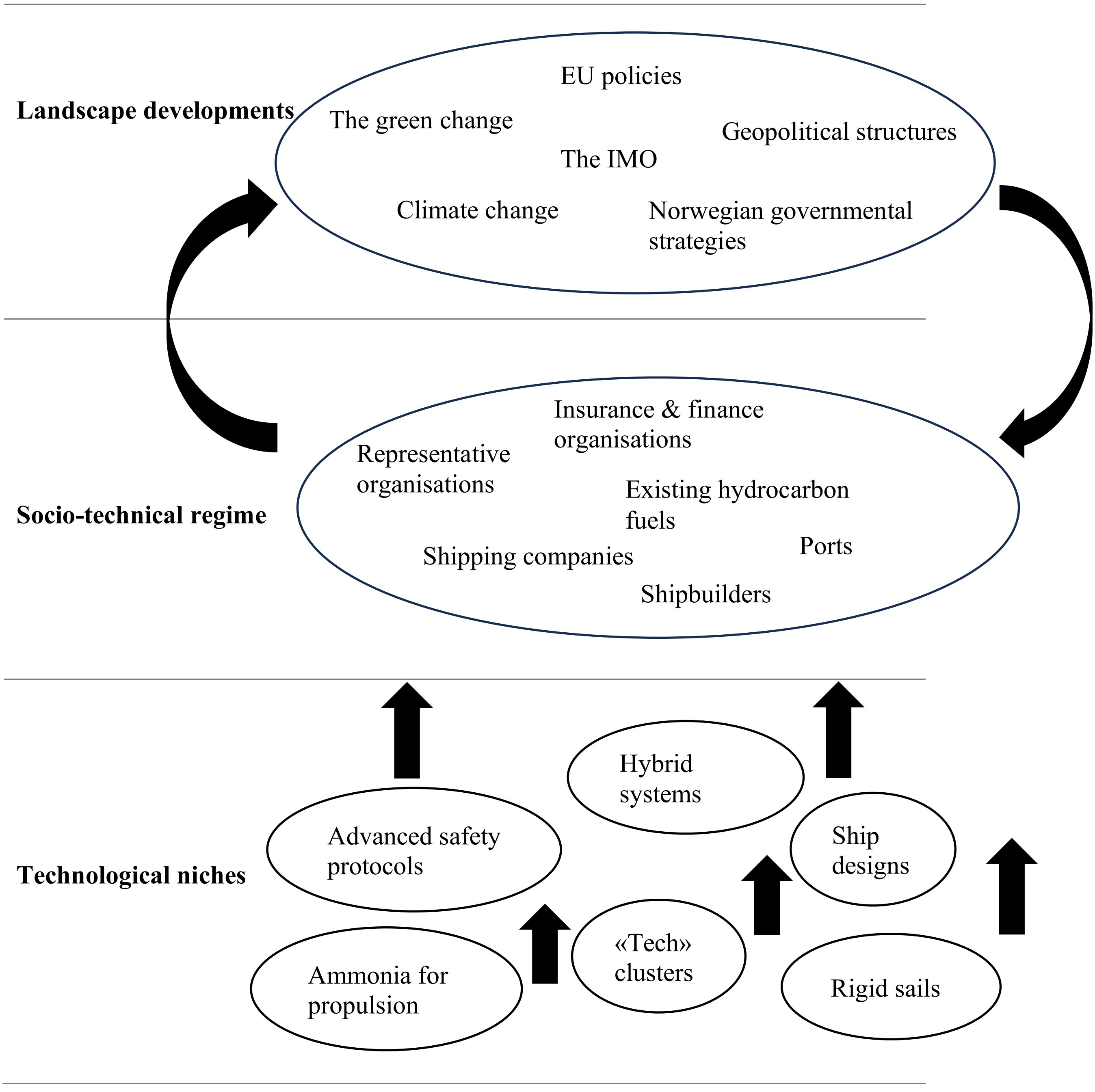

Figure 4: Proposal of MLP in relation to shipping

3.2.4 Criticism of the MLP

Throughout its existence, the MLP has faced criticism on various fronts. Some of the main concerns raised include its tendency to downplay the significance of politics, power dynamics, and cultural interpretation, and its excessive concentration on technological advancements and its overemphasis on bottom-up driven disruptiveness.

Lack of agency

Critics have argued that the MLP theory does not adequately account for the role of agency. Smith et al. (2005) have suggested that the MLP is "too descriptive and structural" and needs more in-depth analysis of agency, with particular attention to power and politics. Genus and Coles (2008) and Bergek (et al., 2018) echo this concern. The MLP may not sufficiently consider the actions of influential individuals, corporations or government policies that play a role in promoting new technologies by only focusing on the structural shift. When not focusing on power and politics, MLP might not sufficiently explore how lobbying efforts, incentives and consumer activism influence new technologies. This critique stems from the fact that all sectors, social groups, and communities are composed of actors with varying power dynamics, and it raises the argument that certain actors are indispensable for instigating change, suggesting a need for greater clarity in the actor perspective within the MLP (Grøv, 2019).

A “bottom-up approach”

Another critic of the MLP is that it has a bias towards bottom-up change models, which emphasize transitions that start within niches and work their way up, often overlooking those directly addressing sociotechnical regimes or originating from broader sociotechnical landscapes. As described in a previous paragraph, Dicken (2015) has suggested that innovation can occur both radically and incrementally. Schumpeter emphasizes this duality, and introduced the concept of “creative destruction”, which describes how the introduction of new technologies, products, or methods can disrupt and replace existing industries and businesses (Alm., Cox., n.d.). The introduction of renewable fuels to the maritime sectors will have negative consequences for companies selling MGO and other fuels but will be positive for the green change.

Unclear landscape level

Critics have argued that the landscape level is often perceived as a residual analytical category, essentially functioning as a “garbage can” concept that attempts to encompass a wide range of contextual influences (Geels, 2011, p. 36). This level comprises numerous factors with varying response times, where some remain unchanged or change very slowly, while others are influenced by external forces like war or oil prices. Additionally, a third factor involves long-term changes in a particular direction, often driven by demographic shifts (Geels, 2011). Therefore, one could argue that the content at the landscape level appears rather diffuse or unclear, presenting itself as a category for residual factors and, thus, distinguishing itself from the two other levels with more specified "content" or actors (Grøv, 2019).

3.3 Organizational Change

“Change or disappear”, “change or die” and “innovate or perish” are expressions used to describe today’s dynamic business landscape, marked by constant change (Jacobsen & Thorsvik, 2013, p. 384). Organizations that cannot successfully develop new products or solutions are at a severe disadvantage in today's competitive environment, where innovation is a key driver of success (Jacobsen & Thorsvik, 2013). For established shipping companies, change is inevitable as IMO, EU, the government, and other agencies put pressure on the reduction of emissions. This increasing pressure may challenge an industry which is commonly thought of as conservative. Change in organizations is said to have happened when they exhibit different traits at different points in time. The change can encompass different aspects, such as alterations in tasks, technology, and strategies. When societal demands and standards for defining a "modern" organization evolve, organizations must adapt to maintain their credibility. On the one hand, radical change necessitates organizations to depart from their established practices. This could involve actions such as bringing in a completely new workforce, venturing into new markets, or transitioning to a different organizational structure. This process aligns with what is commonly referred to as exploratory learning. On the other hand, incremental change occurs when organizations build upon their existing foundations, enhancing and fine-tuning them incrementally. This approach is closely linked with exploitative learning (Jacobsen & Thorsvik, 2013).

3.3.1 Change dimensions

Successful change initiatives typically exhibit several key attributes. Firstly, they involve the creation of a perceived crisis within the organization, emphasizing the imperative for change. Secondly, they feature a well-defined vision and a strategic plan outlining the path for change implementation. Communication of this vision and strategy throughout the organization is crucial, ensuring that employees not only understand the goals but also what aspects will remain unchanged. Information is conveyed in a manner that motivates employees to support the change process. Structural adjustments are made to remove barriers hindering the required transformation. A strong coalition is established to lead the change, with a particular focus on including those directly affected by the changes in decision-making processes. Short-term goals are set and communicated, and there is a system in place to identify improvements compared to the initial vision. Once goals are achieved, this success is disseminated across the organization, and employees who have contributed to the process are rewarded. The changes are consolidated in new structures and processes, ensuring long-term sustainability. The successful change initiatives aim to institutionalize new ways of thinking and acting, effectively establishing a cultural shift away from previous practices that hinder the realization of the envisioned change. While some might interpret these attributes as manipulative, they represent a strategic approach to managing the change process effectively, with a strong emphasis on communication and leadership. Not all organizational developments adhere to democratic ideals, as leadership often plays a central role in the entire process (Jacobsen & Thorsvik, 2013).

3.3.2 Drivers for change

Change agents are those who analyse situations that evolve and change over time, and develop strategies for change. They must actively create a sense of urgency within the organization to drive change. This can be achieved by conducting strategic analyses of economic conditions and competitive factors, highlighting the need for adaptation in response to evolving market dynamics. Proactive change involves anticipating future challenges and opportunities created by societal developments. It requires organizations to leverage their foresight to capitalize on emerging trends, positioning themselves ahead of the competition. Proactive change offers significant advantages, including being a first mover with little competition, building reputation and increasing growth potential. Some disadvantages include uncertainty and risk, internal resistance and pushback, and a lack of immediate returns. In contrast to proactive change, reactive change occurs after changes in the external environment have already taken place. Organizations must adjust to these changes, responding effectively to evolving circumstances. Several factors can contribute to this reactivity, including the perceived risk of adapting to anticipated changes and the difficulty of creating a sense of urgency among change agents when no external pressure is apparent. Advantages include resource conservation, a focus on urgent needs and problem-specific solutions. Disadvantages include missed opportunities, inefficiency, and reputation damage. Most organizations tend to be more reactive in their approach to change (Jacobsen & Thorsvik, 2013).

3.4 Diffusion of Innovations Theory

Es early as the 1920s, Schumpeter positioned technological change, particularly innovation, as the central driving force behind economic growth and development (Sweezy, 1943). Freeman (1985) noted that Schumpeter provided a relatively precise definition of innovation, and it is this definition that has become the norm in the field of "innovation studies" (Fagerbeg et al., 2011). According to Dicken (2015), innovation is essentially a learning process, encompassing experiential learning, practical application, observation, and knowledge sharing. These processes exhibit a unique geographical dimension. (Dicken, 2015). Dicken describes two sorts of innovation. Incremental innovations involve gradual, small-scale improvements in existing products and processes achieved through experience and usage, even though they may seem insignificant individually, their cumulative impact can lead to significant changes over time. Radical innovations, on the other hand, are disruptive events that profoundly alter existing products or processes; however, their widespread influence requires a cluster of such innovations. Changes in technology systems are extensive transformations affecting multiple sectors of the economy, resulting from a combination of radical and incremental technological innovations, often accompanied by appropriate organizational changes (Dicken, 2015).

Throughout history, we are able to observe a recurring pattern where innovation often is not put into practical application until an extended period has passed. An example of this is the acknowledgment that citruis juice, containing vitamin C and thus being proved to prevent scurvy as early as 1601, did not find its way into the diets of British merchant navy sailors until 1795 (Oldenburg, B., Glanz, K., 2008). Rogers developed the diffusion of innovations (DOI) theory in 1962 in his book where he explained how new ideas, innovations or techonologies spread and are adopted by individuals and communities over time. Green ammonia as a marine fuel is to be considered a new technology, and as such, I have chosen Roger's diffusion of innovations theory.

Rogers defines the DOI, as the "process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1983, p. 5). It is characterized as a unique sort of communication, as the messages are concerned with new ideas. According to Rogers, there are five characteristics of innovations, empirically connected, but conceptually independent (Rogers, 1983, p. 211).

Asessing the perceived improvement of an innovation over the idea it replaces, is considered the relative advantage. The degree of advantage is often measured in terms of economic profitability, social standing, or similar factors (Rogers, 1983, p. 213). Rogers points to incentives, either as a payment or by other means to encourage change, as a way of boosting relative advantages (Rogers, 1983, p. 219). Compatibility relates to the extent to which an innovation is seen as aligning with the current values, past experiences, and requirements of potential adopters (Rogers, 1983, p. 223). Complexity refers to the degree to which an innovation seems challenging to use and comprehend (Rogers, 1983, p. 230). Customers who perceive an innovation as complex and hard to use are less likely to adopt it quickly. Trialbility refers to the extent to which an innovation can be experimented with and tested on a small scale. Innovations that offer the opportunity for trial runs are significantly more likely to be adopted compared to innovations that do not provide this option (Rogers, 1983, p. 231). Lastly, observability measures the extent to which the outcomes of an innovation are apparent to others (Rogers, 1983, p. 232). When there is a high level of visibility, it typically leads to rapid adoption. If everyone can easily witness the consequences of adopting an innovation, customers are more inclined to embrace it, especially when the observed outcomes are favorable.

3.4.1 Adopter characteristics

Certain individuals and organizations are more prompt in adopting a particular innovation than others. Depending on how early people or organizations embrace an innovation, they can according to Rogers be categorized into five adopter categories, as seen in the figure below (Rogers, 1983, p. 246).

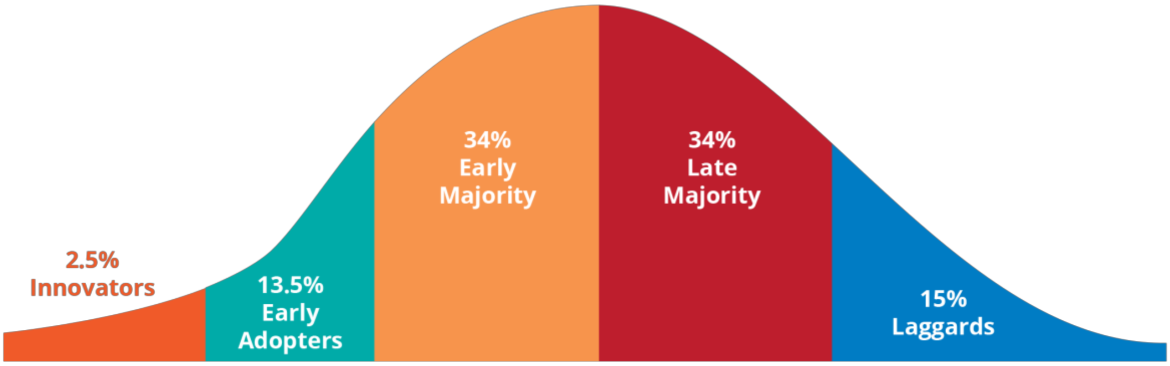

Figure 5: Roger's categories of adoption (Rogers, 1995)

The initial phase involves innovators, who are early adopters of the idea and represent a small fraction of individuals within a system (Rogers, 1983, p. 248). These are described as venturesome and must be able to bear the potential loss of their innovation failing. Early adopters often play an integrated role in their local communities, influencing the opinions and desires of others. In the middle, the largest group of respondents falls into the categories of the early majority and late majority. Large organizations are more inclined to adopt an innovation than small organizations, especially in regard to costly and/or risky innovations (Kimberly & Evanisko, 1981; Kennedy, 1983). The main reason for this is the substantial resources of the large organizations, therefore larger risks can be undertaken. The early majority requires more time before embracing a new idea, but they do so just before the average person in the system. The late majority is more sceptical and refrains from adopting new ideas until most others in their system have already done so. These individuals want to be certain that the idea has been sufficiently tested before they adopt it (Rogers, 1983, p. 248). Laggards, on the other hand, are traditionalists and are the last to adopt an innovation, and in some cases, they may never try it (Rogers, 1983, p. 250).

3.4.2 Weaknesses of the diffusion of innovations theory

Limited literature exists on the weaknesses of DOI theory. However, Lyytinen and Damsgaard address the DOI's perceived weaknesses. First of all, they point to the fact that technologies are not discrete packages. The DOI neglects institutional factors, such as the previously described MLP theory covers (Damsgaard & Lyytinen, 2001, p. 6-7). Push and pull factors in the DOI theory, based on technology features and demand for organizational coordination, do not consistently explain adoption decisions (Damsgaard & Lyytinen, 2001, p. 9). Factors vary across contexts and can be influenced by powerful actors, and rational decision-making is often absent. Adoption parameters are not solely determined by available information and adopter properties, but fluctuate over time and in different social spaces. The DOI theory's staged diffusion curve may not apply to complex technologies, as adoptions occur in various ways, and stages may be layered or embedded (Damsgaard & Lyytinen, 2001, p. 10). Feedback loops, local history, and information dynamics impact the shape of the diffusion curve (Damsgaard & Lyytinen, 2001, p. 11-12). Finally, DOI's short time scales and neglect of past decision history are insufficient for understanding technologies which exhibit path dependencies and require tracing behaviors back into the context's history. This challenges the deterministic view of the diffusion process in the DOI theory (Damsgaard & Lyytinen, 2001, p. 11-12).

4 Methodology

The following chapter will address the methodological approach of the thesis. When choosing a research approach, the quantitative and qualitative methods are of great relevance. The approaches have different attributes, and are often used together, though the combination requires considerable resources (Tjora, 2021). As a result, weighing between the different approaches is vital.

In the context of the qualitative approach versus the quantitative, several factors are brought to light. These include placing more importance on fostering understanding rather than simply providing explanations, maintaining a sense of closeness to the subjects being studied, promoting open interaction between the researcher and the information collected rather than creating distance from the respondents, and choosing to work with textual data as opposed to numerical data (Tjora, 2021).

To achieve a comprehensive and flexible exploration of the topic, I have chosen the qualitative method as a scientific research approach. Consequently, this chapter will adhere to the structure of Larsen's six out of seven phases relating to the usage of the qualitative research approach, described in her «A simpler method» book (2017). The seventh phase, consiting writing of reports, is not relevant to this paper. Although Larsen's phases will be used, theory from the books of Busch's «Academic writing» (2021) and Tjora's «Qualitative research metods» (2021) will also be used. In the next chapters, there will be a brief description of the phases and then my assessments related to these.

Table 1: Phases of the qualitative research process

Phase	*Content*
1.	Problem formulation
2.	Selection of units and variables
3.	Data collection
4.	Data processing
5.	Data analysis
6.	Data interpretation

4.1 Problem formulation

The development of a research question is important when shaping the choice of theory, methodology, data collection, and analytical approach. It should also resonate with the researcher, stimulate curiosity and innovation, and be workable within existing resources (Busch, 2021). In qualitative research, the research question sets the initial direction for the study, but the insights gained by the researcher along the way can lead to the development and modification of the research question (Larsen, 2017). Furthermore, to ensure precision, the scope of the research question should be carefully defined (Busch, 2021).

The development of this thesis' research question was influenced through dialogues with my bachelor's thesis supervisor, the company I was placed in, and my own interests. Seabrokers expressed interest in a thesis regarding ammonia, as the company had observed a catching momentum in ammonia discussions within offshore shipping. Initially, my intention was to undergo a qualitative technical feasibility study regarding green ammonia's implementation. However, as I conducted a literature review on this topic, I observed that several others had extensively analysed it, and thus, I did not perceive room for additional or new research in this area. Furthermore, based on the literature review, I concluded that the implementation of ammonia is technically possibly, and chose rather to look at the interplay between stakeholders of the maritime industry. I figured Seabrokers, being an intermediary between the shipowner and charterer, as well as in dialogue with suppliers, would benefit from this research and adjacent theories, as they engage stakeholders at different levels of the maritime industry. To avoid an overly broad research question, the sub-research questions were consequently formulated.

To support the research question and its sub-research questions, the background chapter builds on assumptions of necessary government support and incentives, a need for stakeholder engagement and collaboration, and that the EU's policies are closely linked to Norway's. It also serves a link to the theoretical framework particularly at the landscape and socio-technical regime levels. The background chapter is considered important for this thesis, as the developments in policy changes are progressing rapidly and is set to influence sustainable shipping on a large scale. In the theoretical framework, the niche level is complemented by the DOI theory, while Jacobsen and Thorsvik's organizational change complemented the socio-technical regime. Utilizing these three theories, I consider both a strength and a weakness. I acknowledge that employing such a broad theoretical framework may leave out comprehensive analysis of all aspects of these theories, while at the same time allowing me to explore the research questions broadly.

4.2 Selection of units and variables

Selecting the individuals or entities to be included in the research is a critical step that significantly influences the subsequent course of the study (Larsen, 2017). In qualitative research, usually a relatively small number of strategically selected units are chosen to achieve depth (Tjora, 2021). The units, or informants, are collectively formed to what we call a “sample” (Larsen, 2017).

In qualitative approaches, statistical generalization is not the primary objective, and the researcher has the flexibility to employ non-probabilistic sampling methods when selecting the informants, to achieve a deeper understanding within a specific topic. It allows for the collection of insights without necessarily reflecting the views of a broader set of interview subjects. The means that the findings should extend beyond the individuals under examination to other groups to achieve transferability, translated to validity. In most instances, research loses its significance if it solely applies to the individuals being studied, except for some rare exceptions (Larsen, 2017).

For my study, subjective selection was chosen. Applying this method, I personally selected the units based on my judgment of how representative they are of the entire population of units and at the same time to achieve a diverse sample. This is a form of strategic selection (Larsen, 2017). To begin, a fundamental requirement in selecting the units was their involvement or association with ammonia at a mainly regulatory or commercial point of view. Then, considering my theoretical approach, selecting units of the landscape, regime and niche levels of the MLP was the next step. The ShipFC project also provided insights into who to interview at the different levels of the industry. Table 2 provides a summary of the units. At the landscape level, the Norwegian Maritime Directorate and the Norwegian Environment Agency can be found. Dividing the other companies into regime and niche levels was challenging. Established firms in the regime, described as DNV, Altera Infrastructure, Wärtsilä, Maritime CleanTech, Salt Ship Design and Eidesvik are all involved in innovative processes and technologies which also fit into the niche level. Vice versa, Breeze Ship Design, established in 2020, which I place in the niche level, has a radical approach to ship designing, but was owned by Wärtsilä in the past. Amogy and Amon Maritime are more easily placed in the niche level, as they are recently established with a basis of innovative solutions. A weakness of choosing these innovative organisations who all are engaged in developing solutions for ammonia, may be that the informants can be overly positive to ammonia implementation. Nonetheless, I assumed choosing these informants was the best option based on their engagement, and therefore assumed knowledge, of ammonia.

Table 2: An overview of interviews

No.	*Organisation*	*Description of organisation*	*Function*	*Duration*	*Method*
1	Norwegian Maritime Directorate	Under the Ministry of Trade and Industry. Regulates ships in Norway and foreign vessels in Norwegian ports ensuring safety and environmental protection. Works on approving ammonia ships and solutions. Circa 300 employees.	Technical/ regulatory Sustainable transitions management	47 mins.	Teams
2	Norwegian Environment Agency	State agency. Main tasks include reducing greenhouse gas emissions, managing Norwegian nature, and preventing pollution. Has active stances on ammonia strategies and barriers. Circa 700 employees.	Technical/ regulatory	40 mins.	Teams
3	Maritime CleanTech	Cluster for clean maritime solutions. Leveraging maritime expertise in the Norwegian sector. Engages in ammonia development. 14 employees.	Technical/ Commercial Sustainable transitions	41 mins.	Teams
4	Eidesvik Offshore ASA	Ship owning- and operation company exposed against offshore supply, subsea and offshore wind market. Large ammonia engagement including the ShipFC project. Circa 600 employees.	Commercial Sustainable Transitions management	40 mins.	Teams
5	Altera Infrastructure Norway AS	Ship owning company. Fleet consists mainly of FPSO units, shuttle tankers, and FSOs. Has active stand on ammonia, and collaborates in bunkering project. Circa 2 300 employees.	Sustainable Transitions management	45 mins.	Physical
6	Wärtsilä Norway AS	Marine solutions, such as fleet optimisation, engines (e.g., ammonia), bunkering, and generating sets. Circa 17 500 employees.	Commercial	50 mins.	Physical
7	DNV AS	Classification society and advisor for the maritime industry. Testing, certification and technical advisory services related to ammonia. Digital solutions. Circa 13 000 employees.	Regulatory Sustainable transitions	45 mins.	Teams
8	Salt Ship Design AS	Majority of portfolio include aquaculture and OSV designs. Engaged in interactions with clients regarding ammonia. 84 employees.	Technical Sustainable transitions	30 mins.	Physical
9	Breeze Ship Design AS	Large design portfolio in many shipping segments. Engages in multiple ammonia projects. Circa 70 employees.	Commercial management & technical	1 hr 10 mins.	Physical
10	Amogy Norway AS	Ammonia energy solutions company for transport sectors. Ammonia cracking to fuel cell; power generation technology. Circa 200 employees.	Commercial & technical	42 mins.	Physical
11	Amon Maritime AS	Maritime project development company. Working on realizing ammonia powered ships. 6 employees in main company.	Commercial/ Technical mgt.	40 mins.	Teams

4.3 Data collection

Validity and reliability will be further discussed in this chapter. On the one hand, validity in research ensures verifiability, credibility, and transfer value. Verifiability assesses the study's relevance, emphasizing that collected data must align with the research question for valid conclusions. Credibility requires unbiased interpretation, avoiding personal opinions. Transfer value ensures the study's broader applicability. Reliability, on the other hand, focuses on the trustworthiness of the study, demanding accurate empirical findings and a systematic research process. Transparency in showcasing the research process is crucial for others to evaluate reliability (Larsen, 2017; Tjora, 2021).

Data collection involves acquiring information from the real world, with qualitative interviewing and observations being the most frequently employed techniques. Researchers often use semi-structured interviews with flexible guides. These guides have pre-set questions and keywords but allow for adaptability in question order and the addition of follow-ups (Larsen, 2017; Tjora, 2021). The flexibility in question order and the inclusion of follow-ups allow for validity, as the questions asked are made relevant to the research question, contributing to the verifiability of the study.

In-depth interviews are a means to encourage open discussions about predetermined research topics. These interviews provide a comfortable setting, often extending beyond an hour, to prompt the interview to reflect on their own experiences and viewpoints. This approach contributes to the credibility of interpretations. The quality of in-depth interviews relies on the established trust between the researcher and the informant (Tjora, 2021). High trust ensures that the information shared by the informants is genuine and accurate, contributing to the credibility and transfer value of the study.

For my interviews, the in-depth interview method, together with a semi-structured interview guide, was chosen. The main reason for choosing a semi-structured interview guide, is the flexibility it provides. My informants did not have the same background and knowledge, and as such, I adjusted some questions during the interview so that the informants would be able to provide an answer. The interview guide was split into categories of seven: warm-up questions (1), today's status of ammonia implementation (2), strategies and barriers for implementation (3), strategy implementation in organizations (4), multi-level perspective (5), diffusion of innovations (6) and closing questions (7). I emphasized the closing questions as a way of gaining information that the previous questions did not cover, which proved valuable and a way of gaining validity.

After receiving approval from the Norwegian Agency for Shared Services in Education and Research (Sikt), a list of potential informants was made, followed by some research into where the informants worked, and what their responsibilities were. Subsequently, the list was narrowed down to eleven people. Initial contact with the informants was in all cases but two cases made over telephone, and website contact forms were used for these two cases. For interviews where geographical differences were large, video communication platform Teams was chosen as the method. Three companies interviewed were located in Stavanger, two of which I met with physically. I also travelled to Stord, notably the location of the Sustainable Catapult Centre, where ammonia technologies are tested, to meet with three companies. Most informants were familiar with Seabrokers, which I believe contributed to the trust established in the interviews.

4.4 Data processing

The data processing phase involves preparing raw data for analysis, transforming it into textual format. This textual transformation should identify underlying patterns and connections within the data and demands a considerable investment of time and effort. To establish a data foundation and to enhance the research's validity, the transcription of interviews is crucial. Often, this is an extensive and time-consuming task. When performing in-depth interviews, utilizing recordings and complete transcription is often recommended (Larsen, 2017).

While this thesis is presented in English, I opted to conduct all but one interviews in Norwegian due to the native language of all but one of the participants being Norwegian. This decision was made to ensure that informants could articulate their perspectives most effectively. During the interviews, I noted the main points of the informants. After the interviews, I listened to the sound recordings and added any points which I did not originally note. This approach was utilized to provide a concise summary of critical concepts, thereby managing the volume of data.

4.5 Data analysis

Data analysis in qualitative studies highlights the phases of coding, categorization, and pattern identification. The data analysis process systematically involves coding text, categorizing these codes into themes, sorting the data based on these categories, and identifying meaningful patterns or processes. Furthermore, data reduction is discussed as an essential aspect of the analysis, aimed at eliminating irrelevant information. Utilizing in-depth interviews, the informants may discuss topics that are unrelated to the research question. This information is not relevant to the research, and should be removed (Larsen, 2017).

After processing the data from the interviews, I summarized the key findings in a separate document, creating descriptive codes. Then, from this document, I organized the codes into main themes of "External Influences on Transformations", «Developments within the Maritime System" and «Technology-focused Niches», with subcategories of «Driving forces» and «Barriers». These codes are based on the initial theoretical framework but operationalized into more measurable concepts. To achieve a comprehensive analysis of the interviews, the most shared views are collected under the subcategories of driving forces and barriers, but there is information which point to both these directions, as I did not want to leave out any views. Initially, I wanted the main coding categories to be "Change in Organisations", "Multi Level Perspective" and "Diffusion of Innovations", directly aligning with my theoretical framework. However, placing codes under these categories was challenging, as the codes often could be placed under more than one main category. Still, the finished coding shown in table 3 is also characterised by this issue, but to a lesser extent. The results are presented as mostly incomplete quotes, as I introduce and finish some quotes myself to improve the flow of the text. In this regard, there is an emphasis on the importance of context. No quotes are presented differently from what is indicated by me.

4.6 Data interpretation

Interpretation in qualitative studies involves deriving meaning from data patterns, distinct from analysis. This requires grounding in observed data, considering relevant literature influence. The process combines insights from data and theoretical frameworks. Comprehension evolves through identifying and contextualizing data patterns, finding a balance between interpretation and faithful representation of informants' narratives. Effective interpretation extracts significance without imposing excessive interpretations on findings, placing the studied phenomena into a broader context, and introducing new perspectives (Larsen, 2017). For my research, the analysis and the theoretical framework was used as a basis for the interpretation.

For my research, the data interpretation phase is characterized as the discussion section. The findings from the analysis were compared with the theoretical framework. The chapter is divided into “A socio-technical transition”, “Driving forces”, “Barriers” and “Leveraging partnerships, collaborations, and government initiatives” to respond to the research questions.

5 Results

In this chapter, the findings will be presented based on the coding shown in the table below. To conserve anonymity, the informants are described from I1 through I11, randomized from table 2.

Table 3: Coding of the primary data

External Influences on Transformations	**Developments within the Maritime System**	**Technology-focused Niches**
Driving forces	*Driving forces*	*Driving forces*
A1 The green change	**B1** Green ammonia is a better alternative to hydrogen	**C1** Early technology adopters inspire others
A2 EU policies & regulations	**B2** Demands from charterers	**C2** Technology clusters & workshops
A3 National strategies & incentives	**B3** New organizational structures facilitate change	**C3** The realm of offshore shipping provides a good testing area
A4 The IMO	*Barriers*	*Barriers*
Barriers	**B4** Green ammonia is costly because of little production	**C4** Ammonia technology provides safety risks
A5 Unclear and unrealistic strategies from the national level to the IMO	**B5** Increased employee competence is necessary	
	B6 Ship owners do not want to make investments perceived as risky: charterers should take a more active role	
	B7 Green ammonia is not sustainable considering the “whole picture”	

5.1 External Influences on Transformations

From table 3, codes A1 to A5, characterized as drivers and barriers for green ammonia implementation, will be presented.

The driving forces

A1 The green change

As I4 puts it, "the world needs less CO_2 in the atmosphere". All informants quickly identified the green change as a leading driver for the implementation of green ammonia. As the world seeks cleaner energy solutions, informants emphasize sustainable fuels' increasing momentum. Green ammonia, is, as previously described, emission free, as long as the related NOx emissions are effectively controlled. I7 highlights that the age of petroleum energy will end, facilitating demand for renewable fuels as conventional fuels such as MGO require petroleum. Several informants point to increased clean energy production through for example solar and wind power, highlighted in the green change, as a major driving force.

A2 EU policies & regulations

Informants were asked whether the EU ETS scheme will influence the adoption of green ammonia or not, and to which degree. The scheme was identified by all but one informant as the EU policy potentially influencing offshore shipping the most, giving incentives to use zero emissions solutions and lowering the cost of green ammonia production. I4 highlights the structure of the scheme; the supply of emission quotas is capped, and so the EU ETS is designed to increase in allowance price, making emissions more expensive to shipping companies. I1 underlined that the EU ETS in its current form will mostly affect larger vessels, while I11's organization is advocating for an inclusion of smaller vessels (4000 GT). Most informants want the EU ETS to be implemented before 2027 for offshore vessels. According to I2, as the scheme manifests itself on shipping companies, the ship operating company units dealing with financials will be more engaged in reporting, and the relationship between technical and financial departments will be more important to correctly report. All but two interview objects agrees that the Fuel EU Maritime regulation, not currently including offshore shipping, would be beneficial for the implementation of green ammonia as a marine fuel, and especially for the price of green ammonia. The two informants sceptical to the regulation, I1 and I2, describe how it would be difficult to implement in the offshore shipping industry, as these ships sail back and forth from the same port in most cases. I2 further emphasizes the opportunity of expanding the Renewable Energy Directive, an EU framework for the development of clean energy, to renewable fuels.

A3 National strategies & incentives

CFDs are identified as an important step for large scale implementation of green ammonia by all but one informant. The majority think CFDs will be necessary in the short to medium term, before green ammonia production scalability, and therefore lower prices, are achieved. I4 has lost faith in CFDs, and points to the fact that such a mechanism may be hard to implement for green ammonia, as there is no state counterpart selling renewable fuels. Creating a state counterpart, such as has been implemented for renewable energy including wind parks, would according to I4 be practically difficult. I11 wants a CFD scheme to be placed at the ammonia producer level. Many informants highlight the need for an increased CO_2 tax as a driver for green ammonia implementation, forcing shipping companies to adopt zero emission solutions. I1, I6 and I5 are more sceptical, believing such taxes and penalties will force ships to flag out. It is noted that for OSVs, particularly PSVs and AHTS vessels, operating on the Norwegian continental shelf, flagging out is not a very realistic option, as national agencies place strict rules on Norwegian Ordinary Ship Register (NOR) and Norwegian International Ship Register (NIS) registration to ensure standards for safety, environmental protection and working conditions, while strong Norwegian maritime labour unions also exert pressure. All informants agree that a global CO_2 tax would be beneficial, as this would level the playing field, although, according to I9, poorer nations would struggle with their emissions, lacking (expensive) sustainable vessels.

When asked which government strategies work, all informants respond that incentives from Enova, The Research Council of Norway and other national agencies are important drivers, and often sufficient in supporting projects. The NOx Fund emerges as a good government initiative by many informants, citing its structure; participating companies pay a lower fee per kg NOx released into the fund instead of paying NOx tax to the state. The money deposited in the fund is then used to promote sustainable technologies. I6 states that despite the fact that incentives are important, an “artificial market” for green ammonia should be avoided, as this industry should continue for many years and therefore needs to become independent of incentives eventually.

A4 The IMO

I3 characterizes the IMO as the "major support for the green change", through strategies such as IMO 2030 and 2050. The recurring theme amongst the informants is that the IMO serves as an overarching catalyst with a broad influence, while not promoting any specific renewable technologies. I4 and I1 mention the most positive development in the IMO as their recent mapping (CCC9) of ammonia as an alternative fuel, while I11 highlights the revised GHG reduction strategy recently amended. The International Convention for the Prevention of Pollution from Ships (MARPOL) and the International Convention for the Safety of Life at Sea (SOLAS) are highlighted by I1 as important tools necessary for the safe usage of ammonia in marine applications. These conventions are developed and maintained by the IMO.

The barriers

A5 Unclear & unrealistic strategies

In the previous paragraphs, national strategies and IMO were identified as driving forces by informants. At the same time, informants believe there are barriers to overcome within these influential factors, necessitating strategic adjustments for successful navigation toward sustainable transitions in the maritime industry.

When asked whether the government does enough to support the implementation of green ammonia in offshore shipping, the consensus is explicit; the monetary support is large, but government strategies and monetary allocation are often unclear and unrealistic. According to I7 and I11, Norway provides the best incentives of any country, but the shipping industry is still impatient. I3 says the government should do "a lot, a lot more", while I5 thinks the government is more about "words and declarations" than action. According to I6, the communication from the government to the private companies should be clearer. I5 states that although incentives are driving forces, they are frequently unrealistic, not accounting for factors such as inflation and interest rates. Furthermore, according to I5, the incentives focus too much on niche technological systems with marginal gains.

I4 believes the government has put offshore shipping in the "worst situation possible", describing a "limbo" in where oil companies are waiting for "demands with large consequences", but without knowing what these demands will be. The informant specifically references Hurdalsplattformen published by the current government, imposing requirements for low-emission solutions from 2025 and zero emissions from 2030 for OSVs. According to I4, the government should either impose concrete demands or state that demands are not coming. I10 and I11 echo these views, expressing that the government does not provide sufficient strategies to meet their ambitions, pointing to the ambition to halve maritime emissions by 2030 as a whole in addition to Hurdalsplattformen.

Moreover, informants point to the IMO, and particularly tank to wake versus well to wake calculations of emissions. Tank-to-wake, commonly used by the IMO, focuses solely on emissions from a ship's operation, while well-to-wake considers the entire life cycle of the fuel, including extraction, production, and transportation emissions. I9, I8 and I5 give examples of ammonia. "Brown" and "blue" ammonia, respectively produced from fossil sources and fossil sources with CCS technologies, will using the tank-to-wake calculation be considered almost zero emission when used in combustion. This, they believe, downplay the importance of green hydrogen for green ammonia production. The IMO's Revised GHG reduction strategy for global shipping adopted in July 2023 tries to address this concern, impleneting well-to-wake emissions calculations. The complicated process of getting approval on ammonia powered ships is also mentioned by I1, I2 and I9 as a barrier, but they emphasize that the IMO has set down committes ordered to deal with this (CCC9). Furthermore, I2 believes the IMO's goals are unrealistic, such as the goal to reduce CO_2 emissions as an average across international shipping, by at least 40 per cent by 2030, compared to 2008. When asked about the IMO's perceived pace of work regarding regulations, all informants are under the impression that the organisation works slowly. I5, I10 and I11 underscore that the EU takes the lead and are more progressive when it comes to requirements, having to "push" the IMO. Still, most informants, having identified the EU ETS as having large implications for shipping, believe that the scheme should be implemented for offshore shipping before 2027 and include vessels under 5000 GT.

5.2 Developments within the Maritime System

From table 3, codes B1 to B7, characterized as drivers and barriers for green ammonia implementation, will be presented.

The driving forces

B1 Green ammonia is a better alternative to hydrogen

A major driving force backing green ammonia's implementation is identified by informants as its perceived advantages compared to pure hydrogen. The most vocal are informants I4, I5 and I9, stating that ammonia is easier to handle, less energy demanding, includes less energy loss and is easier to hold pressurized than pure hydrogen.

B2 Demands from charterers

"Ship owners are responsive when hints from charterers are received". This view, expressed by I6, is explicitly shared with I1, I7, I9, I10 and I11. For offshore shipping, Equinor emerges as the leading commercial driver, setting requirements for low emission vessels and supporting ammonia projects. I11 states shipowners with sustainable ship solutions to a higher degree secure contracts from charterers, for example Equinor and Aker BP. I7 exemplifies two large companies outside of offshore shipping, IKEA, and Amazon, having environmental (ESG) strategies outlining their desire for zero emission shipping of their products. According to this informant, other companies will have similar strategies, thus driving ship owners to adopt environmentally solutions such as green ammonia to secure contracts.

B3 New organizational structures facilitate change

When asked what organizational changes the informants see in the green change, many see new sections as an important step to facilitate sustainable transformations such as a shift to green ammonia. In I1's organisation, a new section for maritime technology has been created. I4 and I11 mentions the creation of departments and positions related to sustainability and innovation, and I6 mentions an energy transitions department created in its department. To foster green change knowledge, I7's organisation has a "decarbonization academy", and focuses on permeating all future plans with sustainable practises. I7 elaborates, saying this new way of doing business is necessary, as "green money is not earned in the same way". Underlining the EU's importance as a driving force for sustainable implementations, I10 states new business units had to be created to deal with the pressure and pace of the EU.

The barriers

B4 Green ammonia is costly because of little production

All informants assert that the cost of purchasing green ammonia to be used as a marine fuel is one of the main barriers for its implementation in the offshore shipping industry. I1 states that "green ammonia is way too expensive compared to conventional fuels". I4 identifies the main barrier for implementation as the price of green ammonia. According to analysis performed by I5's organisation, the price of ammonia as of 2023 is 2,5 times the price of MGO. I9 believes green ammonia will be 3 to 5 times more expensive than conventional fuels. I5's organisation does not want to invest in ammonia solutions, because of "uncertain production estimates". I11 emphasizes the need for sufficient production, as ammonia projects may end up as "pilot projects" instead of large-scale projects.

Although the price is a barrier, informants believe that the price of green ammonia will be reduced as production increases and regulations and taxes are put in place. Planned ammonia production plants mentioned by informants are projects in Western Norway, such as the project in Sauda with an expected production of 200.000 tons of green ammonia from 2028, and in Skipavika with an expected production of 100.000 tons of green ammonia from 2026, as well Yara's green hydrogen plant in Eastern Norway.

B5 Ship owners do not want to make investments perceived as risky; charterers should take a more active role

When the informants were asked whether there is a strong dependence on old technologies within the maritime industry, there was a consensus that this is not the case. However, I6 describes shipowners as "sceptical to anything new". I10 believes ship owners "sit on the fence" when it comes to investing in new technologies, such as ships fuelled by green ammonia. I2 emphasized that it is best to be number two in line when adopting new technologies, but that someone has to be number one, taking on "teething problems". According to I11, being number three is actually the best. The shipowners need investments to change, all informants agree, while charterers must know which regulations should be followed. Demands from charterers were identified as drivers, but all informants believe charterers should take more responsibility and risk in general, so that ship owners are not left as “guinea pigs” with no contracts for their ships. Reasons for the lack of support, according to I11, could be that the charterers, who are often publicly traded, cannot “throw out money”, and must focus on reducing costs as much as possible. Furthermore, informants highlight that the charterers are not obliged by rules or regulations to contract sustainable vessels. For time charters, which characterize the AHTS vessel and PSV market, I11 further highlights the charterers’ role; they are the ones who buy the fuel for the vessels, taking this cost.

B6 Increased employee competence is necessary

A large need for increased employee competence in order to succeed with the implementation of ammonia in marine practices is echoed by many informants. For the most part, the safety aspect is emphasised. I9 states that there is a “hugh lack of competence” in safe ammonia handling. According to I4, ship crews will need new safety courses, training, use extensive personal protective equipment (PPE), while the onshore organization must have a corresponding understanding. I5 states that land organizations could benefit from technology suppliers if they shared their experiences. An increased number of engineers and other technical expertise are suggested by I4 and I5 as ways of dealing with ammonia’s complexity as compared to conventional fuels. In addition to a need for increased safety competence, I10 expresses concerns over lack of expertise within EU regulations and policies, stressing the importance of these in the future.

B7 Green ammonia is not sustainable considering the “broader perspective”

Some informants, although positive to the green change within shipping, wish to highlight the green change in a broader perspective. I2 states that because of the energy loss when producing hydrogen needed for green ammonia, this energy necessary could better be used in other areas without energy loss, for example in decarbonizing the energy grids in Europe, still heavily reliant on fossil sources for power generation. I9 sets a different example of Argentine, where the electricity sector mostly relies on fossil energy. The informant describes a costly electric ferry project, and how little it decreases emissions compared to other potential investments in decarbonizing the electricity sector. To reach sustainability targets through for example green ammonia fuelled vessels, I9 states many do not think of the carbon footprint created by building vessels, an industry reliant on fossil sources. According to I8, the shipping industry should not “become blinded” by the idea that all vessels must be green, as there is a "bigger picture". I10 also suggest that the energy used in green ammonia production is better to use in other sectors, but, as I2, I8 and I9 all express, regulations and emissions goals in the shipping industry must be reached as they have been placed and demands have been set.

5.3 Technology-focused Niches

From table 3, codes C1 to C4, characterized as drivers and barriers for green ammonia implementation, will be presented.

The driving forces

C1 Early technology adopters inspire others

When asked of the importance of early adopters, informants are unanimous; early technology adopters will be crucial for the successful implementation of green ammonia. I4 and I11 state that others will follow if success is observed in demonstrating ammonia technologies. As expressed by I2, someone has to be number one in the line, although being number two might be "best". According to I11, there is only one ship owning company which has stood out as being a frontrunner when it comes to ammonia technologies. I5 describes how their organisation implemented a sustainable solution, and thus swiftly being followed by competitors. Batteries are mentioned by all informants as a technology swiftly embraced by others as soon as success was observed. Informants highlight incentives and safety aspects as the leading drivers behind the first and continued implementation of batteries in vessels.

C2 Technology clusters & workshops

Questions were asked to informants regarding which arenas exist for technological innovations such as maritime ammonia solutions, their importance, and what the barriers to technological diffusion are. All informants view clusters and workshops as essential for the diffusion of technologies. Maritime CleanTech and the Blue Maritime Cluster emerge as leading facilitator for maritime clusters regarding technological solutions such as ammonia implementation. Other facilitators mentioned are the Shipowners' Association, the Green Shipping Programme, conferences such as Nor-Shipping and Zero, the Sustainable Energy Norwegian Catapult Centre and the Mærsk McKinney Møller Center for ZERO Carbon Shipping for testing ammonia solutions. I1 emphasizes these meeting arenas, stating "Knowledge sharing is important, as safety is the main priority", a belief also shared by I11. I3 describes the arenas as catalysts between the public and private sectors. I7 and I11 describe how the shipping industry's, and in particular shipowner's, philosophy on information sharing has changed in the past years, shifting from limited information sharing to openly sharing "most things".

Although a generally good culture of sharing is identified, some informants highlight unbalanced sharing relationships among different stakeholders. I5 and I11 state shipyards and equipment suppliers are more secretive, echoed by I6, describing how these stakeholders work with patents and sensitive information. I9 provides an example of two companies in different size; if a "big player" steals competitive sensitive information from a small company, there is often little this company can do. I9 states, "In reality, everyone has interests, every part of the cluster needs to make money". Furthermore, the informant warns of "echo chambers" in maritime clusters, potentially hindering critical or alternative approaches.

C3 The realm of offshore shipping provides a good testing area

The region of Western Norway, from where most offshore operations are launched due its proximity to offshore installations, emerges as a good testing area for green ammonia implementation, serving as an example for the broader maritime landscape. I9 and I11 claim shipowners in the OSV segment are more innovative than for example shipowners within the bulk segment, who "often only look at price" when contracting vessels. I1, I2 and I3 explicitly assert ammonia implementation is easier for offshore shipping because of the nature of the operations; vessels, particularly PSVs and AHTS vessels, sail back and forth from specialized bases. Informants describe benefits such as ease of establishing bunkering processes, reduced congestions, specialized infrastructure, collaboration opportunities and more focused supply chains. Ammonia's potential together with CCS technologies is emphasized by I2 and I7, for example by producing (blue) ammonia using hydrogen produced from natural gas, transporting the resulting CO_2 emissions for injection into the oil and gas fields. Lastly, as mentioned earlier, the planned green ammonia production plants in Western Norway provide a short haul for ammonia fuelled vessels for bunkering. Considering the design of PSVs, with large open decks for ammonia storage needed for combustion, I11 states these vessels will be easier for green ammonia implementation.

It is however identified that for a larger implementation of ammonia in shipping, and not only the offshore realm, the infrastructure is also seen as a barrier. According to I3, the development of distribution systems on land is necessary. I2 states ammonia bunkering in densely populated areas should be avoided. I4 and I9 also highlight these aspects. Notwithstanding that bases provide good possibilities, I11 states that for offshore bases to provide specialized bunkering facilities such as ammonia bunkering, at least three ammonia fuelled vessels must be regular "customers". For this to be viable, increased operator collaboration is deemed important by the informants.

The barriers

C4 Ammonia technology provides safety risks

I4 and I7 are both under the impression that ammonia technologies are developing fast, and that many solutions are lined up and ready, but at the same time they acknowledge safety risks. I9 states "It is a bit surprising that the safety aspect is not more on the agenda". By most informants, ammonia is described as a chemical challenging to handle, especially regarding its toxicity and explosive nature in its gaseous form. The safety regime is not developed, according to I2, affirmed by I1, who states that guidelines should quickly be put in place to reduce the risk. It is also expressed by both I1 and I2 that ammonia technologies are very dangerous in populated areas, which may be a barrier for areas of operating ammonia fuelled vessels. To downplay the safety concerns, I7 points to gasoline and LNG, explaining that these fuels were considered dangerous at first but that these concerns were quickly dealt with and subsequently the fuels were institutionalized.

6 Discussion

The discussion section will build on the findings from the results, utilizing the theoretical framework, and aims to answer the research questions. Firstly, the results will be discussed in relation to the multi-level perspective theory and a revised model version will be displayed. Secondly, barriers for ammonia implementation incorporating the theories of organizational change and the diffusion of innovations theory will be discussed. Then, drivers will be discussed with these theories. Ways of leveraging partnerships, collaborations, and government initiatives will be suggested as a means to remove the barriers and accelerate the implementation of green ammonia as marine fuel in offshore shipping. Lastly, future work will be suggested, and research criticism presented.

6.1 A socio-technical transition

Considering Geels' (2011) characterization of the three distinct features in transitions towards sustainability, all features can be observed in the interview findings, showing that sustainable transitions involve a mutual relationship and influence between technology, politics, power, economy and markets, and the public sector towards a more sustainable society. In this section, aspects of the MLP by Geels will be utilized to discuss the dynamics and influences shaping green ammonia adoption in the offshore shipping industry, as per the informants' views.

The interplay between levels

The MLP theory suggests that niche innovations gradually gain attention and may challenge the existing regime, while changes in the broader landscape put pressure on the regime to adapt. When the existing regime is destabilized, it creates opening for niche innovations to break through and become more widely accepted. The interview findings will be placed into the categories of landscape developments, socio-technical regime, and technological niches.

Landscape developments

It is observed that landscape factors exert substantial pressure on the regime and niche levels. The green change stands out as a paramount driver. As global initiatives intensify, sustainable fuels gain momentum, with green ammonia emerging as an emission-free option. EU and IMO policies and regulations play a large role. National strategies and incentives further shape the landscape, pushing for the adoption of green ammonia. Despite these driving forces, significant barriers hinder the untroubled integration of green ammonia. The ambiguity and impracticality of the EU, IMO and national strategies pose challenges. The imbalance between support at these levels and industry expectations becomes evident.

Socio-technical regime

Developments from both the landscape and niche levels challenge the socio-technical regime, necessitating a reorganization of the current regime, which would be called a transition. Most driving forces and barriers are found within the socio-technical regime, indicating that this level of the MLP is most sensitive to green ammonia implementation. Within the maritime system, driving forces propel the adoption of green ammonia. Its benefits over pure hydrogen, demands from charterers, and new organizational structures facilitate change. However, challenges persist, including the cost of production, shipowners' risk aversion, and the crucial need for increased employee competence in safe ammonia handling.

Technological niches

In the realm of technology-focused niches, early adopters, technology clusters, and the regional context play important roles. Early technology adopters serve as catalysts for widespread implementation, with success stories inspiring industry-wide changes. Technology clusters and workshops act as important arenas for knowledge sharing, though concerns about unbalanced relationships are potential hindrances to the competition surface. The region of Western Norway emerges as a testing ground, particularly for offshore shipping. Contrarily, ammonia's toxic nature is identified as a major barrier.

A revised multi-level perspective model

Kivimaa and Kern's (2015) and Bilali's (2019) assertion regarding the need for enhanced policy support in fostering niche innovations resonates with the findings from the interviews. In the revised MLP model based on the interview findings, as can be seen in figure 6 on the next page, there is a larger emphasis on top-down dynamics. This is contrary to Geels' model, which builds on a bottom-up approach. The lack of emphasis on top-down dynamics was identified as a critic of the MLP. Looking at the niche level of the MLP, the technologies related to ammonia are not described as the major issue; these are coming. What is observed, is the needed support from the landscape level, specifically the EU, the IMO and the national levels. The revised model also integrates another critic of the MLP, which is the lack of agency. A transition will not always occur without certain actors, with charterers identified being such actors (Smith et. al, 2005). Therefore, in the revised model, there is also influence from the socio-technical regime down to the niche level, contrary to the original model suggested by Geels.

Considering emerging ammonia technologies, it is observable that all these technologies have received support from the EU to the national level to some degree. Wärtsila, who is developing, amongst other ammonia technologies, ammonia combustion engines, has received funding from the Norwegian Government (Wärtsilä, 2023). The ShipFC project receives funding from mainly the EU, Equinor and Wärtsila, as described in the background part. Amon Maritime, which has designed an ammonia fuelled PSV, has received national backing for ammonia powered bulk vessels, in addition to its bunkering solution for ammonia (NTB, 2023). Amogy, while not having received any funding from the national level or above, has benefitted from testing its ammonia-to-power fuel cells systems at the Norwegian Sustainable Energy Catapult Centre, a national organization facilitating national infrastructure for innovation. The ShipFC project, as well as Wärtsilä, both utilize the centre for its ammonia testing. When the niche technologies are incentivised adequately, they gain traction in the socio-technical regime, where maritime companies quickly are able to observe their success through maritime clusters.

In the revised MLP model based on informants' views, drivers are in green, while barriers are in red. Niches' influence is unchanged.

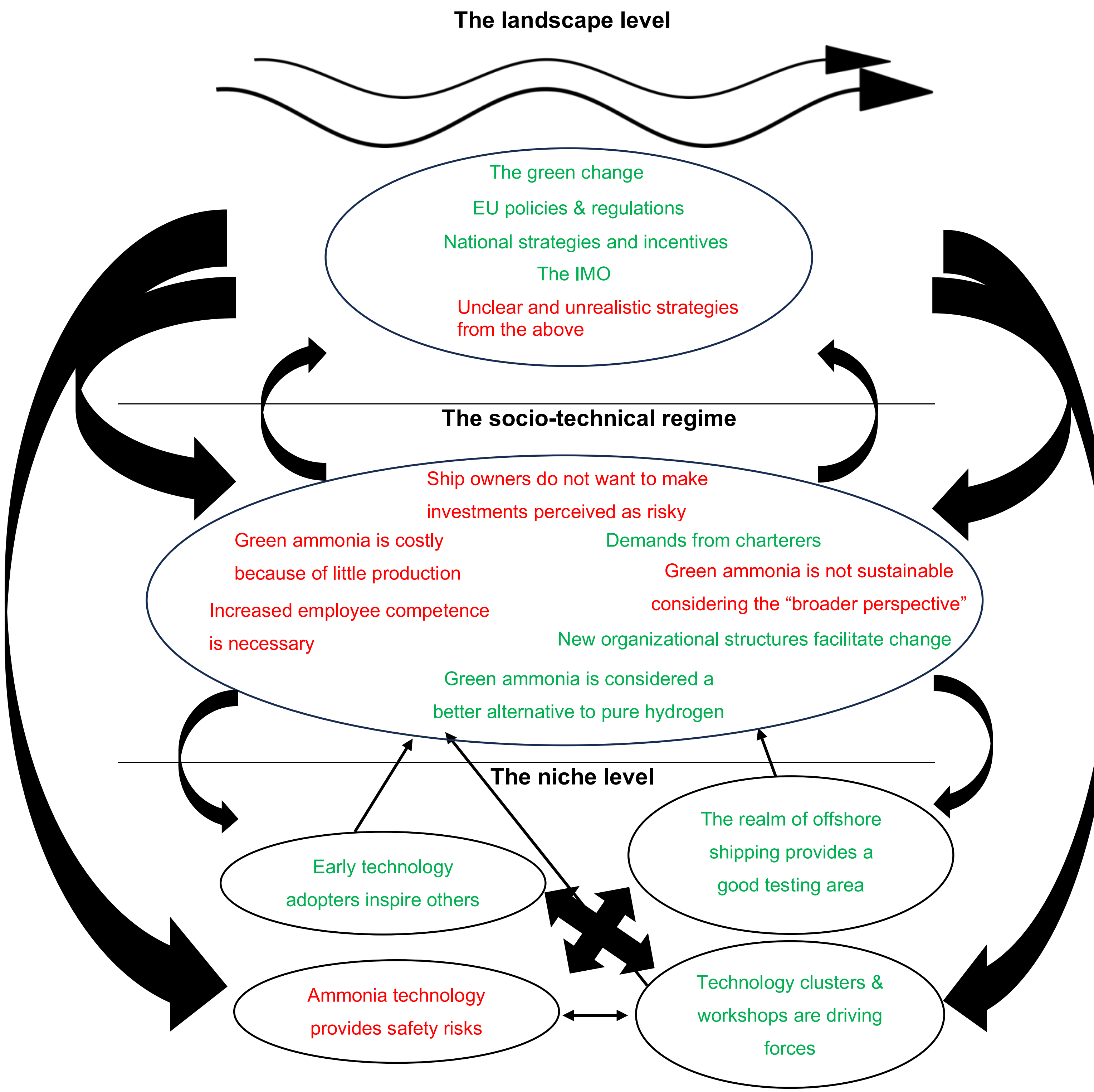

Figure 6: A revised version of the MLP based on findings

6.2 The driving forces

This chapter will further address the identified driving forces for green ammonia adoption, building on the revised MLP model with organizational change theory and the DOI theory.

Green ammonia's identified advantages

For green ammonia, the large relative advantage, highlighted by Rogers (1983), versus conventional fuel, is the environmental aspect. The combustion of green ammonia as a fuel does not release GHG emissions, therefore aligning with the green change, national and IMO/EU goals. Regarding Rogers' complexity aspect, and trialability, used to describe the complexity of an innovation, green ammonia shows potential for rapid diffusion. There are multiple arenas for testing, for example the Sustainable Energy Norwegian Catapult Centre, where ammonia combustion engines, fuel cell technology and other technologies are tested, in addition to the Mærsk McKinney Møller Center for ZERO Carbon Shipping. These arenas serve as drivers for green ammonia implementation. Additionally, the region of Western Norway with its specialized offshore bases provides a good testing arena itself. Lastly, ammonia's advantages over pure hydrogen, another renewable fuel currently in discussions, contributes to its compatibility aligning with requirements of potential adopters (Rogers, 1983).

The role of certain organizations

Regarding Geels' (2011) final characteristic in transformations, the decisive role of certain organizations, drivers are identified in the interview findings. In the context of the offshore shipping industry, a transportation sector, Equinor is such a company, exercising great power. At any given time, Equinor contracts over 40 offshore vessels for their operations (Sundt, 2023). Informants see Equinor as a major driver for the green change in shipping with their vessel requirements and engagement in alternative fuels. The development of new innovations is also emphasized by Geels as being driven by innovative niche organisations. Amogy, with their fuel cell technology, is recognized as one of leaders regarding the development of sustainable ammonia technologies. In addition to Equinor and Amogy, maritime cluster organization Maritime Cleantech appears to an influential organization recognized as a driver. Describing the observability aspect of the DOI theory, Rogers (1983) states that high levels of visibility usually lead to rapid adoption of innovations. Through meeting arenas such as those facilitied by MaritimeCleanTech, different actors will be able to observe and discuss the innovations.

Organizational structures

Although the shipping industry is commonly thought of as conservative, the informants characterize the offshore shipping industry as mostly proactive in its approach to change, recognizing both the green change and upcoming demands and regulations affecting their organizations. As compared to other shipping segments, such as longer haul shipping, the informants believe the offshore shipping industry is driving change, setting an example for the broader maritime landscape. Proactive change is witnessed in the form of innovative companies and early adopters driving the implementation of green ammonia, as well as new organizational structures. The informants describe the transition to new organizational structures as a radical and proactive change. These new organizational structures have been created to deal with sustainability in all organizations, except those organisations which were created with a sustainable vision from the very beginning. These structural adjustments are attributes for the success of change (Jacobsen & Thorsvik, 2013). According to Jacobsen and Thorsvik, another key attribute to successful change initiatives was described as a clear communication of the vision and strategy so that employees gain an understanding of the change. The mention of an informant’s organisation’s “decarbonization academy” is an example of such an attribute. The need for new organizational structures, such as dedicated departments for sustainability and decarbonization academies, signifies an acknowledgment of the importance of creating a culture that fosters green change.

6.3 The barriers

This chapter will further address the identified barriers forces for green ammonia adoption. building on the revised MLP model with organizational change theory and the DOI theory.

Green ammonia as a commodity

Considering Rogers’ (1983) emphasis on an innovation’s relative advantages, the economic aspect is a barrier. It is understood by informants that investing in green ammonia solutions is not considered a good investment in itself, if it were not for perceived advantages of participating in the green change. Green ammonia is expensive, and so is the necessary requisite technology. The transformation to green ammonia as a marine fuel tends to score low on assessments related to profitability and investments costs compared to the cost of the current technology in the maritime sector. Rogers (1983) and Geels (2011) both underline that technologies which have many relative advantages over existing technology, will be adopted faster. The degree of immediate economic advantage over MGO, if not considering securing contracts from charterers, is none.

Green ammonia as a substance

Ammonia as a substance needing to be handled, provides further barriers related to a lack of comparative advantages. The offshore shipping industry has no experience with green ammonia as a marine fuel, and little with the chemical at all, therefore indicating little compatibility (Rogers, 1983). The majority of informants see ammonia's chemical properties as challenging. Batteries on marine vessels were quickly accepted largely due to their safe nature, which underlines the important of safety in new innovations. Throughout the industry's history, dealing with other inherently dangerous chemicals for transportation offshore and for use in vessels, such as liquefied natural gas (LNG), has afforded the industry with experiences in dangerous chemical handling, but informants still emphasize ammonia's complexity.

Differing views

Informants differ in their views of which solutions and policies are best suited to address the larger green transformation, which according to Geels (2011) could be due to the controversy surrounding sustainability in the green change. The rather surprising view by some that green ammonia is not sustainable considering the green change as a whole is such a controversy, and shows that stakeholders in the maritime system do not all view green ammonia as the best solution to sustainable transformation. Considering the commercial sides of shipping, there are also controversies identified concerning an increase in local CO_2 taxes and information sharing in maritime clusters. Some informants believe an increase in local CO_2 taxes and excessive information sharing in maritime clusters limit competitiveness.

Shipowners' risk aversion

Of the 20 established offshore ship owning companies in Norway (Harnes, 2023), not including Amon Offshore, only two of these are known officially to be in the process of implementing ammonia solutions. The number, could, however, be larger, but indicates that there are only about 10 % of ship owning companies which can be characterized as early adopters in offshore shipping, compared to 13.5 % in Rogers' (1995) model, figure 5. Ship owners are reliant on income from the chartering of their ships. In the background chapter, it was described how an ammonia fuelled ship is 10 – 100 per cent more expensive to build than conventional vessels. For their investments to be profitable, this necessitates high rates, paid by charterers, for their vessels.

A need for increased employee competence

Reactive tendencies in the offshore shipping industry are shown through the identified need for increased employee competence to deal with the technological transformation that is a shift to green ammonia as a marine fuel. The "huge lack of competence" stated by one informant, indicate an industry not yet adapted to change. A radical change of shipping companies is implied by informants as necessary, bringing in more engineers and technical personnel to handle ammonia's complexity, in addition to personnel being able to report on the EU ETS, for example. The lack of proactivity in regard to employee competence for ammonia is understood as coming from uncertainty and risk, and a lack of immediate returns, described as disadvantages to proactive change by Jacobsen and Thorsvik (2013).

6.4 Leveraging partnerships, collaborations, and government initiatives

This chapter will discuss drivers which can accelerate the adoption to green ammonia as a marine fuel and remove the barriers. Additionally, strategies will be proposed.

The charterers' role

Informants express that a lack of perceived crisis within their organizations to drive change is caused by charterers. According to Jacobsen and Thorsvik (2013), creating a perceived crisis is a successful change attribute. Although Equinor is a driving force, other charterers do, according to informants, far too little. According to Geels (2011), a transition would happen faster and be easier if large businesses made their resources available to create greater development of environmentally friendly technology. This view is highlighted by many informants. These organizations, according to Kimberly and Evanisko (1981) as well as Kennedy (1983), being more risk accepting because of their size, have the possibility to affect new innovations greatly. The charterers in the offshore shipping industry, e.g. Equinor, DNO, Aker BP, Vår Energi and OKEA (Seabrokers, 2023) are all large organizations who benefit from increased cashflows due to the increase in petroleum prices in light of the enduring energy crisis, and could take increased responsibility to contribute more to renewable fuels within the maritime domain. Equinor's role in the ShipFC project was identified as important, showing that the charterers do in fact have large influence in ammonia adoption. If the charterers would take a more active role, informants believe ships owners' risk aversion could be limited. As the critic of Geels suggests, a transition will not always occur without certain actors, with Equinor and other charterers potentially being such actors (Smith et. al, 2005).

Stakeholder collaboration in the maritime system

When considering Dicken's (2015) two sorts of innovation, the implementation of green ammonia shipping can be defined as a radical innovation, necessitating relating innovations for its support, e.g. in infrastructure, technological- and regulatory frameworks. According to Dicken (2015), the widespread influence of innovations requires a cluster of these. Therefore, stakeholders could emphasize continued collaboration to accelerate green ammonia's adoption in the offshore shipping industry. This way, the free rider problems characterized as a typical problem by Geels (2011) in sustainable transformations and observed by informants, could be avoided. Freeriders can be placed in in the laggards adopter group by Rogers (1983). These laggards will not survive today's competitive environment where innovation is a key driver of success, according to Jacobsen and Thorsvik (2013).

Rogers (1983) points to high levels of visibility leading to rapid adoption of innovations in most cases. This view is agreed upon by informants, who emphasize that early technology adopters inspire others, and that technology clusters and workshops are also important driving forces. If one actor achieves success with green ammonia, others will be able to observe this success. The offshore shipping industry is a cluster, and through meeting arenas such as those facilitied by MaritimeCleanTech and the Blue Maritime Cluster, different actors will be able to observe and discuss the innovations. For the offshore shipping industry, with its bases and specialized nature, the influence of green ammonia does not necessarily rely on extensive geographical distribution or broad market penetration; instead, it depends on targeted and effective implementation within its distinct operational framework. The arenas for meeting could be utilized to overcome the safety barriers, as organizations will be able to discuss these perceived critical aspects.

Lastly, it is worth recognizing that all organizations have put in in place sustainability functions at the organizational level, but at the same time, organizations do not have the means to deal with ammonia's chemical properties. Strategic plans, another key attribute to successful change (Jacobsen & Thorsvik, 2013), for dealing with the safety aspects of ammonia handling are not outlined by informants either. By fostering a culture of shared learning and expertise, the maritime industry can collectively work towards making the adoption of green ammonia more viable and secure. This could be done by utilizing ammonia test centres to a larger degree. Furthermore, the offshore shipping industry now has a chance to be proactive towards ammonia, hiring more technical personnel to deal with ammonia's complexity. The new organizational structures, and "academies" within organizations dealing with sustainability could prove helpful in this regard, identifying areas where additional expertise is needed and diffuse ammonia learning.

Regulatory influences

Geels (2011) believes that there is less chance that environmentally friendly solutions will be prioritized over existing solutions without changing the economic conditions and introducing, for example, state subsidies. He suggests that an increased role by public authorities, is a way of making transformations easier. This is echoed by informants in relation to ammonia, and was particularly identified as the leading driver behind battery systems' large success in vessels. Other successful initiatives were identified as the NOx Fund and incentives from national agencies. Informants wish for a larger responsibility by the government, who set the basis for national strategies related to sustainability through their governance.

According to Geels (2011), the government may have the ability to resist or co-opt sustainability transitions to protect their interests, such as decreasing spending towards incentives. Norway's national budget suggested for 2024, which does not mention CFDs, identified as an importance incentive for the successfully implementation of green ammonia at a large scale, is an example of the government's power in influencing sustainable transformations. Informants believe the barrier of costly production would be overcome if the government implemented CFDs. Furthermore, informants speaking on behalf of charterers, believe that a lack of urgency for these organizations to demand sustainable practices from shipowners also comes from unclear government strategies.

Other landscape development actors, the EU and IMO, also must, according to informants, increase their role in the green change. For example, informants want to expand the EU Renewable Energy Directive to sustainable fuels, reduce GT requirements for EU ETS to 4000 GT, and implement the Fuel EU Maritime regulation to Norway's offshore shipping industry. They also wish for IMO to work at a higher pace, so as to keep up with the industry developments. The broadest influence suggested by informants as having the potential to positively catalyse green ammonia implementation, is a global CO_2 tax. These changes involve a shift in current policies, which, according to Geels (2011), can lead to a political power struggle between users of current and new technology as they will try to resist such changes. This characteristic is not observed by informants, who all seemingly welcome change. However, non-innovative organizations which were not interviewed for this thesis may disagree.

As per Steen (2018), indirect influence from the maritime industry can affect landscape developments. In innovation arenas where shipowners and charterers attend, such as the Green Shipping Programme and the Blue Maritime Cluster, there are many national agencies as observers. Examples of these national agencies are Innovation Norway, The Research Council of Norway, The (Norwegian) Ministry of Trade, Industry and Fisheries, The (Norwegian) Ministry of Climate and Environment and the Norwegian Environment Agency (Green Shipping Programme, n.d.; Blue Maritime Cluster, n.d.). The Norwegian Maritime Authority, observing the maritime industry, has as described in the background chapter, proposed suggestions to the IMO regarding ammonia. There is little doubt that these agencies, working on behalf of strategies outlined by the government, are able to observe suggestions by the industry in the clusters. As seen in the revised MLP model, there is observed influence from the maritime system up to the regulatory organizations, exemplified by The Norwegian Maritime Authority. This influence does not reflect the current policies of the government, exemplified by the lack of action as compared to ambitions in Huldarsplattformen. The offshore shipping industry could leverage its observed large cooperation to further lobby the government in order to achieve clearer and more realistic strategies.

The table below provides a summary of the discussions section, with identified barriers, driving forces, how to use the driving forces, and the main theories used for the suggestions.

Table 4: Summary of discussion

Barrier	**Driving force**	**Leveraging the driving force**	**Main theoretical framework**
Green ammonia is costly because of little production	EU/National strategies and incentives	An increase in incentives from EU/national levels, for example through contracts for differences, and through setting demands for sustainable practices	Multi-level perspective (Geels, 2002; 2011. Diffusion of innovations (Rogers, 1983).
Ammonia technology provides safety risks	Technology clusters, workshops and the realm of offshore shipping. New organizational structures	Actively use established clusters and workshops for information sharing and safety developments, while testing ammonia at specialized offshore bases. Leverage new organizational structures to diffuse ammonia learning	Diffusion of innovations (Rogers, 1983).
Shipowners do not want to make investments perceived as risky	Demands from charterers	Charterers could take a larger role in setting demands for renewable shipping operations, and contribute directly to ammonia projects, such as the commercial commitment by Equinor in the ShipFC project	Multi-level perspective (Geels, 2002; 2011. Diffusion of innovations (Rogers, 1983).
Increased employee competence is necessary	New organizational structures facilitate change	New organizational structures within sustainability can identify areas where additional expertise is needed. Leverage new organizational structures to diffuse ammonia learning	Organizational change theory (Jacobsen & Thorsvik, 2013). Diffusion of innovations (Rogers, 1983).
Unclear and unrealistic strategies from the EU, the national landscapes and the IMO	Technology clusters and workshops	Actively use established clusters to lobby efforts required for the adoption of green ammonia	Diffusion of innovations (Rogers, 1983). Socio-technical transitions (Steen, 2018).

6.5 Future work and research criticism

The interviews revealed diverse factors influencing the adoption of green ammonia. Some informants expressed criticism about the sustainability of green ammonia combustion when compared to alternative measures across various industries involved in the broader green transformation. Future research could offer perspectives for assessing sustainability comprehensively within the context of the broader green transition, as this thesis does not present a way of overcoming controversies related to sustainability, although it is an interesting finding.

The empirical insights gained from this research are largely based on shipping companies' point of view in the sustainable transformation, while the informants' perspectives highlighted an important role of charterers. Future work could also employ the multi-perspective theory to explore sustainable transformations through the lens of charterers. While the charterers are subject to some critique by other stakeholders in the offshore shipping industry, reasons for their inactiveness may provide interesting views in future studies.

Furthermore, while the offshore shipping industry shows enthusiasm for adopting sustainable solutions like green ammonia, it faces challenges due to a deficiency in incentives and regulatory frameworks. In large, there appears to be a disconnect between the Norwegian maritime industry and regulatory bodies at national, EU, and IMO levels. Researching the dynamics of the relationship between the maritime sector and regulatory authorities could provide valuable insights into overcoming these challenges.

Lastly, navigating the research on green ammonia as a marine fuel in a rapidly evolving landscape, while exciting, could be an inherent weakness of this thesis. Notable milestones, such as the release of the 2024 Norwegian National budget shaping regulatory aspects and the finalization of IMO amendments to the IGF Code CCC9 in October 2023, the announcement of the world's first green ammonia-powered container ship and four-stroke engine in November 2023 and the first voyage (on diesel) of the world's first ammonia-capable ship in December 2023 exemplify the constant changes in the industry and the dynamic nature of developments. When this thesis is handed in, further developments are likely to have been made, which may offer new perspectives or information that extend beyond the scope of my current research.

7 Conclusion

The ongoing discussion about adopting green ammonia as a marine fuel comes at a crucial time for the shipping industry's push towards sustainability. While there is a lot of excitement around its potential to meet emissions targets set by the IMO and contribute to the broader green shift, it's essential to recognize the significant challenges that need addressing.

The research question for this thesis is broad, and is therefore built by the sub-research questions. Sub-research question 1 and 2 concern the driving forces and the barriers for green ammonia implementation, and utilize the theories of the multi-level perspective, organizational change and the diffusion of innovations. The research has concluded that the green change, EU policies and regulations, and the IMO, while inherent driving forces, create ambiguity in the maritime system. The lack of demands and incentives from these high levels of institution hinder viable ammonia production prices and hinders active ammonia engagement from stakeholders in offshore shipping. Also being inherent driving forces, are the charterers. Charterers have the possibility to influence green ammonia implementation at a grand scale, and while some have shown this commitment, much commitment remains to be shown. Both the increased need for regulatory measures and the important roles of large organizations such as the charterers are highlighted by the theoretical framework. Organizational change theory looked at the organizations' preparedness to green ammonia implementation, and found that the organizations are proactive on the one hand, having created new organizational structures surrounding sustainability. On the other hand, organizations are not prepared for the practical implementation of green ammonia, because of safety concerns surrounding its chemical properties.

Sub-research question 3 concerns which aspects affect the adoption of new innovations such as green ammonia. The research found that all informants compared battery implementation as the latest grand scale GHG reducing technology comparable to green ammonia implementation, with incentives and safety being the largest drivers. These two aspects are also observed as crucial for green ammonia implementation, showing that implementing new technologies follows distinct pattern as suggested by the theoretical framework.

Sub-research question 4 concerns how the barriers can be overcome to facilitate green ammonia's implementation. The research found that many drivers can be utilized to overcome the barriers. The offshore shipping industry shows a strong culture of sharing and collaboration, which can be used to reduce safety risks and serve as connecting points to regulatory levels affecting the industry. Increased support from the regulatory levels is viewed as crucial for the successful implementation of green ammonia in offshore shipping, an especially for shipping broadly, as other countries do not have the incentives as Norway. An increased charterer responsibility is needed for shipowners to invest in green ammonia solutions. New organizational structures related to sustainability are suggested to be used assess the demand for increased employee competence and reduce safety risks.

This thesis has examined the views of stakeholders regarding green ammonia implementation with a focus on the offshore shipping industry, ranging from regulatory organizations to technology suppliers. It has attempted to contribute to shipping research on renewable fuels through the lense of a socio-technical transition view, complemented by diffusion of innovations and organizational change theory. Measures have been proposed to overcome the barriers identified, so that the offshore shipping industry can reach its goal: a reduction of emissions.

Bibiliography

Alm, R., Cox, M. (n.d.). *Creative Destruction*. The Library of Economics and Liberty. https://www.econlib.org/library/Enc/CreativeDestruction.html

Avelino, F., Rotmans, J. (2009). Power in transition: An interdisciplinary Framework to study power in relation to structural change. *European Journal of Social Theory, 12(4), 543-569.* https://doi.org/10.1177/1368431009349830

Bacha, H., Bergek, A., Bjørgum, Ø., Hansen, T., Kenzhegaliyeva, A., & Steen, M. (Year, in press). Implementing maritime battery-electric and hydrogen solutions: A technological innovation systems analysis. *Transportation Research Part D.* https://www.elsevier.com/locate/trd

Barelli, L., Bidini, G., Cinti, G. (2020). Operation of a Solid Oxide Fuel Cell Based Power System with Ammonia as a Fuel: Experimental Test and System Design. *Advances in Hydrogen Energy, 13(23), 6173.* https://doi.org/10.3390/en13236173

Bergek, A., Bjørgum, Ø., Hansen, T., Hansson, J., & Steen, M. (2018). *Towards a sustainability transition in the maritime shipping sector: the role of market segment characteristics.* https://www.researchgate.net/publication/325781644_Towards_a_sustainability_transition_in_the_maritime_shipping_sector_the_role_of_market_segment_characteristics

Bilali, H. E. (2019). The Multi-Level Perspective in Research on Sustainability Transitions in
Agriculture and Food Systems: A Systemic Review. *Agriculture, 74(9), 5-10.* https://doi.org/10.3390/agriculture9040074

Blue Maritime Cluster. (n.d.). *Cluster members.* https://www.bluemaritimecluster.no/gce/the-cluster/participants/

CORDIS European Commission. (2023). *Piloting Multi MW Ammonia Ship Fuel Cells*.

https://cordis.europa.eu/project/id/875156

Confederation of Norwegian Enterprise. (2023). *Den europeiske hydrogenbanken.*

https://www.nho.no/tema/eos-og-internasjonal-handel/nho-brussel/artikler/den-europeiske-hydrogenbanken/

Cozijinsen, Jos. (2023). *Tightening EU ETS leads to zero emissions before 2040*. https://www.emissierechten.nl/column/tightening-eu-ets-leads-to-zero-emissions-before-2040/

Damsgaard, J., Lyytinen, K. (2001). *What's Wrong with the diffusion of innovation theory? The case of a complex and networked technology.* https://www.researchgate.net/publication/2866133_What's_Wrong_with_the_diffusion_of_innovation_theory_The_case_of_a_complex_and_networked_technology

Dicken, P. (2015). *Global Shift: Mapping the changing contours of the world economy* (7th edition). London: SAGE Publications. https://handoutset.com/wp-content/uploads/2022/06/Global-Shift-Mapping-the-Changing-Contours-of-the-World-Economy-Seventh-Edition-7th-Edition-Peter-Dicken.pdf

DNV. (2022). *Vessel Register for DNV*. https://vesselregister.dnv.com/vesselregister

Enova. (n.d.). *Raskere fra idé til marked*. https://www.enova.no/pilot-e/

Enova. (2023). *Enova planlegger nye støtteprogrammer for "Hydrogen i fartøy" og "Ammoniakk i fartøy"*. https://info.enova.no/nb/haf

European Commission. (2023). *Reducing emissions from the shipping sector.* https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector_en

European Commission. (2023). *EU Emissions Trading System (EU ETS).* https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en

European Council. (2023). *FuelEU maritime initiative: Council adopts new law to decarbonise the maritime sector.* https://www.consilium.europa.eu/en/press/press-releases/2023/07/25/fueleu-maritime-initiative-council-adopts-new-law-to-decarbonise-the-maritime-sector/

Eidesvik. (n.d.). *Viking Energy with ammonia-driven fuel cell.* https://eidesvik.no/viking-energy-with-ammonia-driven-fuel-cell/

Fagerberg, J., Fosaas, M., Bell, M., Martin, B.R. (2011). Christopher Freeman: social science entrepreneur. *Research Policy, 40(7), 897-916.* https://doi.org/10.1016/j.respol.2011.06.011

Garud, R., Gehman, J. (2010). *Metatheoretical perspectives on sustainability journeys: Evolutionary, relational and durational, 41(6), 980-995.* https://doi.org/10.1016/j.respol.2011.07.009

Genus, A., Coles, A. (2008). Rethinking the multi-level perspective of technological transitions. *Research Policy, 37(9), 1436-1445*. https://doi.org/10.1016/j.respol.2008.05.006

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy, 31(8-9), 1257-1274.* https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: response to seven criticisms. *Environmental Innovation and Societal Transitions*, *31(1), 24-40.* https://doi.org/10.1016/j.eist.2011.02.002

Green Shipping Programme. (n.d.). *Partners*. https://greenshippingprogramme.com/partners/

Grøv, Kristoffer. (2019). *Grønn omstilling- Anleggsbransjens byggeplan på veien mot lavutslippssamfunnet.* [Master's Thesis, NTNU: Norwegian University of Science and Technology]. http://hdl.handle.net/11250/2610859

Hagberg, H. (2022). *Maritime transportation will be included in the EU ETS from 2024.* Thommessen.https://www.thommessen.no/en/news/maritime-transportation-included-in-the-eu-ets

Harnes, O. (2023, November 15th). Regelverk for Ammoniakk som drivstoff, DNV. Grønn skipsfart med Vestlandet i førersetet, Stavanger.

Høyland, S., Kjestveit, K., Skotnes, R. (2023). Exploring the complexity of hydrogen perception and acceptance among key stakeholders in Norway. *International Journal of Hydrogen Energy, 48(21), 7896-7908.* https://doi.org/10.1016/j.ijhydene.2022.11.144

IMO. (2023). *Revised GHG reduction strategy for global shipping adopted.* https://www.imo.org/en/MediaCentre/PressBriefings/Pages/Revised-GHG-reduction-strategy-for-global-shipping-adopted-.aspx

Jacobsen, D., & Thorsvik, J. (2013). *Hvordan organisasjoner fungerer.* Fagbokforlaget.

Larsen, A.K. (2017). *En Enklere Metode: Veiledning i Samfunnsvitenskapelig Forskningsmetode* (2nd ed.). Fagbokforlaget

Markard, J., Raven, R. & Truffer, B. (2012). *Sustainability transitions: An emerging field of research and it prospects, 41(6), 955-967* https://doi.org/10.1016/j.respol.2012.02.013

Nordic Innovation. (2023). *NoGAPS: Nordic Green Ammonia Powered Ships.* https://cms.globalmaritimeforum.org/wp-content/uploads/2023/08/NoGAPS-Report-Commercialising-early-ammonia-powered-vessels.pdf

Norwegian Environment Agency. (2023). *Klimatiltak i Norge mot 2030: Oppdatert kunnskapsgrunnlag om utslippsreduksjonspotensial, barrierer og mulige virkemidler – 2023*. https://www.miljodirektoratet.no/publikasjoner/2023/juni-2023/klimatiltak-i-norge-mot-2030/

Norwegian Hydrogen Association. (2023). *Regjeringen dropper hydrogensatsing: - Et stort tilbakeslag for det grønne skiftet.* https://www.hydrogen.no/aktuelt/nyheter/regjeringen-dropper-hydrogensatsing-et-stort-tilbakeslag-for-det-gronne-skiftet

Norwegian Shipowners' Association. (2023). *Budsjetthøring 2024: Differansekontrakter blir helt sentralt for å lykkes med klimamålene.* https://www.rederi.no/nyheter/budsjetthoring-2024-differansekontrakter-blir-helt-sentralt-for-a-lykkes-med-klimamalene/

Nykamp, H., Andersen, A. D., & Geels, F. W. (2023). Low-carbon electrification as a multi-system transition: a socio-technical analysis of Norwegian maritime transport, construction, and chemical sectors. *Environmental Research Letters, 18(9), 094059.* https://doi.org/10.1088/1748-9326/acf67a

The Norwegian Tax Administration. (2023). *NOx tax.* https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/nox/

The Norwegian Tax Administration. (2023). *Mineral product tax.* https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/mineral-product/

Tonje, Haugen. (2016). *Drivkrefter og barrierer for omstilling. En casestudie av utvikling og spredning av velferdsteknologier i Kommune-Norge.* [Master's Thesis, UiO: University of Oslo]. http://urn.nb.no/URN:NBN:no-56540

Oldenburg, B., & Glanz, K. (2008). Diffusion of innovations. *Health behavior and health education: Theory, research, and practice,* 313–333 https://www.researchgate.net/publication/302976277_Diffusion_of_innovations

Panayides, P. (2018). *Principles of Chartering: Third Edition*

Pahle, M., Sitarz, J., Osorio, S., Görlach, B. (2022). *The EU-ETS Price Through 2030 and Beyond: A closer look at drivers, models and assumptions*. Ecologic Institute Science and Policy for a Sustainable World. https://www.ecologic.eu/19034

Rogers, E. M. (1983). *Diffusion of Innovations* (3rd ed.). Free Press; Collier Macmillan Publishers.

Seabrokers. (2023). *SeaPortal internal reports.* https://portal.theseabay.com/login

Ship & Bunker. (2023). *World Bunker Prices.* https://shipandbunker.com/prices

ShipFC. (2020). *About*. https://shipfc.eu/about/

Sjøtun, S. G. (2020). *Engineering' the green transformation of the maritime industry in Western Norway.* [Thesis for the degree of Philosophiae Doctor, UiB: University of Bergen, Norway]. https://hdl.handle.net/1956/21576

Smith, A., Voß, J., Grin, J. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenge. *Research Policy, 39(4), 435-448.* https://doi.org/10.1016/j.respol.2010.01.023

Steen, M. (2018). *Et grønt maritimt skifte? Omstilling til en mer miljøvennlig skipsfart.* SINTEF. https://sintef.brage.unit.no/sintef-xmlui/handle/11250/2585582

Stopford, M. (2009). *Maritime Economics* (3rd ed.) Routledge.

Sundt, M. (2023, November 15th). Bærekraftig skipsfart, Equinor. Grønn skipsfart med Vestlandet i førersetet, Stavanger.

Sweezy, P. (1943). Schumpeter's Theory of Innovation. *The Review of Economics and Statistics, 25(1), 93-96.* https://doi.org/10.2307/1924551

The Government. (2021). *Hurdalsplattformen.* https://www.regjeringen.no/no/dokumenter/hurdalsplattformen/id2877252/

The Government. (2023). *Klimaendringer og norsk klimapolitikk.* https://www.regjeringen.no/no/tema/klima-og-miljo/innsiktsartikler-klima-miljo/klimaendringer-og-norsk-klimapolitikk/id2636812/

The Government. (2023). *Norske posisjoner til CBAM.* https://www.regjeringen.no/no/aktuelt/norske-posisjoner-til-cbam/id2999772/

https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/mineral-product/

The NOx Fund. (n.d.). *Story about the NOx Fund.* https://www.noxfondet.no/en/articles/about-the-nox-fond/

Tjora, A. (2018). *Kvalitative Forskningsmetoder i Praksis* (3rd ed.). Oslo: Gyldendal Akademisk.

Trading Economics. (2023). *EU Carbon Permits.* https://tradingeconomics.com/commodity/carbon

Wells, P., Pettit, S., Abouarghoub, W., Haider, J., Beresford, A. (2018). Future CO2 emissions from shipping: four-scenarios using a multi-level perspective – a proposed methodology. *SHS Web Conf., 58(01031), 1-9.* https://doi.org/10.1051/shsconf/20185801031

Zero. (2022). *Differansekontrakter for hydrogen.* https://zero.no/wp-content/uploads/2022/08/Differansekontrakter_hydrogen.pdf

Illustration References

Figure 1: *Eidesvik. (n.d.). Viking Energy with ammonia-driven fuel cell.* https://eidesvik.no/viking-energy-with-ammonia-driven-fuel-cell/

Figure 2: Cozijinsen, Jos. (2023). *Tightening EU ETS leads to zero emissions before 2040.* https://www.emissierechten.nl/column/tightening-eu-ets-leads-to-zero-emissions-before-2040/

Figure 3: Geels, F. W. (2011). The multi-level perspective on sustainability transitions: response to seven criticisms. *Environmental Innovation and Societal Transitions*, *31(1), 24-40.* https://doi.org/10.1016/j.eist.2011.02.002

Figure 5: Urban Adolescent SRH SBCC Implementation Kit. (n.d.) *What does Diffusion of Innovation tell us about behavior?* https://sbccimplementationkits.org/urban-youth/urban-youth/part-1-context-and-justification/social-and-behavior-change-communication-theory/diffusion-of-innovation/

I. Attachment

Interview Guide

1. **Warm up questions**

   1.1 What is your job title?

   1.2 How many years have you worked in the company?

   1.3 How many years of experience do you have in the maritime sector?

   1.4 Can you provide an overview of your experience and expertise in the offshore shipping industry and your involvement with alternative fuels, particularly green ammonia?

2. **Today's status of ammonia implementation**

   2.1 What is the current level of adoption of ammonia as a fuel in offshore shipping operations?

3. **Strategies and barriers for implementation**

   3.1 What are the main driving forces for the adoption of green ammonia in the offshore shipping industry?

   3.2 What is hindering the adoption for green ammonia in the offshore shipping industry?

   3.3 Do international regulations and agreements organizations like the International Maritime Organization (IMO) influence the adoption of green ammonia; have you observed any specific initiatives or policies driven by IMO or regional agreements that promote the use of environmentally friendly fuels like green ammonia in maritime operations?

   3.4 How does the cost of green ammonia compare to traditional marine fuels, and what strategies can be employed to make it more economically viable for shipowners and operators?

   3.5 Can you discuss any potential collaborations or partnerships that could help overcome barriers and facilitate the implementation of green ammonia as a marine fuel?

   3.6 How will the European Union Emissions Trading System (EU ETS), including offshore ships from 2027, impact the cost dynamics of green ammonia as marine fuel?

3.7 Should the FuelEU Maritime scheme, entering into force from the first of January 2025, include offshore vessels?
3.8 Does the Norwegian government do enough to facilitate the implementation of green ammonia?
3.9 Do you think Contracts for Differences can be utilized to support the adoption of green ammonia in the offshore shipping sector?

4. **Strategy implementation in organizations**
   4.1 Can you provide insights into how organizational change processes and institutional pressures impact the adoption of green ammonia as a marine fuel?
   4.2 Can you describe the process of implementing a new strategic initiative or change within your organization?
   4.3 How does your organization respond to the need for change in a dynamic business environment?
   4.4 How does your organization conform to or diverge from institutional norms and practices within your industry?
   4.5 How do drivers for change, both internal and external, influence the decisions and strategies for organizations in the maritime sector regarding green ammonia adoption?

5. **Multi-level perspective** (explain theory if necessary)
   5.1 What external influences/factors (e.g., social norms and expectations, competitors' practices, regulatory requirements, laws, regulations) require the company to facilitate green transition?
   5.2 Do you feel that the maritime industry is capable of influencing authorities and other national bodies?
   5.3 What challenges have you typically observed organizations facing when it comes to the adoption of new technologies?
   5.4 It is a fact that replacing established technologies and solutions within a sector is often challenging. Do you/your organization feel that green transition is progressing slowly due to strong path dependence on old technology within the sector?

6. **Diffusion of innovations** (explain theory if necessary)
    6.1 In your experience, what factors have influenced the rate at which new technologies or practices are adopted within the offshore shipping industry? Are there certain innovations that have been quickly embraced, and what seemed to drive their rapid adoption?
    6.2 How do you perceive the role of early adopters in influencing the adoption of new technologies or practices? Will others follow if they observe success among others?
    6.3 Which arenas exist for exchanging experiences regarding innovative acquisitions?

7. **Closing questions**
    7.1 From our conversation, is there something that stands out as particularly significant to you?
    7.2 Do you have any additional thoughts or comments you would like to share?

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