

# **How industry structure-related barriers and drivers affect the energy transition towards green hydrogen adoption in the Dutch shipping sector**

A case study in the Dutch maritime industry

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# 1) Introduction

## *1.1 Short introduction and problem statement*

The global community is currently undergoing a significant energy transition aimed at reducing the emission of greenhouse gases (GHG). As the shipping industry is a substantial contributor to global emissions, the whole sector faces increasing external pressure to mitigate its environmental footprint (Mallouppas & Yfantis, 2021). This also holds for the Netherlands, where the shipping industry accounts for 3,96% of total emissions (Centraal Bureau voor de Statistiek, 2022), above the average of 3% worldwide (Chen et al., 2019). The Dutch government demonstrated its commitment towards a green shipping sector by signing the green deal of the International Maritime Organization (IMO), which strives to zero carbon emissions by the year of 2050.

In the search of alternatives for the replacement of fossil fuels that are currently exploited, hydrogen technology have been identified to be a potentially promising technology (Fu et al., 2023; Kovač et al., 2021; Latapí et al., 2023; Melnyk et al., 2023). Currently, approximately 96% of the total hydrogen produced is derived from reforming processes involving fossil fuels such as natural gas, heavy oil, naphtha, or coal (Van Hoecke et al., 2021). Since these methods of hydrogen production continue to generate high emissions of CO<sub>2</sub>, this paper focuses on green hydrogen which refers to the production of hydrogen technology by using renewable energy sources (solar, wind, e.g.), primarily through electrolysis of water (Fu et al., 2023; Ortiz-Imedio et al., 2021).

While green hydrogen is recognized to hold significant potential, its novelty means that limited research has been conducted on how different factors are influencing the decision to adopt this technology (Kovač et al., 2021). Therefore, in response to the requirements for an energy transition, the industry started testing pilot projects (Aarskog et al., 2020; Latapí., 2023; Stolper et al., 2022). Current research tends to mainly focus on difficulties related to costs and feasibility (Aarskog et al., 2020), readiness of the technology (Bach et al., 2020) and the handling and storing of hydrogen on the ships (Van Hoecke et al., 2021). While these studies identified relevant drivers and barriers for the adoption of green hydrogen technology, a better understanding of this energy transition requires a comprehensive, holistic perspective on the drivers and barriers faced by the shipping industry (Latapí et al., 2023).

## *1.2 Research gap and theoretical relevance*

At this stage, a comprehensive study on the barriers and drivers for hydrogen adoption seems understudied in the literature (Bürer et al., 2022; Latapí et al., 2023). Therefore, this study intends to obtain a comprehensive understanding of the barriers and drivers for adoption by looking at the transition from an industry structure perspective.

As has been identified by other studies, challenges for the adoption of new technologies in transitioning industries are influenced by various factors, which are often related to industry structure (Teece, 1996; Wesseling et al., 2017; Yap & Truffer, 2019). As an industry's structure encompasses the competitive dynamics, infrastructure development and regulatory environment within an industry (Porter, 1990), it is important to consider as numerous barriers and drivers for energy transitions are finding its roots in the structure of an industry (Jamil & Martinez, 2023; Kovač et al., 2021; Latapí et al., 2023).

In the context of the Dutch shipping sector, this perspective can describe how the transition towards the adoption of green hydrogen technology is affected by the characteristics that are inherent to the industry's structure. The theoretical contribution would therefore be to look at the barriers and drivers for a transition towards green hydrogen adoption from another theoretical lens, namely industry structure, which has been underscored as important for a transition (Teece, 1996; Wesseling et al., 2017; Yap & Truffer, 2019). In addition to offering a more holistic and broader perspective than previous research (Latapí et al., 2023), the qualitative approach of this study aims to go beyond merely a categorization of barriers and drivers by investigating the interplay between factors and how they mutually affect each other and the transition towards green hydrogen. This qualitative approach will be further elaborated in the methodology section.

The industry structure perspective incorporates elements from the industry structure paradigm, system theory and institutional theory, which shall be further explained in the theoretical framework. Therefore, the objective of the research is to investigate how the industry structure perspective can be used to analyze the interplay of structural factors of the industry and how they affect the energy transition towards green hydrogen for the Dutch maritime sector.

This leads to the following research question: *How do industry structure-related drivers and barriers affect the transition towards green hydrogen adoption for Dutch shipping companies?*

### *1.3 Societal relevance*

Besides adding to the body of scientific knowledge on green hydrogen technology adoption by taking the industry structure perspective, this study may yield beneficial societal impacts for both the shipping industry and the global community in a broader context. Focusing on the Dutch maritime sector is relevant as the Netherlands, being a member of the IMO, has set increased ambitious goals regarding the mitigation of shipping emissions while also being a relatively large player in worldwide shipping activities (CBS, 2022; European Commission, 2023). Hence, as decision-makers in the shipping industry could use the results to comply to the changing demands and restrictions, their future operations stay viable and they may ensure their existence. Next to that, the industry structure perspective of the study provides the decision-makers within the sector with a more comprehensive picture of the complexities involved for the adoption of green hydrogen, which can help making informed decisions and develop strategies that consider the broader context and long-term implications of their decisions. Additionally, it could work both ways as it can help regulatory bodies to make better policies and further enhance the energy transition in the maritime industry.

Furthermore, this research is part of the NWO project SEANERGETIC, which is a multidisciplinary collaboration between businesses, government and research institutions aimed at a circular Dutch shipping industry (NWO, n.d.). As the Radboud University also participates in this initiative, this master's thesis intends to make a contribution to the SEANERGETIC project. Therefore, the paper may also be relevant in a broader context, as a sustainable shipping industry contributes to the global energy transition towards zero fossil fuel emissions. Hence, it could help to prevent further negative environmental impact for society.

### *1.4 Thesis outline*

The remaining sections of the paper are structured as follows. The following chapter will describe the underlying theoretical concepts that form a foundation for this research, following in a conceptual model that visualizes the assumed relationship in this paper. Thereafter, the research methods for data collection and analysis will be explained and substantiated. Subsequently, an analysis of the results will be presented. This will lead to a discussion on the interpretation of the results, answering the research question, a reflection on both theoretical and practical implications of the study, research limitations and

recommendations for future research direction, ending up with a reflection on the design choices and positionality of the paper.

## 2) Theoretical framework

### *2.1 Introduction*

This chapter reviews the relevant literature of industry structure-related barriers and drivers for the adoption of green hydrogen technology in maritime applications. It will analyze what encompasses the transition of an industry and how elements from system theory, the industry structure paradigm and institutional theory are crucial for the adoption. Thereafter, relevant theories within the industry structure paradigm are elaborated further while relating them to the context of this research. Subsequently, previously conducted studies on barriers and drivers for hydrogen adoption that are relevant for this research will be related to the theoretical foundation of this paper. Finally, the conceptual model visualizing the relationship of the research variables is presented.

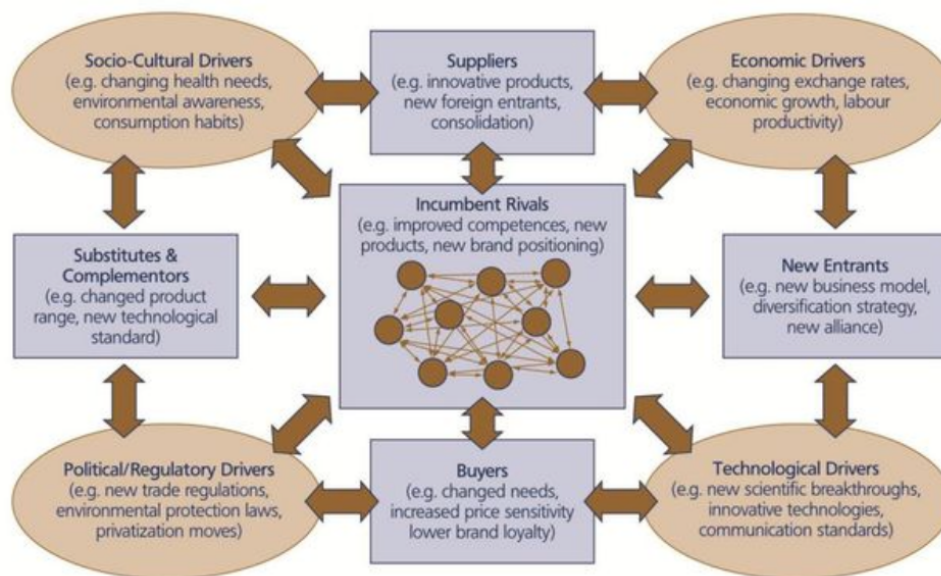
### *2.2 Transitioning industries and the relevance of the industry structure paradigm, system theory and institutional theory*

Industries are in a constant state of evolution, driven by technological developments, shifts in consumer demands and changes in regulatory environments (Dosi & Nelson, 2010; Oreggioni et al., 2021). This is especially evident in industries that are facing an energy transition, where fossil energy sources are being replaced by renewable alternatives to address environmental concerns and achieve sustainability goals (Liu et al., 2023). This energy transition also holds for the shipping industry in the context of hydrogen adoption, as the sector encounters increasing external pressure to mitigate its footprint (Mallouppas & Yfantis, 2021). Energy transitions are characterized by a complex interplay of factors, necessitating a theoretical framework that can comprehensively investigate the dynamics of an industry (Cherp et al., 2018). To get grip on the complex interplay of influencing elements in a transitioning industry, the literature highlights elements of systems theory, which understands organizations or industries as complex open systems with interdependent activities within the organization or industry as well as in its relations with the external environment (Latapí et al., 2023). Reviewing the literature on industrial development, the distinction between external and internal drivers for change is often used (De Wit, 2017; Latapí et al., 2023). The external

drivers for change are roughly categorized into socio-cultural, economic, political or regulatory and technological. The competitive dynamics within the industry are derived from the five forces model of Porter (1980): suppliers, buyers, threat of new entrants, threat of substitutes and rivalry among existing competitors. This is integrated in Figure 1 below (De Wit, 2017). This model is part of the industry structure paradigm, which will be explained in more detail.

**Figure 1**

*Divers of industry transitions*



*Note.* Adapted from “*Strategy: An international Perspective* (6<sup>th</sup> ed., p. 509), by B. De Wit, 2017. Copyright by Cengage Learning EMEA.

As is depicted in the factors of Figure 1, the driving elements for change are related to the industry structure paradigm (Porter) and institutional theory, as the five forces model can be used to analyze the competitiveness of an industry’s structure and political or regulatory drivers are elements of institutional theory. Insights from these theories can provide a framework to understand the challenges of transitioning industries (Bürer et al., 2022; Fang et al., 2018; Milchram et al., 2019; Porter, 1990).

### *2.3 Industry structure paradigm, institutional theory and system theory*

The industry structure paradigm is a theoretical framework used in economics and strategic management to analyze and understand the competitive dynamics within industries (Porter, 1990). Proponents of the industry structure paradigm argue that these structural features significantly influence firms' behavior, competitiveness and innovativeness within the dynamics of an industry (Porter, 1990). In this way, the structure of an industry creates barriers and drivers for changes within an industry, in this context the energy transition towards green hydrogen in Dutch shipping. The industry structure paradigm incorporates elements of institutional theory, which emphasizes the role of institutions in shaping organizational behavior and industry transitions (Fuenfschilling & Truffer, 2014). In the context of energy transitions, institutional forces play a crucial role in shaping the adoption and diffusion of renewable energy technologies (Cherp et al., 2018). Hence, supportive policies and regulations promoting renewable energy adoption can accelerate the adoption of green hydrogen technology, while resistance from incumbent firms and regulatory barriers may hinder the transition (Bürer et al., 2022). Institutional theory helps to clarify how these institutional contexts influence firms' strategies and industry dynamics during periods of industry transitions.

Next to institutional theory, system theory is also relevant for the industry structure paradigm. Systems theory helps in understanding how different firms and components within an industry interact and affect each other (Latapí et al., 2023). This aligns with the industry structure paradigm's focus on the relationships and dynamics between entities. The theory emphasizes the dynamics and feedback loops within systems, which includes relations with the external environment (Latapí et al., 2023). This can be applied to the industry structure to analyze how regulatory changes, technological advancements, or shifts in consumer behavior can lead to industry-wide transformations.

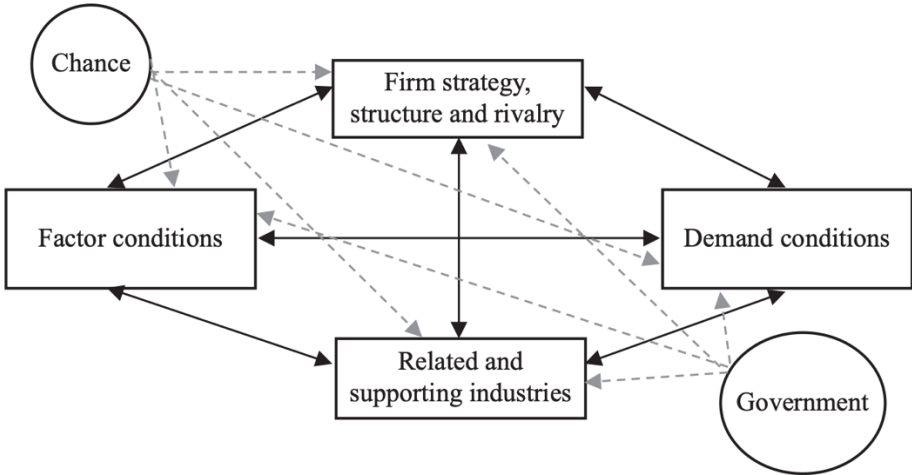
Within the industry structure paradigm, the diamond model of Porter (1990) provides valuable insights (Irfan et al., 2019). The framework integrates components of Porter's earlier theories, including the competitive five forces theory depicted in Figure 1, the value chain framework and the theory of competitive advantage, into a cohesive model that explores the sources of competitiveness and innovativeness within a national context (Porter, 1990). It serves as a comprehensive tool for analyzing both a firm's performance within a national market and a nation's ability to compete in an international market, which makes it relevant for this research as this study focuses on a national market in a globally oriented industry as

the maritime sector (Corbett & Winebrake, 2008).

The diamond model identifies four interrelated factors that influence a nation's competitive advantage and innovativeness: factor conditions, demand conditions, related and supporting industries, and firm strategy, structure, and rivalry (Porter, 1990). The factors are complemented with two additional factors: government and chance. These factors support and complement the system of national competitiveness and innovativeness but do not create enduring competitive advantages (Smit, 2010). The factors are derived from the broader analysis of the industry structure paradigm by Porter (1990).

While the diamond model is not explicitly an integration of the industry structure paradigm, institutional theory and system theory, it does consider various factors that overlap with these theories. Demand conditions, firm strategy, structure and rivalry for example may be viewed through the lens of institutional theory, considering how regulatory frameworks, government policies, and societal norms influence firms' strategies and behavior. Next to that, the identified factors interact as elements of a system. Therefore, the framework allows for the consideration of factors that embrace the important theories in this research, making it a comprehensive tool for analyzing national competitiveness, innovativeness, industry dynamics and thus the industry structure-related barriers and drivers for the energy transition. The diamond model is depicted in Figure 2 below.

**Figure 2**  
*Porter's Diamond Model*



*Note.* Adapted from “An adapted Porter Diamond Model for the evaluation of transnational education host countries,” by V.Tsiligiris, 2018, *International Journal of Educational Management*, 32(2), p. 211. Copyright 2018 by Emerald Publishing Limited.

To provide a deeper understanding of how industry structure can create barriers and drivers for the energy transition, the diamond model's elements are elaborated further (Porter, 1990).

Factor conditions include both basic and specialized factors within an industry or country. Specialized factors, such as a skilled labor pool, technological innovation, infrastructure, and capital, are crucial as they can create a sustainable competitive advantage and accelerate innovation. These are regarded as more important than basic factors like climate and raw materials (Porter, 1990). In the context of energy transition, factor conditions influence the availability of renewable energy sources, expertise in clean energy technologies, and supportive infrastructure for energy production and distribution.

Demand conditions refer to the characteristics and preferences of customers, businesses, and governmental regulations (Porter, 1990). For energy transition, demand conditions encompass growing consumer preferences for sustainable shipping, regulatory pressures to reduce carbon emissions, and market incentives to adopt renewable energy technologies.

Strategic partnerships between shipping companies, technology providers, and government agencies facilitate knowledge sharing and cost reduction. High domestic competition creates a dynamic environment where companies innovate and improve operations. Local competitors drive each other to reduce costs, enhance quality, develop new products and processes, and adopt innovative practices (Porter, 1990). Thus, the level of domestic competition and cooperation within an industry can significantly influence energy transitions.

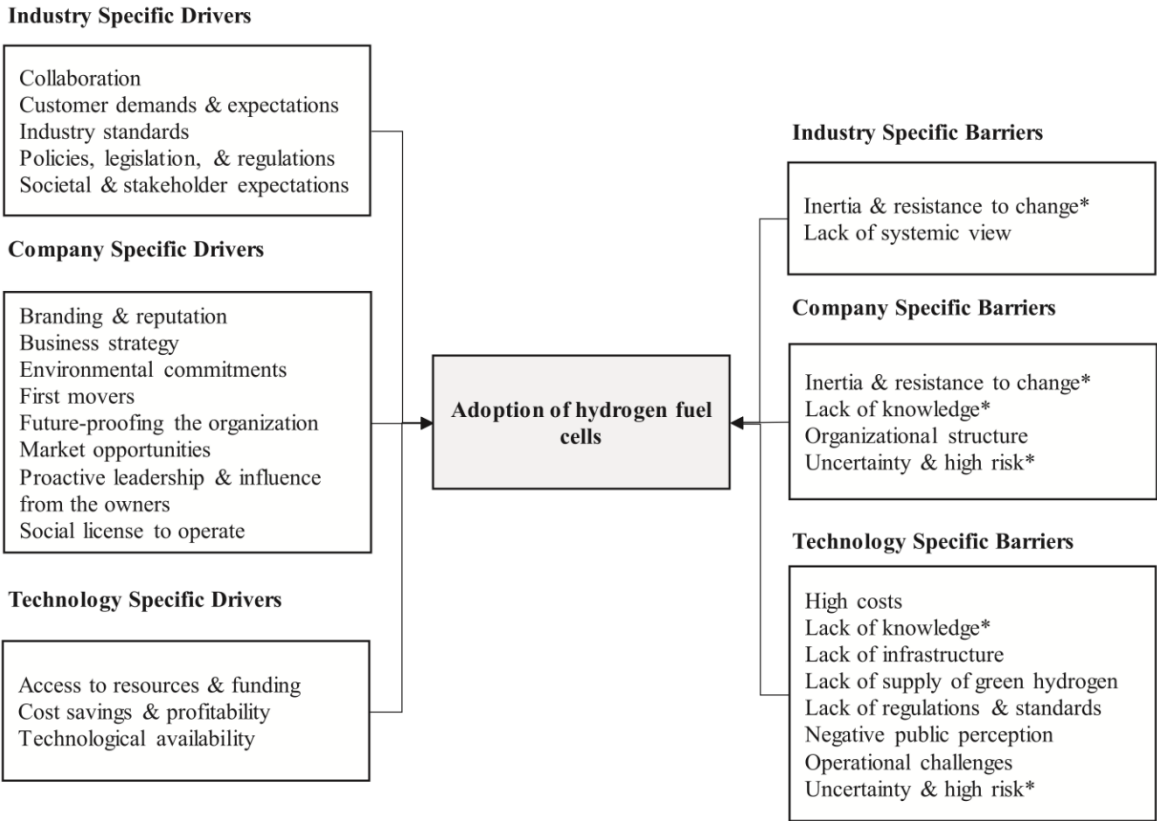
Related supporting industries emphasize the presence of supplier industries and complementary sectors that enhance an industry's competitiveness and innovativeness. Examples include suppliers of renewable energy solutions and equipment, research institutions, and collaborative partnerships like SEANERGETIC, which focus on clean energy technologies. These supporting industries can either promote or hinder the energy transition.

#### *2.4 Existing literature on barriers and drivers in the context of green hydrogen adoption*

Latapí et al. (2023) performed a study on barriers and drivers for the large-scale adoption of hydrogen fuel cell (HFC) technology in the Nordic shipping industry. They looked at the barriers and drivers from an organizational perspective, meaning that organizations are influenced by an interplay between internal and external factors that need to be strategically

managed to satisfy demands of several stakeholders in an increasingly complex and competitive world (Latapí et al., 2023), where the authors ground their analysis in system theory. The researchers identified sixteen factors motivating the decision of adoption, which they categorized into internal, external and connecting drivers. Oppositely, they distinguished eleven limiting factors that they split in behavioral, economic, organizational, and technological barriers. The drivers and barriers combined are then grouped as company-specific, industry-specific, and technology-specific (Latapí et al., 2023). These different groups are depicted in Figure 3 below.

**Figure 3**  
*Categorization of key barriers and drivers for the adoption of hydrogen fuel cells*



*Note.* Adapted from “Drivers and barriers for the large-scale adoption of hydrogen fuel cells by Nordic shipping companies,” by M, Latapí, B. Davíðsdóttir and L. Jóhannsdóttir, 2023, *International Journal of Hydrogen Energy*, 48(15), p. 6116. Copyright 2023 by Elsevier Ltd.

While Latapí et al. (2023) examined the drivers and barriers from an organizational level rather than an industry level, their analysis provides some valuable insights in the challenges

that individual companies are facing for the adoption of green hydrogen which is, while having a slightly different theoretical lens, ultimately also the level of investigation for this research. Moreover, the identified categories show overlap with the barriers and drivers for adoption from the industry structure paradigm, system theory and institutional theory. However, as an energy transition requires industry-wide changes, the industry structure perspective of this research may yield a more holistic and comprehensive understanding of the intricate interplay of factors that are influencing the energy transition (Cherp et al., 2018).

Another study that investigated the present barriers for hydrogen adoption is that of Fu et al. (2023). According to their analysis, high costs and lack of technological infrastructure are limiting the adoption of hydrogen technology. Investments in infrastructure, such as hydrogen refueling stations and port facilities, provide the necessary ecosystem to support the adoption of hydrogen technology by the shipping industry while underdeveloped infrastructure for green hydrogen can hinder adoption efforts (Bürer et al., 2022). However, Fu et al. (2023) also propose that the active development of industry standards and regulations by both countries and organizations will gradually promote and thus drive the green development of the industry. Bürer et al. (2022) also emphasize the importance of institutional support by regulations and policies for the adoption of hydrogen technology, which underlines that the presence of strong institutional supportive frameworks could form a driver for hydrogen adoption. However, in case of a lack of supportive policies, regulatory voids can create barriers for hydrogen adoption (Bürer et al., 2022).

In conclusion, the literature review of barriers and drivers for green hydrogen adoption in the shipping sector emphasizes the important role of industry structure dynamics. Studies by Latapí et al. (2023) and Fu et al. (2023) reveal the interplay between various industry-related factors, ranging from organizational strategies and balancing stakeholders demands to technological infrastructure and regulatory frameworks. Next to that, institutional pressures and regulations are also identified to be a potential barrier or driver for energy transitions, in this context the adoption of green hydrogen in the shipping industry (Bürer et al., 2022).

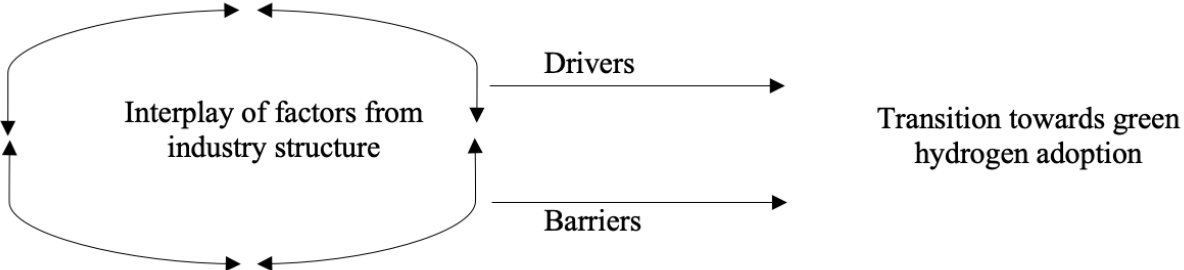
This chapter tried to incorporate key concepts from the industry structure paradigm, institutional theory, system theory and related frameworks to create a comprehensive lens through which the research variables will be examined. After building upon insights from elements such as factor conditions, demand conditions, industry dynamics, and institutional environments, a couple of conclusions can be made. While often intertwined, the literature makes a distinction between internal and external drivers. Without losing sight of eventual other factors, the external drivers and barriers can roughly be categorized as regulatory,

technological, economic and social-cultural (De Wit, 2017; Latapí et al., 2023; Porter, 1990). Internal to the industry, drivers and barriers can be related to infrastructure, skill-level of the workforce, industry rigidity competitive rivalry among many other factors. (Latapí et al., 2023; Porter, 1990). To allow for any unforeseen insights into internal and external barriers for the energy transition, the data collection will be done by semi-structured interviews, allowing for deeper insights in motivations by asking follow-up questions. This will be elaborated in the methodology section, together with the operationalization of the research variables.

*2.5 Relationship of research variables and conceptual model*

Thus, as described in the theoretical framework, the industry structure paradigm encompasses an interplay of different factors that are mutually influencing each other and affect the energy transition. Drivers and barriers shaped by these factors facilitate or hinder the energy transition towards green hydrogen adoption for Dutch shipping companies. The different barriers and drivers as distinguished in the conclusion of the theoretical framework are all incorporated in ‘interplay of factors from industry structure’ in the conceptual model. However, as this conceptual model is mainly designed to visualize the relationship of the research variables, the model is kept abstract by not including all categories of barriers and drivers. The proposed relationship is depicted in Figure 4. On the left side, the independent variable is illustrated. The interplay of drivers and barriers coming from industry structure-related factors are assumed to affect the transition towards green hydrogen adoption, which is the dependent variable depicted on the right side.

**Figure 4**  
*Conceptual model*



### 3) Research design

#### *3.1 Motivation for qualitative method*

For this research, a case study with a qualitative approach has been chosen. The study aims to get a better understanding on how the industry structure-related barriers and drivers affect the transition towards green hydrogen adoption. One of the keys benefits of qualitative research is that it allows a researcher to see and understand the context within which human decisions and actions take place, therefore it is well-suited to investigate complex phenomena involving many interacting aspects (Myers, 2013). The main objective of the qualitative approach is therefore to get deeper insights into underlying reasons, motives and contexts behind human behavior, experiences and interactions, laying the focus on understanding the why and how of a phenomenon rather than quantifying the data (Myers, 2013). As an energy transition involves a whole system of influencing factors that all play a part, a qualitative method that allows for in-depth analysis and interpretation of the particular context of the Dutch shipping industry is suitable. This context is best understood by talking to people (Myers, 2013), which this research aims to do by conducting semi-structured interviews.

By performing a case study on the Dutch shipping industry, this paper intends to capture how the contextual factors of the industry's structure affect the transition towards green hydrogen adoption. This approach allows to take a deep dive by gathering rich data on the different complexities that are playing a role for the transition towards green hydrogen adoption. Next to that, hydrogen technology is a topic that is rather novel and limited studies have analyzed the factors that influence its adoption (Latapí et al., 2023). According to Myers (2013), a case study is particularly useful in early stages of adoption.

As has been mentioned, the data gathering will be done by semi-structured interviews. By asking open questions, the research anticipates to gain more in-depth information on the challenges that different stakeholders in the Dutch shipping industry face for the adoption of hydrogen technology. Another important benefit of semi-structured interviews is flexibility, as it allows to follow a predetermined set of questions while also having the possibility to explore unexpected avenues that arise during the conversation (Karatsareas, 2022). This flexibility enables the interviewer to adapt the interview process to the unique context and experiences of each participant.

### *3.2 Data sample, data sources and data collection*

The data sample consists of eleven high-level decision-makers in the Dutch shipping industry representing multiple companies and stakeholders from diverse parts of the industry. By speaking to stakeholders with different perspectives and interests, this research intends to gain a more complete overview of the factors that are playing a role in the energy industry, underscoring the holistic approach of this research. As this thesis is part of the NWO project SEANERGETIC, the targeted organizations of the research sample are contacted in cooperation with this master thesis supervisor, a PhD student and fellow master thesis student Guyon de Lau. SEANERGETIC is a multidisciplinary project between Dutch shipping companies, the government and multiple universities (Radboud University e.g.) aimed at a transition towards zero-emission and circular shipping (NWO, n.d.). Due to this participation, relevant respondents can be targeted and interviewed to acquire the necessary data to answer the research question. All respondents are contacted and interviewed in cooperation with fellow student Guyon de Lau. After receiving permission of each respondent, the interviews were all conducted, recorded and transcribed into English.

As individuals are selected based on non-random criteria, the data sample is determined by non-probability sampling methods. A representative sample is selected by a mixture of purposive and convenience sampling. This entails a combination of most accessible respondents and a sample selection that is most useful to the purposes of the research. However, as most targeted respondents are somehow involved in the SEANERGETIC project, a certain level of expertise on the topic may be assumed. Next to that, all respondents are high-level decision makers in their respective organization. Expected limitations coming from this selection method are described further in this chapter.

The utilized data consists of a mixture of primary data sources and secondary data sources. The primary data regards empirically acquired data collected by semi-structured interviews. To be able to conduct these interviews, the research variables were first operationalized as outlined in the codebook (see Appendix A). The secondary data consists of the existing scientific literature on the topic that have been reviewed and other relevant documents such as sustainability and project reports.

This literature includes both qualitative and quantitative studies. Regarding the search for useful literature, databases such as Business Source Complete, Google Scholar, Research Gate and Web of Science are consulted.

### *3.3 Data analysis process*

Hence, the data to be analyzed consists of the semi-structured interviews. For the analysis, both primary data from the industry structure related- barriers and drivers as the interplay between different stakeholders of the fellow master student on the SEANERGETIC project are utilized. To conduct a sound analysis on the acquired empirical data, the analysis consists of multiple steps. First, the semi-structured interviews are transcribed. As this qualitative research involves semi-structured interviews, the variables are measured through thematic analysis. In the first stage of the analysis, the transcriptions will be explored to get familiar with the acquired data and perhaps identify some initial patterns or trends. Thereafter, the transcriptions will be coded to categorize the data. Therefore, this paper utilized ATLAS.ti, a software program developed to code qualitative data. Subsequently, the coding consists of a three-fold process: open coding, axial coding and selective coding (Myers, 2013). During the coding, pre-existing codes or elements from the theoretical framework will be applied. After coding the data, overarching themes or patterns that emerge across the transcriptions will be identified and grouped. These themes aim to capture key aspects of the research topic that represent the underlying meaning of the data (Myers, 2013). The documentation of these codes can be found in the codebook in Appendix A.

To address the validity of the data, the empirical data will be triangulated with the existing literature on this research topic to enhance the credibility and trustworthiness of the findings (Myers, 2013). Next to that, respondents of the study will be asked for feedback on the interpretations of the findings. Reliability of the research will be enhanced by inter-coding with the fellow student on the project.

In the last step, the findings in relation to the research objectives and theoretical framework will be interpreted. These interpretations will be reported in the discussion of the results, which will eventually lead to implications for theory, practice and suggestions for further research on the topic.

### *3.4 Limitations of research project and research ethics*

As this research entails a case study, generalization of the results might be problematic. As the study's sample size may be limited because of time and resources restraints, it may not be representative for the whole Dutch shipping industry. Next to that, purposive and convenience data sampling may lead to sample bias and selection bias, which might also have a negative

effect on the representativeness and generalizability of the data. Furthermore, as the analysis of qualitative data involves interpretation and subjective judgement, researcher bias could be involved. Another limitation regards the generalizability to other nation's industries. While the study has the potential to create valuable insights in adoption of green hydrogen technology in the Dutch shipping industry, different industry structures in other countries may cause the identified barriers and drivers not to be applicable for those industries.

Conducting qualitative research involves respecting research ethics. As the involvement of human subjects in qualitative research raises ethical considerations (Smith, 2003), the integration of research ethics into the research design is important. Therefore, all guidelines as stated by Smith (2003) are followed. First, intellectual property will be discussed frankly and respected by citing data sources appropriately. Next to that, the researcher will be conscious of the multiple roles he fulfills. Therefore, potential conflicts of interest will be treated with integrity and transparency. Furthermore, informed-consent rules will be followed. This involves providing participants with clear and comprehensive information about the purpose, procedures, risks, and benefits of the study, as well as their rights and options for participation. The researcher must ensure that participants understand this information fully and have the capacity to make an informed decision about their involvement. Confidentiality will be respected by taking measures to safeguard sensitive information such as anonymizing the collected data and limiting access to authorized people only. Lastly, the researcher will tap into available ethics resources and support systems to ensure ethical conduct throughout the research process (Smith, 2003).

## 4) Analyses and results

### *4.1 Analysis of data sources: interviews, reports & papers*

The analysis of this paper has been done by triangulation of data collection methods to enhance validity and credibility of the results (Myers, 2013). The data methods consisted of primary data by conducting semi-structured interviews and secondary data sources by analyzing and consulting scientific literature, annual reports and company websites. All these data sources are integrated into the analysis. The interviews each had a duration of 40-60 minutes, in which Fabian Veldwijk and Guyon de Lau in turn had the opportunity to ask questions. Hereby, the first half of the questions focused on the barriers and drivers for the energy transition, the second half of the questions were focused on stakeholder management, alignment and motives. To enhance the representativeness of the research sample, the primary

data sample consisted of eleven high-level decision-makers in the Dutch shipping industry representing multiple companies and stakeholders from diverse parts of the industry. The anonymized description of the individual respondents is depicted in Table 1 below, where the number in the left column will be used as reference for the quotes in the analysis.

**Table 1**

*Descriptive overview of the respondents*

<b>Interview nr</b>	<b>Stakeholder segment</b>	<b>Function</b>
1	Shipbuilders and System Integrators	General Manager Research and Innovation
2	Knowledge Institute / Forum	Managing Director
3	Maritime Research Institute and Consultant	Senior Project Manager / Research Coordinator Zero Emission Shipping
4	Ports and Container Terminals / Dredging	Managing Director / Chief Executive Officer (CEO)
5	Shipbuilders and System Integrators	Principal Research Engineer
6	Cargo Owner Network / Policy and Regulations Bodies	Board Member / Coordinator
7	Shipowners and Ship-Operators	Senior Project Manager Hydrogen / Strategic Advisor
8	Hydrogen Fuel Cell Manufacturer and Developer	Chief Commercial Officer (CCO)
9	Industry Association of Shipowners	Policy Advisor Climate and Environment
10	Trade Association Shipyards, Suppliers and Service Providers	Sector Manager
11	Infrastructure Stakeholder / Port	Commercial Manager

With this approach, different perspectives on the energy transition are discussed, increasing the completeness of the data.

To conduct a sound and cohesive analysis, the initial demand for the energy transition is first discussed. Subsequently, the technological availability of alternatives and the role of hydrogen are discussed. Thereafter, the economic environment in relation to regulations is analyzed, following in an analysis of the conditions for a successful energy transition to conclude with an analysis on the competitive structure of the maritime industry.

It is important to note that the categories or groups cannot be seen apart from each other as they are often intertwined. Therefore, the analysis attempts to describe how the different factors are mutually influencing each other and how they affect the energy transition.

#### *4.2 Initial drivers for energy transition*

Interviews with industry stakeholders and company reports indicate societal demand and forthcoming regulatory requirements to be the main drivers for the energy transition in the maritime sector, following the general tendency of increasing societal awareness about environmental issues and climate change. Several respondents therefore even mentioned society as the most important stakeholder in the transition.

Hence, companies are motivated to adopt environmentally friendly practices to enhance their reputation and comply to current and future regulations. This shift is evident in the growing interest in corporate social responsibility (CSR) and the inclusion of sustainability reports in shipping company disclosures (Lund-Thomsen et al., 2016). Next to companies with direct maritime activities, respondents also indicate the cargo owners to be influential drivers for the energy transition as they are trying to set up completely zero emission, sustainable supply chains which includes green transport by cleaner maritime fuels (Nike, IKEA, e.g.).

The initial demand for greener operations of (shipping) companies finds its way into regulatory institutions. As local and international governments and organizations are setting legislations policies to lower carbon emissions, they are forming a driver for shipping companies to make the transition. This is done by restrictive and supportive policies such as CO<sub>2</sub> pricing mechanisms and subsidies for renewable energy projects. However, these regulations also come with great challenges, which are further elaborated in the rest of the analysis.

#### *4.3. Technological developments on alternative marine fuels and the role of green hydrogen in the energy mix*

Driven by a demand for greener operations by society and governments, investments into new, cleaner technologies are required. Several of the stakeholders in the sample stated that achieving significant reductions in emissions of international maritime transport requires

both less energy usage by increasing energy efficiency and cleaner types of energy by using renewable and lower-carbon fuels. Increasing efficiency and optimizing operations was for most companies the main focus, as these smaller-type innovations are easier to accomplish than changing complete supply chains. An example of this innovation is increased energy efficiency of ships by using wind energy as assistant thrusting power (Ventifoils, e.g.). After increasing energy efficiency and operations, the next step in the path to circular shipping is changing the fuel. This is where a major barrier comes into play: the lack of consensus on future directions in terms of fuel technologies.

Aligning the assumption that other upcoming technologies in the field of alternative marine fuels could positively or negatively affect the adoption of green hydrogen, the respondents were asked to indicate what sustainable alternative marine fuels they generally saw the most and which one they thought were most promising.

Analyzing the perspectives of the different stakeholders, it can be stated that there is no general consensus in the market about the optimal solution for the future of sustainable shipping. The answers given by the respondents varied largely, as they mentioned and assessed different alternative fuels to be most promising. First of all, an important distinction can and should be made between inland shipping and long distance, deepsea going vessels. In that sense, the operational requirements are the major determinant for a particular alternative fuel. With regards to expected feasibility of sustainable alternatives, respondents were more optimistic for inland shipping than for deepsea shipping. This quote of a representative of a shipbuilder and system integrator is indicative for the general tendency in the industry:

*There is a big difference between seagoing and inland waterway vessels. It is basically related to the power ranges, for seagoing vessels with long ranges it is very difficult to get clean fuels onboard. (Interviewee 1)*

The respondents mainly indicated low power ranges and low energy density of alternative fuels as main reason for this distinction. The low energy density of the alternatives means that an engine running on sustainable fuels would take much more space on a ship, which comes at the costs of the cargo space where many ship operators derive their income from.

However, for inland shipping, methanol, hydrogen, ammonia and maritime batteries were most named as promising alternatives. All these alternatives are indicated to bear several disadvantages and advantages. Nonetheless, for the scope of this research, these different alternatives can be investigated relatively similar related to the structure of the industry. A respondent of a trade association said the following about the challenges:

*They are not only linked to hydrogen, they are also for other fuels as well, if you as a ship owner, if you need to invest in a ship, in a technology, you need to have some certainty. And at this moment, certainty for all alternative fuels is relatively low. So this is really hampering the market for the uptake of any alternative fuels. (Interviewee 10).*

For seagoing vessels, all of the alternatives come with greater challenges because of the earlier describes energy density in relation to power demands. However, methanol is indicated to be most promising for sea going vessels (RVO, 2024), which has been underscored by large investments as described in the sustainability report of a major ocean carrier in setting up a whole methanol supply chain (Maersk, 2023). Next to that, as methanol is a liquid, current infrastructure can be adapted more easily than some other alternatives.

However, while methanol is considered to be cleaner than conventional fossil fuels, it still produces some emissions while being combusted. Therefore, to reach a completely zero emission energy mix of marine fuels, other alternatives need to be included.

When specifically asking stakeholders about their vision on green hydrogen, the expectations were mixed. Some did not see any future in green hydrogen as the main energy carrier for ships. However, they saw a role for green hydrogen as a feedstock for other green fuels or as a power source for auxiliary power units, supportive engines on a ship:

*As end-use on the ship it might not be the solution in 50 years, only for a limited number of ship types but as a feedstock for green fuels. It might play a huge role if it becomes available for the maritime sector, and that's the other thing we need to make a lot of green hydrogen to get to green methanol and green ammonia. (Interviewee 3)*

Nonetheless, some respondents believed in the large-scale adoption of green hydrogen as the main thrusting power source suitable for both inland and sea shipping. However, they acknowledged accelerated developments in storage and handling solutions as a condition for industry-wide usage. To put it into perspective, in some of the cases, the positive sides were actively involved in hydrogen pilot projects and development of fuel cells, while the negative side was mainly active in other maritime applications. Therefore, it might be hard to assess what the potential of the different alternatives is.

Summarized, opinions and expectations about the different alternatives varied extremely as some of the respondents completely discarded some alternatives as non-feasible while others were relatively positive about it.

As the current supply and availability of the different alternatives cannot cover the whole energy need on their own, a mixture of energy sources is required. This was both indicated by respondents and the report on the roadmap for the energy transition of the RVO

(2024). Therefore, the industry is spreading investments. Apart from several different but solely operating fuels, one of the outcomes of the future energy mix usage could be implementation of hybrid engines:

*Think about also battery technologies and wind. And I think if you combine those type of technologies, also fuel cells and hydrogen, could be a good alternative in deep sea shipping.*  
(Interviewee 8)

Hence, by using different, complementary renewable energy systems, the technologies could eventually also be applicable for deepsea shipping. However, as the Dutch maritime industry is mainly involved in short distance shipping, the sustainable technologies bear opportunities for the Netherlands (RVO, 2024).

#### *4.4 Economic environment and regulations*

Despite technological advancements in cleaner fuels, out of thousands of Dutch ships, the report of the RVO (2024) indicates that only a couple of them are zero emission at the moment. As described in last paragraph there are innovations, but most upcoming technologies stay in pilot phase without being widely adopted. This has lots to do with the challenges that still need to be overcome. One of these challenges is the economic feasibility of the alternatives. This economic feasibility concerns both the high initial investment costs into vessels and bunkering infrastructure as high sustainable fuel costs, compounded by a lack of uncertainty regarding which type of fuel will prevail in the market. Due to this lack of relative security on the future value of investments, companies are generally hesitant to commit substantial capital to a fuel technology that may not become the industry standard. Next to that, as the shipping industry is a capital-intensive industry, characterized by long-life assets of 20-30 years, large investments are required into the ships, both capital expenditures (CapEx) and operational expenditures (OpEx). These life cycles are forming a barrier for a fast-moving transition, especially when certain investments have just been done.

Additionally, the maritime industry is a sector where margins are traditionally low, especially in inland shipping. Therefore, respondents state that cost-driven and cost-sensitive business models dominate the competitive landscape while sustainable fuels are most suitable for inland shipping because of the lower power ranges and required energy need of the engines. The combination of high investment costs and low profit margins discourages companies to adopt new technologies rapidly.

Therefore, to stimulate adoption, better subsidy schemes are widely acknowledged to be needed. At the moment, available subsidies are mainly focused on initial investments (CapEx), while there is also a call for subsidies on the high operational costs of the vessels and the fuels (OpEx). Both for the costs as the unclarity of regulations and future perspective, respondents declare an important role for regulations by the government. As a representative of a knowledge institute underscored, for the industry to implement a successful transition, technology and regulations should go hand in hand. Right now, companies are unsure what the future regulations will be and what the (safety) policies will be for the alternatives. Therefore, both national and international regulations, along with clear and workable targets from governments, are essential to create a level playing field. Without such regulatory frameworks, there is a risk that shippers adhering to new green standards will be outcompeted by those that do not, particularly in regions with less stringent environmental regulations. This creates a very unattractive business environment to invest:

*But if you put this clear target there, then you will see that it starts to change and then entrepreneurs will step in and say, hey, my investments are safe and now I'm gonna put a lot of money in it because then I'm 1st and I own the infrastructure and I can then make some money in 10 years from now. So for me, the policy, the sort of forcing instruments to make the transition happening is the biggest challenge. They're not there. They're lacking clarity, and they're also lacking real targets. (Interviewee 8)*

As explained by the respondents, the government should turn from a barrier into a driver for the transition by creating a level playing field. To create a level playing field, CO<sub>2</sub> pricing is an instrument to promote sustainable practices by making carbon-intensive options less economically attractive. Ultimately, while regulations can force or promote the adoption of green hydrogen, respondents underline how a sustainable business case is needed to ensure long-term viability. Green transport must be economically feasible to justify the transition. This necessitates not only regulatory support but also a market environment where green hydrogen can be competitively priced and integrated into the existing maritime business models. However, the critical question remains who will eventually bear the financial burden of this transition. This issue will be further investigated in the section of competitive structure of this analysis.

## 4.5 Conditions for transition

### 4.5.1 Human capital

The respondents declared human capital as one of the major factors for a successful transition, as a successful integration of innovations involves people, both white and blue collar, to be capable of working with these new technologies. A major barrier that was highlighted by several respondents is the shortage of labor in the maritime industry, both on operational and management level. A representative of a trade association named the relative negative image of the shipping industry as one of the main reasons for this shortage. This trend is attributed to the relatively small size of the shipping sector and the concurrent energy transitions occurring across other mobility and energy sectors, which may offer more attractive opportunities:

*As an industry we are coping with a, quite a negative image, ship building, ship operations. Well, people rather do some fancy stuff in AI or Google or whatever. And then on the other hand, people rather work at Starbucks than being a welder on the shipyard. So these are really the struggles we face. (Interviewee 10)*

Hence, the maritime sector is facing competition from other industries that (high) potential candidates may regard to be more interesting, making it harder to find suitable people that can contribute to a successful transition.

Opposingly, there are also developments in human capital that could form a driver for the transition. To begin, the industry is actively involved in recruitment as both associations and individual companies organize campaigns focused on attracting talented people to the industry. Additionally, the industry works on the development of curricula on sustainable alternative marine fuels in collaboration with schools and universities. Besides that, as part of the Maritime Master Plan (2024), huge investments are made into human capital.

Consequently, the necessary expertise may be developed within research companies and academic institutes. These factors might enhance the attractiveness and innovativeness of the industry workforce, forming a driver for the energy transition.

### 4.5.2 Infrastructure and energy supply

The transition to sustainable technologies such as green hydrogen is significantly hindered by the current state of infrastructure, which is either non-existent or extremely underdeveloped. Therefore, the rollout of bunkering infrastructure is widely recognized by stakeholders in the industry as a critical factor. However, as the Netherlands has a favorable geographical location, it possesses 25% of the current bunkering volume in Europe, bearing the potential to

be a key player for the transition worldwide (RVO, 2024).

At the moment, without the availability of hydrogen fuel in ports, shippers are reluctant to invest in new hydrogen-powered vessels. Opposingly, terminal operators will not build the infrastructure if there is no demand. This scenario exemplifies the classic ‘chicken-and-egg’ problem, which was mentioned by multiple respondents. They often made a comparison with the less polluting liquified natural gas (LNG), for which the adoption faced similar issues regarding infrastructure:

*What we have seen there is that it took a very, very long time for that single fuel to be incorporated in the in the industry. And one of the issues was the chicken and egg situation where the ship owner said, OK, well, we can have LNG, but there is no, there is no availability while the terminal operator said OK, we can deliver you energy but there is no demand by ship owners. (Interviewee 10)*

This was already an issue with the implementation of one fuel, while the future energy mix requires multiple solutions. Hence, for successful adoption, charge and fuel stations need to be available in ports and on platforms at sea and on bunker vessels that can supply the fuels. To enhance green hydrogen adoption, a port representative opted for a so called ‘transition fuel’. This regarded an increased production of blue and gray hydrogen, which helps to develop the necessary rollout of bunkering infrastructure for green hydrogen in the future. As pipelines, storage tanks, refueling stations etc. are largely compatible across different types of hydrogen, a gradual shift to greenly produced hydrogen can be accomplished.

Apart from this interesting insight, respondents proposed collaborations through pilot projects to be essential for accelerating this slow-moving transition. Clustering hydrogen activities in a major port could serve as a significant driver for change by combining infrastructure, technical knowledge, and development in one location. Among others, the Port of Den Helder is active in these kinds of projects (Zephyros, 2020). While some ports have thus begun developing hydrogen infrastructure, a further market push needs to be supported by government initiatives and selective innovations programs, as proposed by a representative of a terminal operator.

The limited availability of renewable energy sources further complicates the transition. The shipping sector represents a small fraction of the total energy demand compared to other industries such as automotive, aviation, and general energy consumption. This means that the fuel suppliers, driven by larger market demands of other industries, will influence the availability of hydrogen for shipping. Consequently, the amount of green hydrogen accessible

for shipping remains uncertain, given its limited supply.

Overall, overcoming these infrastructural and supply-related challenges will require coordinated efforts across the entire chain from production and distribution to end-use in ships. Substantial government support and strategic clustering of hydrogen activities could drive the transition towards green hydrogen in the maritime sector.

#### *4.6 Competitive structure of maritime industry*

So far, while there is some overlap, mainly external barriers and drivers for the energy transition in the maritime sector are discussed. Next to that, competitive structural features within the sector were investigated such as industry characteristics and developments, collaboration, competition, power relations and responsibilities within the industry.

##### *4.6.1 Industry characteristics and developments*

Respondents regarded the shipping industry as a competitive, open market, where competitors typically take cost-driven strategies, which may form a barrier for companies to make high investments into innovations. Another characteristic for the shipping industry is the typically international environment of the sector, which cannot be seen completely apart from the national context. This is why multiple respondents indicated an important role for the IMO by taking a more active role to accelerate the transition. On top of that, by creating an international level playing field, competitors coming from countries where green regulations are lacking cannot gain international advantage by exploitation of current polluting practices and activities. In this way, Dutch shipping companies can remain competitive on the international playing field.

Besides that, the conservative character of the industry may also form a barrier for large changes in the market. This was underscored by a research coordinator:

*The maritime industry in general is a quite a conservative industry. So it takes some effort to convince people in the maritime industry that they need to do things in a different way. (Interviewee 2)*

Hence, several stakeholders recognized only a few frontrunner that are actively working on new innovations while the vast majority is lagging behind.

##### *4.6.2 Collaboration and competition within industry*

In general, there is a large call for better collaborations throughout the industry. As mentioned by a respondent, a distinction with cooperation has to be made:

*You need to collaborate and collaboration means working together on the same goal. It's different than cooperation. Then you work together. Collaboration means working together on the same goal and target. (Interviewee 1)*

This entails both collaborations between governments and the industry as collaboration between companies within the industry. At the moment, as was told by a knowledge institute project leader, the industry has a relative closed character with few knowledge sharing and disclosure of prices and practices, especially with direct competitors. Respondents mentioned unequal input as one of the major reasons for resistance of sharing knowledge. Therefore, they underscored how collaboration needs to work both ways:

*That actor was responsible and there's the other one who's driving it and then everyone is just leaning back, waiting for what will happen. So you have to make it a collaborative approach where everyone feels that they have to change, to be part in the chain to change something. (Interviewee 6)*

These collaborations are most valuable when there is a commercial potential benefit and a common ground. In this way, shared development costs, shared goals and shared, clear targets are identified to be important drivers for a successful energy transition.

In the light of collaborations within the industry, respondents opt for small consortia of the willing as industry-wide collaborations are not always feasible. Projects like SEANERGETIC, Zephyros and especially the Maritime Master Plan have the potential to accelerate the transition. For all of the projects, a focus and collaboration of the whole supply chain is stated by stakeholders to be of major importance for the project to become a driver for the transition.

#### *4.6.3 Power relations and responsibilities within industry*

Another major characteristic of the industry that makes the transition harder are the complex relations within the industry, and therefore who is 'responsible' to be taking the lead for the transition. It starts already at the level of a single ship, where the crew, the technical staff and the cargo owner are all managed by different companies in different countries with different rules. If you then take it to a higher level, this quote depicts a clear view of the unclarity of responsibilities within the shipping industry:

*So you have to ship the goods. The carrier, who is the service provider. Then you have to ship owner and then you have all kind of actors like ports, for waters or inland ports who are having a role in having that good from A to B. The ship owner is always the most, it's the first actors who are not in on the table or only every actor has their own group where they talk with, but not together in the*

*whole supply chain. So that's the difficulty part, who is, who feels responsible for making a green, green supply chain. (Interviewee 6)*

And:

*The most barrier is to, who's investing and who have the benefits? Lot of issues now is that the ship owner who owns the ship invest in the ship is not the one who's executing the ship. He rent the ships to a carrier and they renting the place on the ship and are even more actors involved sometimes. (Interviewee 6)*

As large investments are needed for the transition, some respondents indicate a large role for capital intensive, large incumbents. More specific, the cargo owners are regarded to be influential in the industry. As there is a trend of large internationals that want to make their whole supply chain green, there may be an important role for them in this transition. This is clearly illustrated by this quote of a shipbuilder:

*So even a ship owner that owns the ship and for instance, carries goods for a Nike or Ikea. I just called to mention two companies that have sustainability on their road map. If IKEA and Nike would not have put that on their road map, the ship owner from which they charter those ships, would never go to alternative fuels. And why is Nike or Ikea doing it because we as well the clients of those are requesting, it's a sort of social demand for the energy transition that comes from the society. (Interviewee 3)*

Concludingly, new ships and accessory fuels require huge investments, even with governmental subsidies. Hence, there is an industry-wide consensus that for long term, sustainable changes there need to be a viable business case. The challenge thus really entails how the transition to green transport will be get paid. In the industry, many stakeholders do not expect that end-customers are willing to pay extra for green transport. Multiple respondents opted for regulations by the government that make green transport mandatory for cargo owners, operators and ships owners. Once they are obligated, they could include green transport in the price of their product, to let the end-customer eventually pay for green. As transportation costs are generally about 5% of the total price of a product, more expensive transport does not necessarily imply a large increase in total price of a product. In other words, make green transport a standard and not an option. Whether it is an obligated green transport fee for the end-customer or another mechanism, governmental leverage seems to be a major condition to become a driver for a successful energy transition in the maritime industry. To get insights into the results per respondent, see Appendix B.

## 5) Discussion and conclusions

### 5.1 Interpretation of results

In this paragraph, the results will be interpreted in light of the research question and the theory.

#### 5.1.1 Answer on research question

The research question of this paper was: *How do industry structure-related drivers and barriers affect the transition towards green hydrogen adoption for Dutch shipping companies?* Driven by a societal demand for an energy transitions and the upcoming restrictions and probable CO<sub>2</sub> taxes, the industry started to realize that changes need to be made. While last ten years the first investments and phases of the energy transition have started to take shape, there are still a couple of major barriers.

The first major challenge is the lack of consensus in the market on which alternative fuel is the optimal solution for the future of the maritime industry. As the expectations about hydrogen as the main maritime fuel for the future varied largely, it became clear that the future will probably embrace an energy mix of sustainable alternatives such as batteries, hydrogen, methanol and ammonia. This is also related to the competition from other industries for the limited renewable energy supply to produce the fuels in a green manner. Overall, stakeholders foresee a role for green hydrogen either as the main thrusting power source of a ship or as an auxiliary or hybrid engine. However, as stated by various respondents, the different alternatives face relatively similar issues in light of the industry structure perspective.

The uncertainties make it hard for shipping companies to invest in ships running on sustainable fuels as it requires capital-intensive expenditures. Next to that, ships have an average lifespan of 30 years, which impedes fast-moving transitions when substantial investments are already made. Therefore, without having a certain level of security on future ROI, the investments currently seem to bear too much risk for most companies. Additional to technological and financial issues, this uncertainty is reinforced by unclear or lacking regulations and policies from local governments and international institutes as the IMO are forming a serious concern for shippers. Therefore, there is a call for subsidies by the industry from the government. Apart from the high initial investment costs, the operational costs of sustainable fuels are also much higher than regular fossil fuels. Therefore, governmental subsidies should not only consider CapEx but also OpEx. Ideally, as an important

characteristic of the shipping industry appeared to be its inherently international nature, regulations and subsidy schemes should be arranged internationally by organizations as the EU and IMO. By establishing a global level playing field, the EU or IMO may ensure the competitiveness of Dutch shipping companies in the international playing field as it could prevent international competitors from exploiting lax regulations and continuing polluting practices. In this way, regulatory barriers could turn into drivers for the energy transition.

Another challenge for the maritime sector is the competition of other industries regarding attracting necessary human capital, both on operational and management level. As other related industries are often seen as more attractive by potential candidates, the required workforce for a successful transition is currently forming a barrier. However, as industry-wide initiatives are collaborating are focused on attracting human capital, this might change in the future.

Beside technological, economic, regulatory and workforce-related barriers, the necessary infrastructure for an industry-wide adoption of green hydrogen and other sustainable alternatives is extremely underdeveloped at the moment. As developments for the production, storage and distribution of green hydrogen are needed to realize the full clean energy potential of the green hydrogen, investments in these areas are very much needed. While the Port of Den Helder is already investing in this infrastructure, the investments need to gain enough support to fully realize large-scale adoption of hydrogen. An option for this might be an increasing production of hydrogen technology including non-sustainable blue and gray hydrogen. As this helps to develop infrastructure, a gradual phase-out combined with increased green hydrogen could enhance the transition.

Furthermore, respondents emphasized the need for better collaboration within the shipping industry to become a driver for the energy transition. This regards both collaboration between companies as between the industry and government. Effective collaboration, involving shared goals and mutual knowledge exchange, is essential. Industry-wide initiatives and small consortia like SEANERGETIC, Zephyros, and the Maritime Master Plan can drive the energy transition, provided there is comprehensive engagement across the entire supply chain. Above that, as suitable policy making is complex from the government side because of the uncertainties regarding the technologies, pilot projects like Zephyros also contribute to development of effective policy making for green hydrogen adoption.

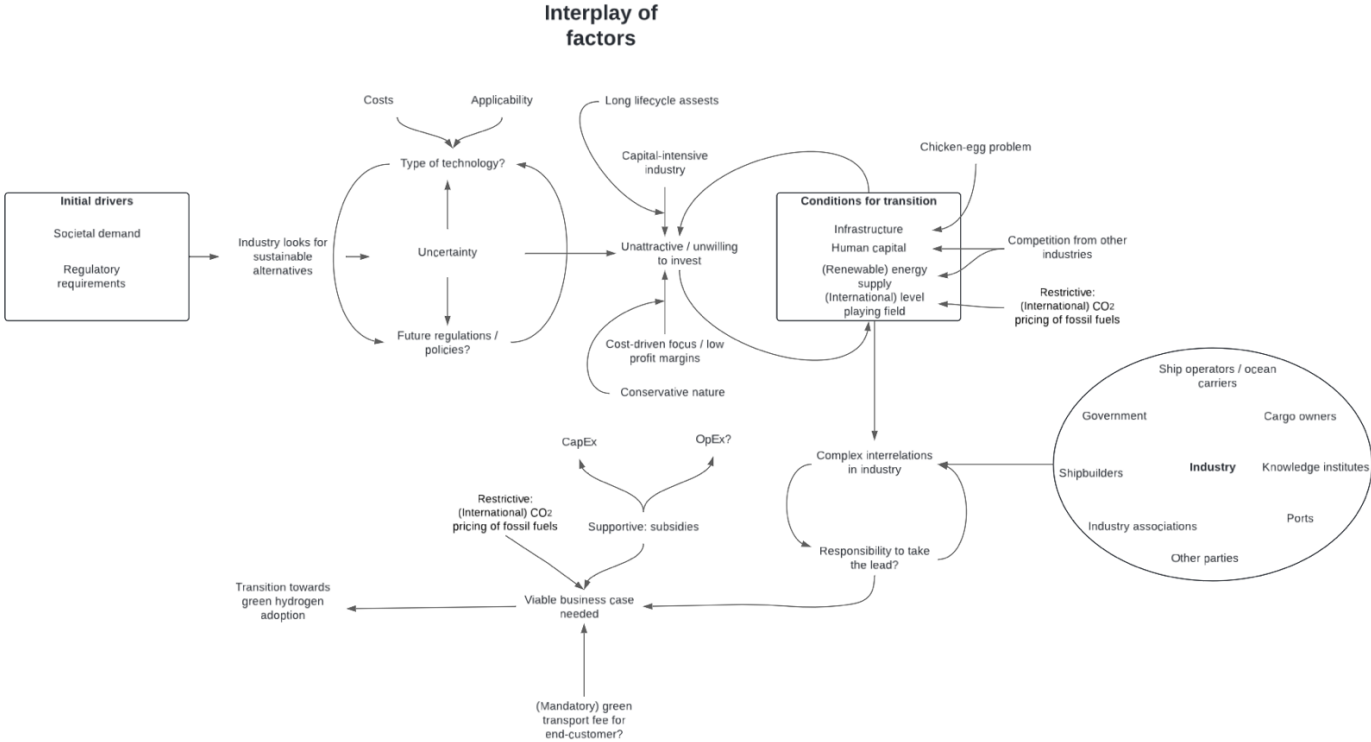
Another major challenge is the fact that inland shipping, for which the alternative fuels at current particular technological stage are mainly applicable, is a cost-driven industry with relatively low profit margins. Therefore, high investments are harder to make while green,

more expensive transport is hard to justify. In addition to that, the industry’s conservative character may hinder significant transitions. That is where the next barrier comes forward: who is eventually going to pay for the transition. The complexity of industry relations poses a challenge in determining leadership for the energy transition in shipping. Key stakeholders, particularly capital-intensive incumbents and influential cargo owners aiming for green supply chains, seem crucial. Governmental leverage appears pivotal for making green transport economically feasible and standard practice in the maritime sector's transition to sustainability. However, even with governmental support significant investments are required, necessitating a viable business case for sustainable practices in the future. Stakeholders advocate for a standard integration of green transport charged at the end-customer, either implemented by the industry itself or by regulatory enforcement of the government.

Figure 4 below intends to describe the assumed interrelations within and outside the industry. The figure merely serves as a visualization tool of the indicated results, it does not suppose all relations are depicted perfectly.

**Figure 5**

*Interplay of factors influencing the energy transition in the maritime industry*



### *5.1.2 Theoretical reflection*

The questions and topics of the interview guide (Appendix C) were mainly based on the categorization of barriers and drivers for large-scale green hydrogen adoption in the paper of Latapí et al. (2023). Next to that, the industry structure paradigm of De Wit (2017) as depicted in the theoretical framework which includes insights from Porter's five forces theory and institutional theory was leading for the perspective of this research and the interview. While there was a predetermined topic list for the interviews, open questions in the begin of the interviews mostly led to similar groups of external and internal barriers and drivers as identified by the literature: economic or financial, regulatory, infrastructure and technological issues (Bürer et al., 2022; Fu et al., 2023; Latapí et al., 2023). Next to that, moving away from a strictly technological viewpoint allowed for a more holistic investigation of interrelations within the industry and between industry and the government. Elements of above theories were integrated in the diamond model of Porter (1990). While the model bear relevancy in providing a comprehensive tool for assessing Dutch companies' competitiveness and innovativeness regarding new technologies in a typically international context of the maritime industry, the model may have limitations in capturing the dynamic and evolving nature of technological innovations and environmental policies. Hence, it might not fully address the complexities and interplay of multiple stakeholders of an energy transition in the industry. Reflecting on the model in relation to the findings of this paper, the results access similar importance to factor conditions, demand conditions, related and supported and firm strategy, structure and rivalry to be major drivers or barriers for an energy transition. However, the diamond model implies that the government is a supportive factor which cannot create a sustainable competitive advantage for an industry. However, analyzing the data of both the respondents and the reports, in nearly all categories, regulations are identified to be of major importance for those categories to become a driver for the transition. While the transition also requires initiatives from the industry side, creating a level playing field in both national and international markets by governments could potentially form a sustainable competitive advantage and thus become a major driver for the energy transition towards hydrogen adoption.

## *5.2 Theoretical implications*

Relating the findings to existing theories on the energy transition towards hydrogen adoption in maritime applications, most papers recognized relatively similar barriers and drivers (Bürer et al., 2022; Fu et al., 2023; Latapí et al., 2023). However, the industry structure perspective allowed this research to get a clearer picture of the complex interrelations within the maritime industry and between the industry and the government and the internal and external challenges they face. Therefore, besides listing barriers and drivers, the research added to the theory by getting insights in the way these barriers and drivers mutually influence each other and how they affect the energy transition (Figure 5).

Relating these insights to the broader context, the research contributes to transitioning theory by investigating a sector with relatively long asset lifespans with significant capital investments. As this comes along with industry-specific challenges, this research expands our understanding of transition theory, emphasizing the need to consider sector-specific barriers and drivers.

Hence, it became clear how the intricate interrelations imply that the unclarity for responsibility of stakeholders might be the largest challenge for this energy transition, which could be an interesting direction for future research as will be elaborated further in this chapter.

## *5.3 Practical implications and recommendations*

There is an obvious need for development and clarity of regulations and more certainty in investments to create a more attractive investment climate and business case. To establish this, collaborations between government and the industry should be intensified as ideally, the development of technologies and regulations are growing hand in hand, providing the necessary regulatory support and financial incentives for the transition (subsidies on both CapEx and OpEx e.g.). An example of this is the Zephyros project, which contributes to policy development for green hydrogen technology. Ideally the regulations should also be opted in international contexts, by for example the IMO.

Next to that, for effective regulations, both the industry and government can look at energy transitions in other industries (EV's in automotive e.g.). By learning from policies and practices that worked out successfully in related industries, the transition may be enhanced in the maritime sector.

Within the industry, a ‘let 100 flowers bloom’ strategy is recommended, which highlights the importance of a multitude of collaborative initiatives within the maritime industry. This pluriform approach is particularly relevant given the complex interrelations and significant challenges faced by the industry where they could benefit from the competition of ideas and approaches, leading to the discovery of the most effective solutions for each segment of the maritime industry. These kind projects may be recommended to set up in larger ports and collaborations integrating whole supply chains.

Furthermore, the government can think of introducing a mandatory green tax for transport, paid by the end-consumer. As transport generally amounts to 5% of the total price of a product, it might not influence the affordability of products too largely. Without direct political interference, this might also be implemented by the industry itself by making it a standard option. Here might also be a role for cargo owners, demanding their carriers to let their ships sail greenly as they are identified to be most influential by the respondents. Hence, the energy transition also requires efforts from outside the direct maritime industry.

Concludingly, the industry could invest in more training programs and recruitment initiatives to enhance human capital capabilities in handling new technologies and innovations.

#### *5.4 Research limitations*

The design of the study implies several limitations. First, due to a limited timespan, the relatively small sample size may limit the ability to generalize the results to a broader context. While the researchers managed to speak to at least one stakeholder of all categories, more stakeholder per category would probably have enhanced the reliability and representativeness of the outcomes.

Another limitation regards the applicability of the results for all different segments of the Dutch maritime sector. As has become clear in the analysis, different segments require different operational requirements and challenges. Therefore, an industry-wide, theoretical lens might not be applicable for all specific segments.

Furthermore, the study had a local focus on the Dutch shipping industry while the maritime sector has several times be indicated to be a typical international industry, which indicates that a global focus may had enhanced the quality and reliability of the research.

Another limitation may regard the fact that all interviews were conducted in English. As English was not the first language for both the respondents and interviewers, interviews in Dutch might have led to more profound conversations, providing more useful insights.

### *5.5 Future research*

Looking at the major barriers for the energy transition, the regulatory policies for all categories seem to be of major importance. For this barrier to become a major driver for the transition, the funding and policy mechanisms should be restructured. For this to be effective, future longitudinal research can investigate how different subsidies schemes on both CapEx and OpEx influence adoption of sustainable technologies. These insights could be immensely useful for policy making and a successful energy transition.

Another interesting topic would be a focus on the structural relations in the industry with a focus on business models. As the complex interrelations indicate how the unclarity for responsibility of stakeholders might be the largest challenge for this energy transition, future research could focus on a who should take the lead in the transition and how costs and benefits can be spread among the entire value chain to ultimately create a viable business case for sustainable shipping in the future.

Additional to the practical side of learning from energy transitions in related industries, future research could investigate how barriers and drivers for the energy transition as indicated in related industries (which are in a further stage) such as agriculture (Olvermann et al., 2023) and EV's in automotive (Berkeley et al., 2017) might be useful or applicable for the maritime sector.

### *5.6 Conclusion*

In addressing the research question, several key insights have emerged. First of all, the transition towards climate-neutral shipping is identified as very complex, as Dutch shipping companies face numerous uncertainties.

These include challenges regarding regulatory developments and requirements, societal pressure and demand, issues regarding availability of skilled personnel, the quality and potential of alternative sustainable fuels, the availability and cost of these new energy sources, high financial and operational investments, lacking infrastructure, complex mutual relations and the rigid character of the industry. These uncertainties and challenges hinder

investment decisions and strategic planning, which are expected not to be solved by one single company.

To overcome challenges and turn barriers into drivers, a successful transition towards sustainable technologies such as green hydrogen requires collaboration among industrial stakeholders over the whole supply chain, including the national and international governments. For those collaborations and initiative to be successful, a viable business case for all companies involved is assumed to be of crucial importance. To create this viable business case for Dutch companies in the maritime sector, there seems to be an important role for the government, both by supportive and restrictive policies. Ideally, these regulations need to be arranged internationally in organizations as the IMO to create a level playing field worldwide. With this being a condition, transport by sustainable technologies such as green hydrogen may be achieved by mechanisms such as CO<sub>2</sub> pricing for companies or green transport fees for end-customers.

### *5.7 Reflection on design choices and positionality*

For the data collection phase, there were a couple of challenges. This master thesis was conducted under the umbrella of the SEANERGETIC project. Therefore, the necessary contacts were expected to be easily accessible. As we were awaiting initial meetings, reaching the contacts appeared to be a harder task than expected. Therefore, the first deadline was not feasible. However, we picked up it quite fast from there and arranged eleven interviews with relevant stakeholders within the timespan of one month.

Afterwards, the choice for qualitative research was probably well chosen. The interviews really gave the opportunity to take a deep dive into the subject, with means that I actually got the feeling that I learned a lot about the subject, which may ultimately be beneficial for the quality of the findings.

To reflect on my own background, this may have influenced the results. As my educational roots are in business administration and strategic management, my personal business lens could have influenced the results by missing particular factors (technical aspects e.g.). However, to mitigate this, outcomes were afterwards discussed with respondents to account for missing elements or other remarks.

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# Appendices

## Appendix A: Codebook

Variable	Code	Definition	Example quote
Industry structure-related barriers and drivers	Regulatory / policies / role of government	Refers to local, national, or international regulations, policies, and the role of government in influencing the adoption of green hydrogen and other sustainable technologies. This includes legislative actions, governmental support, regulatory challenges, and compliance requirements.	<i>“You have to get subsidy, so it's government. Government is a key player. Not really at the start maybe, but now they have to act. And they also have to act on regulations because what you see is, if regulations are unclear, people don't act. You don't take risks if you don't know what the regulations are” (Interview 3).</i>
	Technological issues and developments of hydrogen	Technical challenges and advancements related to hydrogen production, storage, distribution, and usage in the shipping industry.	<i>“If you take the curve of development of hydrogen over the last 5 to 10 years, it has been accelerating extremely, meaning that it's becoming more and more attractive. Still, hydrogen has some very big issues. The storage of hydrogen takes too much space and that that is a real issue. You see that also on smaller vessels on inland locations. You can roughly say that you need almost 10 times the space that you</i>

			<i>today have on your diesel vessels and space on the vessel is important because that's where they make the money with. The more space on the vessel, the more money you can make. So that's the challenge I would say at this stage as main fuel, it's not close, not even close. You need to not only to do something about the storage, but you also need to do something about the efficiency of the engines itself” (Interview 4).</i>
	Economic / financial	Encompasses economic and financial aspects related to the adoption of green hydrogen, including costs, funding, investments, financial risks, and economic incentives.	<i>I think most companies stay, they only take those decisions if there's actually money to be made, not just because they think it's something that they need to do as their responsibility” (Interview 2).</i>
	Socio-cultural	Captures the social and cultural factors influencing the adoption of green hydrogen, including societal attitudes, cultural resistance, and public perception.	<i>“I guess similar to the complete energy transition, it's a shared sense of urgency and a shared goal that we are indeed moving there and that we want to move there as fast as we can. So it's more the social aspect that with reducing emissions” (Interview 8).</i>
	Infrastructure	Physical infrastructure required for the	<i>“You need to have a substantially different</i>

		<p>production, storage, distribution, and use of green hydrogen and other sustainable technologies within the shipping industry.</p>	<p><i>infrastructure. Suppose that we could all use hydrogen, we need to have a point where we can fuel hydrogen or where we can load hydrogen or whatever. Or can have bunker vessels coming alongside those big vessels and giving you some hydrogen. That infrastructure is nonexistent at this moment” (Interview 4).</i></p>
	<p>Suppliers / energy supply / availability of renewable energy</p>	<p>Factors related to the supply of renewable energy (wind, solar e.g.), related to green hydrogen but also to other green alternatives.</p>	<p><i>“One of the flaws of our industry is that we believe that our industry is quite substantial, which it is in some perspective. But if you look at it from the supply side, from alternative fuels, we as an industry are not that relevant. There is a lot more demand for energy. If it's hydrogen, methanol, ammonia doesn't matter. But there's, we as an industry are just a small amount of energy demand. And so basically we as an industry can think of everything, but we are still tied to what the suppliers of the energy will produce and they will decide what they will produce depending</i></p>

			<i>on the total demand” (Interview 10).</i>
	Human capital	Encompasses the workforce-related aspects, including the availability, skills, and training of personnel required to support the green hydrogen transition in the shipping industry, includes workforce on both operational and management level.	<i>“In the Netherlands, we have the Maritime Master Plan that now has a sort of second subsidy ground that there is a big part. I think it's something like of the 200 million, it's about 25 or 30 million that goes into human capital and human capital” (Interview 3).</i>
	(End) – customers / cargo owners / power relations	Complex power relations within the industry, mostly related to who to charge for the green alternatives.	<i>The most barrier is to, who's investing and who have the benefits? Lot of issues now is that the ship owner who owns the ship invest in the ship is not the one who's executing the ship. He rent the ships to a carrier and they renting the place on the ship and are even more actors involved sometimes” (Interview 6).</i>
	Competitive environment / industry characteristics and development	Characteristics inherent to the shipping industry, including elements related to competitive rivalry, includes all characteristics relevant for the energy transition towards sustainable alternatives.	<i>“The maritime industry in general is a quite a conservative industry. So it takes some effort to convince people in the maritime industry that they need to do things in a different way”. (Interview 2).</i>
	Collaboration in industry	Regards the collaborative efforts within the industry, including	<i>“So that takes extra time to do that collaboration together. Common</i>

		<p>partnerships, consortia, and joint initiatives aimed at promoting adoption of green hydrogen technology but also other sustainable alternatives.</p>	<p><i>ground on how you work together and that you share the information. So yeah, that everyone sees there is a commercial benefit in it. So you, you stimulate it. So it was a quite of open. Because we put some effort in the beginning that you really have common grounds to have the showcase developed”</i> (Interview 6).</p>
	Other sustainable alternative fuels / hybrid engines	<p>Alternative sustainable fuels and hybrid engine technologies other than green hydrogen that are being considered or used in the shipping industry, mainly regards methanol, ammonia, maritime batteries and LNG.</p>	<p><i>“Holding it back for alternative fuels because batteries are only suitable, or these full battery powers only suitable, for a limited range of ship types, so you will need to have alternative fuels to deal with this. This can either be hydrogen, methanol, ammonia or bio fuels, depending on what the operational requirements are for the ship and what the operational area is”</i> (Interview 2).</p>
	Integrated supply chain	<p>The integration and coordination of the entire supply chain, from production to end-use, includes green transport.</p>	<p><i>“Companies like IKEA like to make their whole supply chain also zero emission and that means also that the shipping then needs to go to zero emission of course, they ship a lot of</i></p>

			<i>furniture around the world”</i> (Interview 5).
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Appendix B: Results per respondent

<b>Interview nr</b>	<b>Major results / outcomes</b>
1	<p>High costs of green alternatives / main focus on efficiency improvements, currently no viable business environment.</p> <p>Promise of hydrogen not yet delivered (costs, safety etc.).</p> <p>Green hydrogen as building block.</p> <p>Current legislation is driving down transition, government needs to create level playing field.</p> <p>Government not competent to come up with good regulations, important role for whole industry to step up.</p> <p>Infrastructure: Chicken-egg problem.</p>
2	<p>Mixture of future sustainable alternatives in shipping: hydrogen, methanol, ammonia, batteries.</p> <p>Hydrogen only applicable with battery to account for power fluctuations.</p> <p>Support of government needed as energy transition is needed for climate, not because it is easier or better.</p> <p>Companies in the end most driven by business case; needs to become viable.</p> <p>Required human capital for transition is lacking; competition from other industries.</p> <p>Current developments in sustainable alternatives dependent on distance to end-customer.</p> <p>(Global) collaborations needed in industry (nationally, IMO e.g.).</p> <p>End-customer generally unwilling to pay for greener transport.</p>
3	<p>Reducing emissions: main focus on efficiency.</p> <p>Investments should be funded/subsidized.</p> <p>Low energy density of hydrogen, low power ranges; mainly for inland shipping.</p> <p>Green hydrogen as feedstock for other sustainable fuels.</p> <p>Competition from other industries for supply of green fuels.</p> <p>Infrastructure; Chicken-egg problem.</p> <p>Collaborations/ consortia between different stakeholders; green hydrogen applicable with fixed, short-distance routes.</p> <p>Subsidies until maturity; parallel with solar and wind energy.</p> <p>Investments in human capital are needed (Maritime Master Plan e.g.).</p> <p>Knowledge sharing in industry of major importance; currently relative closed.</p> <p>Demand for energy transition comes from society and cargo owners (IKEA, Nike e.g.)</p> <p>Slowly acting government needs to step up; clear policies and regulations are needed for companies to make certain investments.</p> <p>Technology and regulations needs to go hand in hand.</p> <p>Support should also be focused on OpEx.</p>
4	<p>Green hydrogen mainly applicable in inland shipping because of low energy density.</p> <p>Methanol for seagoing vessels.</p> <p>Competition for green hydrogen from other (better) sustainable fuels.</p> <p>Hydrogen suitable as auxiliary power.</p>

	<p>Social demand as driver for energy transition; leads to CSR practices of companies.  Regulatory enforcement as driver for energy transition.  Major role for government in transition by selective innovation programs, both in regulations as development of infrastructure.  Currently government more a barriers than a driver for energy transition.  Required knowledge not widely available in industry.  Accelerated development needed for hydrogen to succeed.  Clustering of (hydrogen) activities to enhance energy transition.  Semi-open access to knowledge can enhance energy transition.  Shipping typically an international industry; regulations are needed in international level.</p>
5	<p>Critical on applicability of green hydrogen, more potential in other e-fuels; therefore limited role for green hydrogen  Energy density/storage/safety issues of hydrogen on board of a vessel.  Emission regulations as driver for energy transition (CO<sub>2</sub> pricing e.g.)  Cargo owners most influential in industry as they are trying to green their whole supply chain which includes green transport.  Regulations should be more internationally arranged because of nature of shipping industry.  Hybrid solutions will be leading for the future of sustainable maritime transport.  Basic knowledge of new technologies in industry.  Collaborations should consider whole integrated supply chain.  Infrastructure; Chicken-egg problem.  Governmental subsidies are required because of high costs of sustainable alternatives.  Increasing demand of green alternatives led to entry of new innovative players.  Cost-driven nature of shipping industry hampers investment in innovations.  Companies can learn from each other by sharing knowledge without sharing IP; however collaborations need to work both ways.</p>
6	<p>Cargo owners most influential in industry; ability to influence the shippers of their cargo.  Renewable energy mix dependent on geographical circumstances.  Major barrier for the energy transition is the mixed up investments and benefits in sustainable alternative because of complex interrelations in shipping industry.  Long life-cycle of vessels hampers fast-moving energy transition.  Charge end-customers with additional costs of green shipping; nonetheless can be difficult.  Rating systems for green transport help to enhance CSR activities.  Regulations are too slow and should preferably be more internationally arranged by organizations such as the IMO.  Sort of oligopoly of ocean carriers who don't have service mind related to green transport.  Uncertainty of responsibility for energy transition because of complex interrelations in the shipping industry.  Collaboration in the industry should be better aligned; works better with common ground and mutual benefits because it needs to work both ways.  Advocate for coalition of the willing regarding more sustainable practices.  Pilot projects in consortia sometimes hard as reductions in CO<sub>2</sub> can only be accounted to one company to avoid double bookkeeping.  Investments require consideration of whole supply chain.</p>
7	<p>Hydrogen pilot projects essential to drive transition.</p>

	<p>Whole integrated supply chain of hydrogen should be considered to enhance adoption.</p> <p>Hydrogen still faces challenges, for seagoing vessels methanol also an option.</p> <p>Fundings / subsidies needed from government to invest.</p> <p>Facilitating government as main barrier for transition.</p> <p>End-user is not prepared to pay for additional costs of green transport.</p> <p>With Maritime Master Plans first steps are taken regarded to CapEx, now also increasing focus on OpEx.</p> <p>CO<sub>2</sub> pricing could enhance adoption of sustainable alternatives.</p> <p>Innovative SMEs will be taken over by incumbents with the financial required resources.</p> <p>Operational staff needs to be retrained; collaborations on development of curricula on sustainable fuels between industry and universities/schools.</p> <p>Green hydrogen (fuel cells) are expensive.</p> <p>Social demand for energy transition.</p> <p>Currently only a few frontrunners that are taking initiative because being a frontrunner does not pay off yet.</p> <p>Collaboration triangle advocated: between government, industry and end-customer.</p> <p>Rollout of bunkering infrastructure is a large challenge.</p> <p>Transport companies are willing to invest but end-customers are not willing to pay premium.</p> <p>Companies have to invest for future regulations / restrictions.</p>
8	<p>Hydrogen pilot projects show potential of the technology.</p> <p>Multiple applications for hydrogen fuel cells: as main thrusting power (inland shipping), as auxiliary power and in a hybrid engine (also for ocean shipping).</p> <p>Regulatory enforcement needed for companies to take action.</p> <p>Clear (International) regulations needed to create level playing field.</p> <p>IMO now acts as a barrier, should become a driver.</p> <p>Clear targets to work on are essential for adoption of green hydrogen.</p> <p>No urgency in the market to change because the business case is not there.</p> <p>Governmental support should consider both Capex and Opex; in the end funding requires healthy business models.</p> <p>Because of small margins in inland shipping hard to invest in green for shipping companies.</p> <p>Main challenge is who to charge for greener transport; end-customers might be willing to pay extra but only if there is an alternative.</p> <p>Advocating for a standard inclusion of green transport in end price as transport element in total price is only small.</p> <p>Green transport could create business case for shipping companies.</p> <p>Financial companies are forming barrier for transition as investments in sustainable alternatives are regarded as risky.</p> <p>Intertwined relations on the ship and in the industry make responsibility for energy transition complex.</p> <p>Companies don't want fast transition: exploitation of current businesses.</p> <p>Cargo owner is most influential in shipping industry.</p> <p>Shared sense of urgency in society for energy transition needed.</p>
9	<p>For reduction of emission great focus on efficiency (Wind sails e.g.).</p> <p>High price and low energy density forming barrier for green hydrogen adoption, current hydrogen most of the time not greenly produced.</p>

	<p>EU ETS (CO<sub>2</sub> pricing) as driver for transition; advocate to reinvest revenues into greener alternatives.</p> <p>Market forces need to be supported by the government.</p> <p>Unwillingness of end-customer to pay premium for green transport.</p> <p>IMO should set regulations as it is an international industry; otherwise other countries could continue polluting practices and outcompete Dutch shipping companies.</p> <p>Renewable energy is expensive.</p> <p>Whole infrastructure needs to change; role of supporting government.</p> <p>Advocate for mandatory fee to B2C companies for green transport.</p> <p>Infrastructure: Chicken-egg problem.</p> <p>Long lifespan of ships increases complexity of investments.</p> <p>Clear regulations are needed for companies to work with.</p>
10	<p>Development of other sustainable technologies can impact adoption of green hydrogen; however green hydrogen regarded as applicable for both inland and seagoing ships.</p> <p>Availability and costs main factor for hydrogen adoption.</p> <p>All sustainable alternatives face relatively similar issues.</p> <p>Uncertainty of future fuel makes investments complex; therefore no regulations at this stage of technological development.</p> <p>International regulations is slow because of rigidity of IMO while industry is awaiting (international) regulations.</p> <p>There should be a business case for green fuels to accelerate the energy transition.</p> <p>Largest part of companies mainly driven by regulations I.O. intrinsic wants.</p> <p>Shortage of human capital on operational and management level, partly because of negative image of shipping industry; competition from related industries (Automotive, aviation, energy e.g.); however industry-wide initiative to attract human capital.</p> <p>Infrastructure: Chicken-egg problem as before with LNG, now even multiple fuels are needed.</p> <p>Larger related industries determine clean energy supply as suppliers focus their activities on those industries, shipping will probably have to follow.</p> <p>Focus of Dutch government on total emissions reductions instead of promoting particular alternative fuel.</p> <p>Variety / lack of standardization of ships complicates large-scale adoption of sustainable alternatives.</p> <p>Large incumbents will probably take over smaller innovative companies; could enhance energy transition as fewer companies might be easier to manage.</p> <p>Advocates for innovation by competition instead of cooperation.</p> <p>Closed character of industry: few knowledge sharing.</p>
11	<p>No viable business case yet.</p> <p>Solving Chicken-egg problem by developing infrastructure.</p> <p>Hydrogen pilot projects to contribute to governmental policy making.</p> <p>No subsidies on operational costs are a barrier.</p> <p>To accelerate transition, government is needed.</p> <p>Shortage of human capital on operational and management level; competition from other industries.</p> <p>Hydrogen supply and underdeveloped infrastructure as main barriers for transition towards hydrogen adoption.</p> <p>Advocate for increase blue/gray hydrogen production for transition phase.</p> <p>Government should consider transition phase alternatives.</p>

## Appendix C: Questionnaire

Example of the questions used during an interview (Varied per respondent, interviews mainly followed a topic list). Derived from questionnaire of Latapí et al. (2023).

1. Can you indicate what alternative, sustainable marine fuels you see the most and what do you think are the most promising?
  - a. How does green hydrogen fit in the global panorama of alternative marine fuels and technologies?
2. Which are the main policies that should be considered for the adoption of green hydrogen in Dutch shipping (at the national and local level)?
  - a. Are these policies pushing forward or limiting the adoption of green hydrogen for Dutch shipping?
  - b. How are they doing so?
3. Which are the main regulations that are relevant for the adoption of hydrogen fuel cells in Nordic shipping (at the national and local level)?
  - a. Are these regulations pushing forward or limiting the adoption of hydrogen fuel cells for Nordic shipping?
  - b. How are they doing so?
4. What do you think are the main considerations for companies to make an energy transition? Is it because of future Co<sub>2</sub> pricing and restrictions / societal pressures / promising (cheap) technologies
5. What are the main drivers that can be expected to push forward the innovation chain for hydrogen fuel cells for Dutch shipping (from research and development to commercialization and wider adoption)?
6. What infrastructural developments are necessary to support the widespread use of green hydrogen (or other fuels) in shipping? (electrolyser, pipe connection, hydrogen fuel station, bunkering station, other users of green hydrogen)
7. What are the main barriers that exist for alternative marine fuels?
  - a. And for the use of hydrogen fuel cells for Nordic shipping (from research and development to commercialization and wider adoption)?

- b. How can these barriers be addressed?
8. What are the main concerns for the large-scale deployment of green hydrogen for Dutch shipping?
  9. Other stakeholders mentioned the importance of a viable business case for hydrogen in the future, how do you think this can be established? How can using hydrogen be profitable, who is going to pay for it in the end?
  10. Should the government take an active role or has it to be done by market forces? What do you think about the current role of the government in this transition? Should they be more actively involved or not?
  11. Is it a competitive market, do you feel like companies that will not make the transition are missing out or will not survive in the long term?
  12. Besides inland shipping / short sea shipping, do you think green hydrogen can also be of importance in long-distance ocean / deep sea shipping?
  13. If we look at human capital, the knowledge within the industry, do you think there is enough knowledge in the industry to work with new technologies (operational / management level)?
  14. Do you believe the current workforce is adequately prepared for the transition to green hydrogen, and what further training or education might be necessary?
  15. How do you see the future of the shipping industry, how do you think the competitive landscape will evolve?
  16. What steps and policy options should be taken to facilitate the large-scale deployment of green hydrogen for Dutch shipping?
  17. Is there any additional information that you think would be of relevance for this research?
  18. Are there additional people that you would recommend that we interview for this research?