Carbon Capture in the Maritime Industry
the role of stakeholders in standardisation

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Preface

Starting the Master of Maritime Technology (MOT) had multiple reasons for me. I wanted to prolong the student life experience, avoid full-time work for a while, but most importantly, obtain a technical master's degree from the TU (Technical University) that could complement my maritime background with entrepreneurship, policy knowledge, and strategic thinking. After months of hard work, I successfully achieved this, with this thesis as final product. I am very thankful for the opportunity to delve into my passion, which lies within the maritime industry. I would like to express my gratitude to my first supervisor at the university, Geerten van de Kaa, who provided unwavering support throughout the research and significantly contributed through our systematic Thursday meetings. Besides my first supervisor, I would like to thank my second supervisor, Linda Kamp. Besides Linda and Geerten, I would like to thank Jurrit, who helped me significantly with fine-tuning the methodology for the research and I enjoyed reading his paper that was just released after the start of my thesis project. Additionally, I want to thank the eight interview participants of which I unfortunately cannot tell the names, because of privacy reasons. All participants were very involved and took the time to receive me at their offices or in some cases online, which is much appreciated. Even more thanks to Rolf and Jurriaan from Value Maritime, to not only give me the chance to work with them together in Amsterdam, but helped me with finding many interview participants. I somehow even enjoyed Rolfs fit mindset and followed him several times after lunch, by taking the stairs to the 10th floor where the office is based.

In addition to the support from the university and the industry, I would like to extend my heartfelt gratitude to my dear girlfriend, Nina. She provided invaluable encouragement throughout my thesis journey, brightening my days with cheerful "thesis survival packages" filled with fresh fruits and accompanying me on mindful walks through the park in Rotterdam. Her support helped me unwind and recharge, allowing me to avoid being consumed by my research after working hours.

Throughout the process of writing this thesis, I was deeply engaged in various developments related to onboard carbon capture. I thoroughly enjoyed assimilating new information and closely following news publications on this subject. Moving forward, I intend to continue staying updated with such news, particularly focusing on the outcomes of MEPC meetings worldwide!

Tim van den Eertwegh

Rotterdam, July 2023

Executive Summary

Industries are adopting new practices and innovate globally in response to climate change. The EU has set targets for carbon neutrality by 2050, and the maritime industry has been included in the EU Emissions Trading System, requiring shipping companies to purchase carbon permits for their emissions. The International Maritime Organisation (IMO) aims to reduce greenhouse gas emissions from international shipping by 50% by 2050 and has adopted strategies to phase out emissions entirely. However, there are concerns about the feasibility of these targets. Standards in the maritime industry may serve as a gateway for implementing innovations, with onboard carbon capture (OCC) being a promising technology to achieve the international CO2 reduction targets. However, current standards for OCC are lacking or undefined, which hinders its widespread adoption in the industry and leading some stakeholders to push for accelerated changes to the existing maritime regime. Therefore, this thesis focuses on onboard carbon capture in the maritime industry and examines how stakeholders influence standard development in this context. The complex international nature of the maritime industry, with its unique operational and technical characteristics, necessitates the involvement of relevant stakeholders in the standardisation process. The following corresponding research question was defined:

"How do onboard carbon capture stakeholders influence the standardisation process in the maritime industry?"

To answer the question a systematic step-by-step approach for stakeholder identification, classification and the mapping of a standardisation process was developed as an expansion of an original academic stakeholder identification method. Classification was conducted based on the attributes, power, legitimacy and urgency and, the standardisation process was divided in pre-defined standardisation phases, showing all the main actors. The methodology, composed of nine steps divided into three parts, was created through a review and revision process involving three experts in the maritime and carbon capture field. Eight semi-structured interviews related to specific search categories were used to gather additional information based on 23 pre-defined questions. The method was applied in the form of a qualitative case study about onboard carbon capture.

87 unique stakeholders across different categories were identified, with multinational companies and start-ups being present prominently in the production chain category. Carbon capture projects were concentrated in Japan, the Republic of Korea, Norway, and the Netherlands and most stakeholders were located in Europe. There where relatively few stakeholders from Japan and South Korea compared to their project and fleet sizes. The stakeholder classification of onboard carbon capture standardisation highlights key stakeholders such as governmental bodies, classification societies, shipping companies, ship owners, and technology providers. However, ship owners, shipping companies, and technology providers are considered dependent stakeholders who rely on governmental support. Within governmental organisations there is a lack of urgency for carbon capture standardisation. Stakeholders primarily demonstrate legitimacy, with certain stakeholders serving as observers. Non-stakeholders may provide financial incentives but do not directly contribute to the standardisation process. The maritime sector takes a unique approach to standardisation, prioritising industry initiatives and consortia instead of established institutions like ISO, CEN, and NEN. Two distinct standardisation processes were identified: safety/functional and environmental. Safety/functional standardisation involves classification societies leading the approval phase, influenced by for-profit firms and allowing for iterative inclusion of new technologies. Environmental standardisation is primarily led by governmental bodies, with dependent stakeholders initiating the process and engaging with flag states through representative organisations. Consensus-driven approval involving multiple stakeholders characterises the slower environmental standardisation process. Overall, the maritime sector's distinct approach underscores the significance of industry initiatives and consortia in both safety/functional and

environmental standardisation.

Lobbying plays a significant role in influencing standardisation processes, and early collaborations with classification societies and consortia are vital for successful lobbying efforts. Overall, the thesis provides insights into stakeholder dynamics and the distinct standardisation approach in the maritime sector's onboard carbon capture technology.

This research offers a step-by-step approach for managers to identify and classify stakeholders in the standardisation process, providing valuable insights into stakeholder dynamics. By mapping the process, managers can choose effective strategies such as lobbying and allocate necessary resources accordingly. Standard development organisations can benefit from this method by ensuring the inclusion of all relevant stakeholders. Policymakers can also utilise this research to produce targeted policies that address the needs of stakeholders impacted by standards.

One limitation of the methodology used in this study is the assessment of power, which may overlook the unique authority held by legislative bodies to shape processes through regulations and laws. This absolute power possessed by authorities can outweigh factors such as financial resources, technical expertise, and network position, leading to a potential underestimation of their influence. Another limitation is the assignment of attributes to broad categories in the classification process, which may result in a distorted understanding of the significance of specific organisations. Lastly, the anonymity of interview participants, while necessary to protect sensitive information, presents a challenge for replication since the participants' names and affiliations are not disclosed.

This study contributes to the literature on standardisation and stakeholder theory by replicating and extending an existing method in a new context. The significant contribution of the study lies in Part 3, which introduces a novel methodology for systematically mapping the standardisation process and addressing the lack of a clear visual representation in existing literature. The combined approach incorporates Part 1 (identification), Part 2 (classification), and Part 3 (standardisation process) to create a comprehensive standardisation map. This map categorises stakeholders based on their organisational type and facilitates the identification of specific modes and selection of appropriate strategies to influence them. By incorporating the degree of salience from Part 2 through a colour scheme, the map enables the identification of relationships and bottlenecks among stakeholders.

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Acronyms

AIP Approval In Principle. 38

CEN European Committee for Standardization. 24

CII Carbon intensity indicator. 23, 24

DCS Data Control System. 24

EEDI Existing Efficiency Design index. 41

EEXI Energy Efficiency Index for Existing Ships. 23, 24

EU European Union. 1

EU-ETS European Union Emission Trading System. 1

GHG Greenhouse Gasses. 1

IMO International Maritime Organisation. 1, 42

ISO International Organisation for Standardisation. 12

MEPC Marine Environment Protection Committee. 40, 41, 46

MRV Monitoring Reporting and Verification. 24

NEN NEderlandse Norm. 12, 24

OCC Onboard Carbon Capture. 2, 29, 35

SDO Standard Development Organisation. 5

SEEMP Ship Energy Efficiency Management Plan. 24, 41

1 | Introduction

1.1 Maritime decarbonisation efforts

In the era of climate change, industries are obliged to adopt new practices and innovate on a global scale. Everyone is required to comply with new national, European, and international regulations and targets. An example of such a regulation is the Green Deal, which aims for a CO2 neutral European Union (EU) in 2050 (European Commission, 2019). With the Fit For 55 package, ideas and targets from the Green Deal are being translated into regulations, therefore EU members are now obliged to reduce Greenhouse Gasses (GHG) by 55% in 2030. Although the maritime industry was excluded from the targets, the European Union decided on November 30, 2022, that ships would be included in the European Union Emission Trading System (EU-ETS) (European Commission, 2023). In particular, this means that shipping companies will be required to purchase EU carbon permits for 40 percent of their emissions starting in 2025, with a gradual increase to 100 percent.

Besides European targets and regulations, several significant events concerning decarbonisation targets for shipping have taken place. The leading organisation to create regulatory frameworks for shipping is the International Maritime Organisation (IMO), which is part of the United Nations (IMO, n.d.-a). In 2018, the IMO adopted a greenhouse gas emissions reduction strategy that aims to reduce emissions from international shipping by at least 50% by 2050 compared to 2008 levels. In 2020, the IMO adopted an initial strategy on the reduction of greenhouse gas emissions from ships, which includes a vision to reduce emissions and pursue efforts towards phasing them out entirely firstly aiming for an emission mitigation of 70% (MEPC73, 2018). The set targets are seen as a significant step forward in the efforts to decarbonise the shipping industry. However, there are still concerns about the feasibility and effectiveness of these targets and the lack of concrete measures to achieve them (Balcombe et al., 2019).

In the traditional maritime industry, which is typically subject to slow incremental change, ship owners are now obliged to adapt and invest in greener technologies (Balcombe et al., 2019). This is complex due to the international nature of the maritime industry and its corresponding government structure (Stolper et al., 2022). Figure 1.1, depicts the main stakeholders that are responsible for the regulatory framework in the maritime industry. The IMO (UN) is responsible for worldwide maritime regulations that are interpreted by its 175 member states, also referred to as flag states (IMO, 2019). Every merchant ship is registered under a flags administration and has to follow the interpretation of that specific flag (KVNR, 2021). This interpretation may be defined by a rule and/or standard. In this way, different flag states may use different standards while still following the same regulatory framework of the IMO. Besides the interpretation of the IMO regulations, flag states can provide input to adjust or create new IMO regulations. Shipping companies can choose under which flag they want to sail, which can give large fleets a certain amount of power because the revenue of a flag state is dependent on the tax income of the ships under their registration (KVNR, 2021).

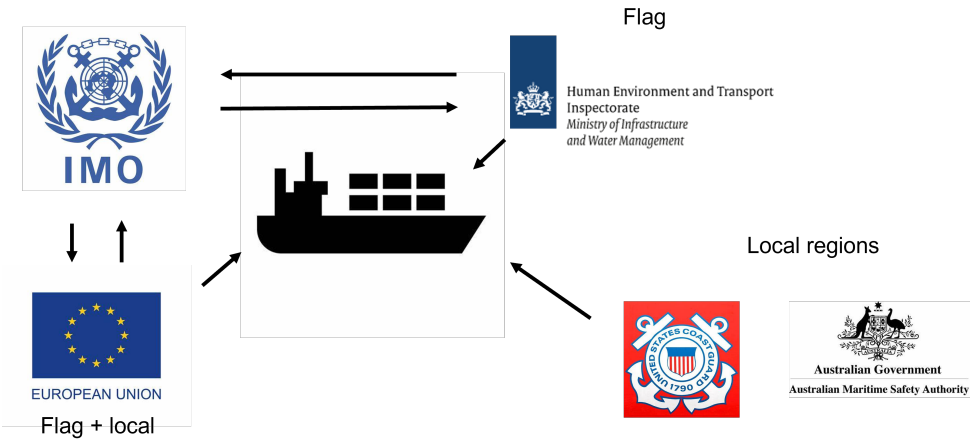

Fig. 1.1. Main regulatory stakeholders in the Maritime industry

The regulatory measures from the IMO that are opposed by all its stakeholders can be described as a form of hierarchical standardisation (Wiegmann, de Vries, & Blind, 2017). An example of IMO standardisation in the context of decarbonisation is CO2 monitoring onboard of vessels. The IMO obliged vessels to use their Data Collection System (DCS) standards, where all ships need to monitor CO2 emissions that form the basis for CO2 accounting on ships. These standards may play an important role in the decarbonisation of shipping. Research shows that standard setting is essential to achieve significant improvements in energy efficiency and to overcome the market failure that is associated with pollution (Jaffe, Newell, & Stavins, 2005). For the maritime industry, this means that standards may form a gateway to the implementation of innovations and green alternatives such as green fuels (Balcombe et al., 2019) (Paltsev, Morris, Kheshgi, & Herzog, 2021). An upcoming technology to mitigate CO2 is onboard carbon capture, in which exhaust gases from ships are filtered and the CO2 is captured. One of the promising types of carbon capture is indicated as chemical absorption, in which CO2 is captured while bound to a solvent (Paltsev et al., 2021). Especially with the upcoming EU-ETS, some shipping companies are now interested in Onboard Carbon Capture (OCC). However, the standards for this technology are vague or do not even exist yet. With the first adaptors already implementing carbon capture technology as of now, some stakeholders aim to speed up and alter the current maritime regime.

1.2 Problem description

The described lack of standards form a significant barrier to the widespread adoption of carbon capture technology in the maritime industry (Balcombe et al., 2019)(Stolper et al., 2022). This barrier is also identified by Value Maritime that claims to already have a functional CO2 capture system in commercial use. To overcome the barrier they want to speed up the standardisation process. However, standardisation is a particularly complex process in the maritime industry due to the large amount of international stakeholders involved. Due to the unique operational and technical characteristics of ships, land-based standards cannot directly be applied. Therefore, action is required from relevant stakeholders to develop carbon capture standards in the maritime context. However, who the stakeholders are, where to find them and how standardisation exactly works in the maritime industry are not clear.

1.3 Objective

The purpose of this research is to add to stakeholder and standardisation theory by studying the complex maritime stakeholder environment concerning standardisation for chemical absorption based carbon capture on ships. In particular, this thesis tests an existing stakeholder identification methodology for standardisation in a new context. Besides reproducing the methodology a step-by-step identification and classification guide was created to make the methodology more robust and applicable for other scholars.

Additionally, this thesis helps with filling knowledge gaps of companies that want to participate in a standardisation process and form strategies to influence the process.

1.4 Research questions & approach

Based on the problem description, a research question was formed with an emphasis on how to influence standardisation in the maritime industry. With Value Maritime as an example, many stakeholders are active and want to make a change now. Therefore, the main research question is:

"How do onboard carbon capture stakeholders influence the standardisation process in the maritime industry?"

To form an answer, the main question has been divided into three distinctive parts: stakeholder identification, classification and the standardisation process.

sub-questions
To answer the main question, three sub-questions are defined.

1. **Who are the current stakeholders in onboard carbon capture, related to standardisation?**
   The first question was addressed because it helps to identify the actors that are involved in onboard carbon capture and who are likely to have an impact on standard development in the maritime industry. By understanding the stakeholders involved, it is possible to identify their interests, goals, and motivations, which can help to predict how they may influence the standard development process.

   *Method:*This research question was answered via a stakeholder identification method for standardisation processes (de Vries et al., 2003). The method provides broad search categories to identify stakeholders. Via a brainstorm session with three experts in the maritime or carbon capture field, the original method was expanded by adding projects as a search category and focused on the maritime industry,.

   Result: A long list with stakeholders sorted by pre-defined categories.

2. **What are the positions of the stakeholders? (power, legitimacy, urgency)**
   This sub-question is addressed because it helps to identify the relative power, legitimacy, and urgency of the stakeholders involved in onboard carbon capture. By understanding these factors, it is possible to predict how much influence each stakeholder will have on the standard development process and to identify potential conflicts of interest that may arise. Furthermore, understanding the stakeholders positions will help with an understanding of the motivations behind actions and the strategies they may employ to achieve their goals.

   Method: To determine the power, legitimacy and urgency attributes of the stakeholders, the stakeholder classification method of de Vries et al. (2003), was applied. A step by step guide was created to provide an even more concrete approach of the method. The method was complemented by 8 semi-structured interviews with industry experts from the pre-defined search categories of part 1.

Result: List with stakeholders and their type of salience (Dormant, Discretionary, Demanding, Dominant, Dangerous, Dependent, Definitive, Non)

3. **How are standards being developed in the maritime industry?**
   By understanding how standards are developed, it is possible to identify the potential points of influence where stakeholders may be able to shape the standards to reflect their interests. Furthermore, understanding the standard development process will help to identify potential barriers to the adoption of onboard carbon capture technologies and to suggest strategies to overcome these barriers.

   Method: The method of de Vries et al. (2003) stops after the classification of the stakeholders. Therefore, the last sub-question is answered by adding a new part to the the original method. This new standardisation part consists out of two steps, 1) mapping the standardisation process and 2) identifying bottlenecks related to the stakeholder salience types from sub-question 2. Via 8 semi-structured interviews, information about the standardisation process was obtained.

   Result: Visual representation of the standardisation process with the main actors included with their respective salience type (part 2) and potential bottlenecks.

1.5 Thesis Structure

This Thesis consists out of six chapters. Chapter 2, describes the theoretical basis of the Thesis and consists of standardisation and stakeholder theory. The next chapter describes the adjusted and applied methodology for the research. Chapter 4: results, provides a case description for onboard carbon capture. After the description, a stakeholder inventory with carbon capture stakeholders and their corresponding salience is described. In addition, the chapter introduces a view on the standardisation process the stakeholders are operating in and describes the process of standard creation for the specific case. Chapter 5, discusses the findings and limitations. The last chapter describes the conclusion of the thesis in which the research questions are answered and future research directions.

2 | Theory

The research questions are characterised by stakeholders, their positions and their involvement in a standardisation process. Therefore, this chapter emphasises on standardisation and stakeholder theory, which is used as a basis for the thesis.

2.1 Standardisation theory

Standardisation is a crucial concept in various fields as it ensures consistency, interoperability, and quality by providing a common language and set of guidelines (Wiegmann et al., 2017). Standardisation may further by defined as, a process of creating and documenting a tangible set of solutions for existing or potential problems, that benefit all involved parties, of which the solutions are meant to be continuously used or for a certain duration. (de Vries, 1999) Standardisation is driven by a combination of firms, governmental bodies, and standards organisations, with institutional regimes playing a crucial role in shaping the standardisation landscape (van de Kaa & Greeven, 2017b) (van de Kaa, 2015). Therefore, the landscape is characterised by a mix of political, professional, and business interests, making the process highly complex and dynamic (van de Kaa & Greeven, 2017a) (Backhouse, Hsu, & Silva, 2006). It involves numerous stakeholders with varying political interests, which can impact decision-making procedures. Moreover, standardisation is linked to technological dominance (Suarez, 2004)(Schilling, 2002). The standardisation process can confer significant benefits on firms that are able to establish themselves as dominant players in their respective industries.

Standardisation is further quantified by modes. From a classical perspective van de Kaa and Greeven (2017a) describe two modes, committee based and market based standardisation. Committee based standardisation is referred to as de jure while, market based standardisation is referred to as de facto (Suarez, 2004)(Schilling, 2002). Besides the two modes, there is hierarchical standardisation which is captured in a government based mode. This process is described in the literature as formal standardisation and also called de jure. Government regulations may be part of this de jure type (van de Kaa, 2015). Wiegmann et al. (2017), discuss that standardisation does not per definition follow one of the three sole modes and introduces multi-mode standardisation. They argue that standardisation dynamics are heavily characterised by relevant actors and identified a gap in knowledge about the dynamics in multi-mode processes.

The literature defines different phases in a standardisation process, which in general can be classified in two categories 1) pre-standardisation and 2) standardisation stage (Smits, 1993). Lim (2006) compared these categories with the standardisation process of Cargill et al. (1995). Who describes a linear three stages process, containing a pre-conceptualization phase in which ideas are presented by different actors and ends with a proposal to a Standard Development Organisation (SDO). The formal standardisation phase which includes defining the concept, a discussion in a committee and the description of the standard. After this phase, implementation is further elaborated upon, because there must be demand for a standard and the willingness to implement it. More recent literature divides the process in a 1) development and 2) diffusion category (Botzem & Dobusch, 2012)(Weitzel, Beimborn, & König, 2006). Figure 2.1, shows a comparison between the different categories and phases. Different actors are linked to different phases which can give insights in stakeholder dynamics and their positions in a standardisation process. Lyytinen and King (2006), describes the following four distinctive phases, which are not easily comparable with the aforementioned literature: (1) idea/problem, (2) development/design, (3) approval/enforcement, and (4) diffusion/implementation.

	Phases		Phases
Pre-standardisation	Proposal	Pre conceptualization	Pre conceptualization
	Proposal submission		
	Decision about proposal		
	Decision to absorb the project into the working program		
Standardisation	Choosing group experts	Formal standardisation	Conceptualization
	Definition and specification of the standards		
	Extensive study of the standards concept		Discussion
	Voting in the technical Committee		
	Voting of the members		
	Publication		Writing
		Implementation	Implementation
	(Smits, 1993)		(Cargill et al., 1995)

	Phases	Phases
Development	Determination of need	Need for a standard
	Discovery (info acquisition)	Standard Development and Approval
	Documentation development	
	Public review process	
	Determination of consensus	
Diffusion	Publication and distribution	Making standards available
		Acceptance/implementation
		Impact
	(Baron, 1995)	(de Vries, 2008)

Fig. 2.1. Standardisation phases

Influencing standardisation

There are different available strategies for actors to influence standardisation, which can be categorised per respective standardisation mode. Within government based standardisation, government institutes might employ policy and regulation as an incentive for the industry to standardise. Additionally, they might use their hierarchical position to make or request standards (Blind, Petersen, & Riillo, 2017). An example is the European Commission, with the "new approach" legislative framework, in which European recognised Standard Development Organisations may be mandated to create a standard. These standards are named harmonised standards (Borraz, 2007). To influence the governments decision, private actors are limited to lobby efforts (Wiegmann et al., 2017). In committee based standardisation, which is primarily dominated by private actors, the process is defined by reaching consensus (van de Kaa & de Bruijn, 2015)(Büthe & Mattli, 2010). Standard Development Organisations attempt to bring all appropriate stakeholders together and industry actors might influence this process by participating on their own account (Botzem & Dobusch, 2012). Within the committee, achieving consensus might be influenced by a specific defined decision making process. Hierarchical interventions such as discussion rules may be applied (van de Kaa & de Bruijn, 2015). Within market based standardisation, competition is central while, private actors may join the market and influence decisive factors, such as install base (David & Greenstein, 1990). In all modes the role of resources is evident. Actors might dedicate resources such as technical knowledge, time or money to better communicate and collaborate with other stakeholders and convince lobby targets (Wiegmann et al., 2017).

There is a strong relationship between standardisation and stakeholder theory, Stakeholder theory can provide a useful framework for understanding the dynamics of stakeholder involvement in standardisation processes (van de Kaa & Greeven, 2017a) (de Vries et al., 2003). It can help standardisation organisations to identify and prioritise stakeholders, to engage them in the standardisation process, and to address their concerns and interests (de Vries et al., 2003). Standardisation can also serve as a mechanism for addressing stakeholders' concerns, promoting collaboration among stakeholders, and enhancing trust and legitimacy. Besides positive effects, standardisation can also have potential negative impacts on stakeholders, such as creating barriers to entry for smaller firms, stifling innovation,

or disadvantaging certain groups (Kujala, Sachs, Leinonen, Heikkinen, & Laude, 2022). Stakeholder theory provides a lens for evaluating and mitigating such negative impacts, and for ensuring that the standardisation process is transparent, inclusive, and accountable (Wiegmann et al., 2017) (de Vries et al., 2003). Therefore, the next section further elaborates on stakeholder theory.

2.2 Stakeholder theory

60 years ago, stakeholder theory found its introduction in the academic world via the Stanford Research Institute memo from 1963 (Freeman, 1984). The definition of a stakeholder was described as a group that supports an organisation, however when the support stops, the organisation will not survive. Continuing on the definition, Freeman (1984) is one of the founding fathers of stakeholder theory. He combined several theories to come to the development of stakeholder theory. He uses Corporate Social responsibility theory, organisational theory, system theory and he came up with a wide and narrow definition for a stakeholder. The wider definition of a stakeholder is described as somebody who can affect the accomplishment of an organisations objectives, or is affected by the accomplishment. The narrow view is more similar to the definition of the Stanford memo. And is defined by: On which the organisation is dependent for its continued survival (Freeman, 1984). Freeman describes that stakeholder theory is about how a business works and how to get all stakeholders in a certain direction. There is a specific focus on the strategy in the organisation. Because the broad and even the narrow definition of Freeman, are somewhat vague and not concise, it has been criticised by different authors. Mitchell et al. (1997) is one of the prominent sources on the area of stakeholder theory and extended the works of Freeman by trying to create consensus about who stakeholders exactly are, and to what is being payed attention. Who stakeholders are is in the literature also described as stakeholder identification (Bryson, 2004) (Mitchell et al., 1997). To what is being payed attention to, is described as stakeholder salience (Mitchell et al., 1997). Stakeholder identification is documented by the literature as an important tool for an organisation to be successfully (Bryson, 2004).

Stakeholder identification

There are different types of stakeholder identification methods available in the literature. Brainstorming, contextual, systematic and combinations (Salado & Nilchiani, 2013). Sometimes there is no clear deviation between the identification and classification of the stakeholders as the criteria are combined (Areizaga, Sanò, Medina, & Juanes, 2012). When performing a stakeholder identification, stakeholders may be overlooked when not using a systematic analysis (de Vries et al., 2003). Therefore, de Vries et al. (2003) composed a list of nine search directions to identify all stakeholders within a standardisation process in the IT industry. The directions form a checklist to not miss any stakeholders. It could be that no stakeholders are active in a specific direction. The following nine categories are identified (de Vries et al., 2003): production chain, end users, designers, physical system, inspection agencies, regulators, research and consultancy, education and representative organisations.

Stakeholder Positions

To help managers assess stakeholder relationships and stakeholder salience, Mitchell et al. (1997) created a model based on the power, legitimacy, and urgency of a stakeholder. Power relates to the relationship between actors. It is about the extent to which an actor influences another to do something he would not have done otherwise. Legitimacy is about norms, beliefs, and values. It tells something about how desirability and appropriateness are perceived by the stakeholder. Urgency describes a certain degree of immediate action as proposed and called out by the stakeholder (Mitchell et al., 1997). The described constructs combined form stakeholder salience, which can be defined as how managers give priority to certain stakeholders (Mitchell et al., 1997). With different construct combinations, eight different stakeholder typologies can be obtained. Figure 2.2, shows the different combinations and stakeholder typologies.

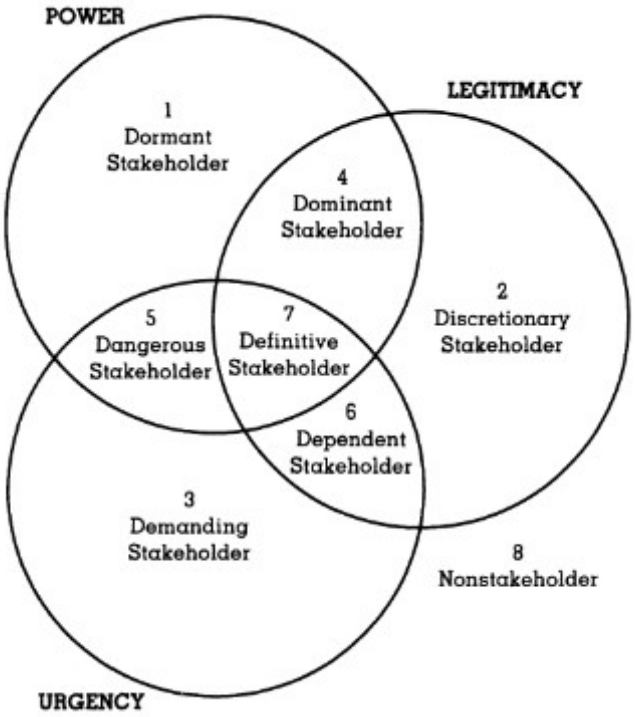

Fig. 2.2. Stakeholder typologies sorted in three attributes (Mitchell et al., 1997)

2.3 Standardisation and stakeholders

de Vries et al. (2003), integrated the salience model of Mitchell et al. after systematically identifying stakeholders, and is one of the few concise stakeholder identification and classification theories for standardisation processes. To expand knowledge and build further upon de Vries et al. (2003), a forward cite analysis was conducted which is shown in table 2.1.

Four case studies investigated barriers for participation of weaker SME parties in formal standardisation, by reviewing historical standardisation cases in the Netherlands (Willemse, Verheul, & Vries, 2003) (Gottlieb, Verheul, & de Vries, 2003)(Karaöz, Verheul, & Vries, 2004)(Jorritsma & Vries, 2003). The case studies all begin with identifying the stakeholders via an inside-out approach, starting with the users of a product who are concerned with the standard. Jorritsma and Vries (2003), describes a case study about the translation of the code for information security:2000 and identified that the most important stakeholders were not sufficiently represented because, there was insufficient awareness of IT risks and a restricted understanding of information security under the SMEs. Karaöz et al. (2004) identified that stakeholders were selected on their knowledge instead of their importance. Gottlieb et al. (2003) primarily identified the lack of of appropriate communication and internal communication by the committee chairperson. Which resulted in missing input on the agendas of the committee meeting. All cases discuss that openness is required in standardisation because, all stakeholders should be able to join. During the cases, it was identified that there was no appropriate stakeholder identification or classification conducted.

Other literature discusses the importance of institutional regimes and infrastructure for standardisation (van de Kaa & Greeven, 2017b)(van de Kaa, 2015)(van de Kaa, Greeven, & van Puijenbroek, 2013). They provide insights into the impact of regulatory and market forces on standardisation outcomes. Additionally, the need to improve institutional regimes and infrastructure to promote standardisation in specific for developing countries was identified.

Ozkan and Spruit (2019), discusses the challenges and barriers for weaker SMEs in cybersecurity standardisation and conducted the methodology of de Vries et al. (2003), to identify and invite all key stakeholders. Together with this group five standards gaps were identified: 1) lack of awareness and

involvement, 2) lack of cybersecurity standards addressing SMEs, 3) Adaption of existing standards, 4) financial barriers and 5) lack of cooperation between the stakeholders.Salado and Nilchiani (2013) criticises the categorisation of stakeholders, as it results in three limitations. The enforcement of categorisation results into in-the box thinking and hampers creativity. Completeness cannot be assured and correctness is therefore not possible to assure. To overcome the limitations, system thinking is proposed. Markus, Steinfield, and Wigand (2006) discusses Vertical Information System standards in the mortgage industry and indicated the importance of a stakeholder with many partners to stimulate the diffusion of a standard, by adaption. Additionally, the importance of implementation is discussed to be key for the diffusion.

Tab. 2.1. Forward cite analysis on de Vries et al.(2003)

Nr.	Title	Context	Type	Source
1	Paints and varnishes –Determination of release rate of biocides from antifouling paints'	Participation of Weaker parties (SME) in standardisation in the paint industry (maritime)	Case Study	(Gottlieb et al., 2003)
2	Stakeholders participatie bij de herziening van een norm voor kwalificatie van lassers	(Welding industry)	Case Study	(Karaöz et al., 2004)
3	Caseverslag code voor informatiebeveiliging:2000	The code for information security	Case Study	(Jorritsma & Vries, 2003)
4	Herziening NEN 1824	Ergonomics ISO standards	Case Study	(Willemse et al., 2003)
5	LED standardization in China and South East Asia: Stakeholders, infrastructure and institutional regimes	Examines the institutional LED standardization environment	Case Study	(van de Kaa & Greeven, 2017a)
6	Contextual-and behavioral-centric stakeholder identification	system thinking for with a new stakeholder identification approach	Framework	(Salado & Nilchiani, 2013)
7	Standards battles in China: opening up the black box of the Chinese government	Role of Chinese Governmental stakeholders in standardization battles (EVD, WAPI)	Case Study	(van de Kaa et al., 2013)
8	Facilitating standardization in corporate greenhouse gas accounting	Factors that influence the adoption of standardized GHG calculations	Thesis (Case Study)	(Hoogerbrugge, 2020)
9	The Stakeholders' Perspectives and a Research Agenda	Cybersecurity standards (SME)	Workshop	(Ozkan & Spruit, 2019)
10	LED lighting in Asia: How standardization regimes influence stakeholders in standard setting	LED standardization development in developing countries	Case study	(van de Kaa, 2015)
11	Industry-wide information systems standardization as collective action: The case of the U.S. residential mortgage industry	Mortgage industry standardisation	Case Study	(Markus et al., 2006)
12	Adoption of quality standards for corporate greenhouse gas inventories: The importance of other stakeholders	Factors that influence the adoption of standardized GHG calculations	Case Study	(Hoogerbrugge, van de Kaa, & Chappin, 2023)

3 | Methodology

This chapter describes the different methods that were developed and applied during this research. Aside from reproducing an existing stakeholder salience method from de Vries et al. (2003), a novel addition was made by expanding the method with a new part that focuses on standardisation processes.

3.1 Case study

For this thesis, the case study method was selected. The method is identified as applicable to answer descriptive questions, which are often specified with how and/or what questions (Yin., 2003) A single embedded case study was selected, as the focus lies solely on onboard carbon capture stakeholders. Other cases could be the stakeholder influence on standardisation of other maritime onboard innovations such as alternative fuels. However, the size of the scope for additional cases is considered not feasible. A risk while performing an embedded case study is that the sole focus could be on a sub-unit while losing sight of the original unit of analysis (Yin., 2003). For this specific research, an example could be the sole or very detailed focus on Value Maritime, because the company supports this thesis in the form of direct advice. All time should be allocated evenly to all stakeholders.

3.2 Stakeholder salience methodology

To conduct the case study, the methodology of de Vries et al. (2003) was used as a starting point. The original method consists out of two parts: part 1: stakeholder identification and part 2: classification, which were both originally designed for the IT industry (de Vries et al., 2003). Part 1,- describes 9 broad search directions to identify stakeholders, whilst the second part determines the attributes of a stakeholder (power, legitimacy and urgency). For the sake of simplicity and reproduction, the parts have been subdivided in more specific steps. Because the methodology lacks in defining any standardisation process an expansion was created: part 3: standardisation process. This part should guide researchers in mapping a standardisation process divided in specific phases, and get more insight in actor dynamics and possible bottlenecks in the process. Through a brainstorm session with three experts in the maritime and carbon capture field, the method was reviewed, revised and a plan with nine steps was composed and categorised in three parts (See table 3.8, for the participants). Every part aims to answer the corresponding sub-questions chronologically. The method is supported by semi-structured interviews to get richer information. The step-by-step guide, and the original method is further described in the next sections.

Part 1: Stakeholder identification

1. Existing and required standards
2. Category expansion
3. Projects and consortia analysis
4. Collect and categorise organisations

Part 2: Stakeholder classification

5. Determine attributes (Power, Legitimacy, Urgency)
   A) Power
   B) (perceived) Legitimacy
   C) Urgency
6. Identifying stakeholder salience.

Part 3: Standardisation process

7. Mapping the standardisation process(es)

8. Visualise actor dynamics
9. Identify bottlenecks

3.2.1 Part 1: Stakeholder identification

In this part stakeholders of the standardisation process are identified and categorised via broad search heuristics. This is necessary due to the open nature of standardisation and the risk of excluding or overlooking stakeholders (de Vries et al., 2003).

Step 1 Existing and required standards

The methodology decribed by de Vries et al. (2003), does not explicitly describe this step and rather starts with defining search directions in part 1. However, they indicated a case study as example and start with defining a standard to give context. This context is required to define stakeholders in the topic of interest. The step provides a starting direction to find stakeholders through an 'inside out' approach by looking at a standard and its main users (Willemse et al., 2003) (Ozkan & Spruit, 2019) (Karaöz et al., 2004). By looking at the code or standard, stakeholders may be identified, for instance buyers of an ISO code.

- Search for references to stakeholders in the documents (direct stakeholders)
- Search for users of the standards
- Search for 'buyers' of the standards and frameworks

When no or insufficient standards exist, this step helps with determining standards that are considered to be required by the industry. The standards that are required, may be used as input to define a corresponding standardisation process. The following interview question is key and was asked to experts:

- What kind of standards do you believe are necessary for onboard carbon capture?

Another resourceful way to find important standardisation issues is to attend a standardisation committee meeting from a standardisation development institute. Examples are the International Organisation for Standardisation (ISO) or NEderlandse Norm (NEN). In new committees, participants vote and discuss standardisation directions and topics.

Result: Contextual overview of key issues for standardisation and possible required standards.

Step 2 Category expansion

Because search categories within standardisation may vary significantly, the second step is to investigate if there are missing categories besides the nine categories as defined by de Vries et al. (2003):

1. Production Chain
2. End Users
3. Designers
4. Physical system
5. Inspection agencies
6. Regulators
7. Research and consultancy
8. Education
9. Representative Organisations
10. (.....)

For this research the context is defined by: onboard carbon capture for sea going vessels. The search categories have been discussed with three experts and the following questions were asked:

- Are the current categories sufficient?
- Are there any categories missing?

Result: (New) List with more specific search categories

Step 3 Projects and consortia analysis

Leiponen (2008), discusses that affiliation or connections to consortia do have an effect on standard setting. Therefore, projects and consortia may form rich information concerning stakeholders in a technology. To identify these stakeholders, the following step was initiated:

- Search for projects/consortia concerning the technology

Result: Contextual overview and a list of projects and consortia that are working on the technology/standardisation, with the participating organisations included.

Step 4 Collect and categorise organisations

After the initial identification, the method is strengthened by semi-structured interviews. The interviews are of an exploratory nature to identify stakeholders via experts. The following question were asked:

- Do you know any other stakeholders in the sector?

Result: Long list of stakeholders in the following format:

Tab. 3.1. Stakeholder list

Category	Stakeholder	Source
(...)	(...)	(...)

3.2.2 Part 2: Stakeholder classification

Following the model of Mitchell et al. (1997), the following attributes should be identified to determine the stakeholder salience: power, legitimacy and urgency. There are eight degrees of salience, which are defined by de Vries et al. (2003) as: Definitive stakeholders are the most important because they have the power to influence the process, commitment to achieve their goals and are accepted by other stakeholders. Dominant stakeholders, lack commitment, or immediate attention to the standardisation process however, they play a crucial role as they are accepted and do have power to influence the process significantly. Dangerous stakeholders are not welcome in the process however, do have the power to take what they want, and should therefore be taken into account while forming strategies to influence standardisation. Dependent stakeholders are important as they support the standardisation process however, lack the resources to be powerful enough to influence the process on their own. Dormant stakeholders only have power and therefore cannot simply participate in a standardisation process, they lack the commitment and are not accepted by other stakeholders. Discretionary stakeholders are accepted by other stakeholders however lack commitment and resources. They might become committed in a later stage of the process, therefore discretionary stakeholders are not excluded and may participate in a standardisation process. Demanding stakeholders only posses urgency and are less important, they could insist to participate while already being represented by another organisation who possesses more attributes.

Table 3.2, was obtained via van de Kaa and Greeven (2017a), who classified the stakeholder degree of salience from A to H. Additionally, they sorted the degrees on importance in a standardisation process. This table was used for the research as it clearly shows the differences between the types. Part 2 of the methodology further describes how to classify the identified stakeholders from part one.

Tab. 3.2. Stakeholder salience degree sorted on importance (Mitchell et al., 1997)(van de Kaa & Greeven, 2017a)

Salience degree	Power	Legitimacy	Urgency	Importance
A. Definitive	Y	Y	Y	Very important
B. Dominant	Y	Y	-	Important
C. Dangerous	Y	-	Y	Important
D. Dependent	-	Y	Y	Important
E. Dormant	Y	-	-	Less important
F. Discretionary	-	Y	-	Less important
G. Demanding	-	-	Y	Less important
H. Non-stakeholders	-	-	-	Not important

Step 5 Determine attributes (Power, Legitimacy, Urgency)

The assessment of a stakeholders power, legitimacy and urgency is required to attain the degree of stakeholder salience from table 3.2. This was approached by asking a variety of questions in eight semi-structured interviews. The three attributes were divided and are described below. The different attributes may change overtime, therefore the degree of salience may differ when replicating this research.

A) Power

Power refers to the power of a stakeholder to influence a firm (or in this case, the standardisation process or the success of the resulting standard). Power can be defined via the question: "Has the stakeholder the resources to affect the standardisation process or the success of the resulting standards?" (de Vries et al., 2003). The characteristics that define resources are described below (de Vries et al., 2003)(van de Kaa, 2015)

- Time available: the time available and financial positions are intertwined, with more money, more people can be hired which results in more time available. To make the method more tangible within the research period, the time available of a company is excluded from the power attribute.
- Financial position
- Technical expertise
- Position in network of firms

The following question were asked:

- As a stakeholder in the maritime carbon capture industry, what are your main priorities and goals in relation to this technology?
- What is your financial position according to onboard carbon capture? (availability of funds)
- Who are your direct partners?
- Who are your direct competitors?
- How is/was the power divided between your partners?
- Which stakeholders do have the most power and why?
- What is your relation to the other stakeholders you mentioned? (from step 4)

Result: Indication of power possession by yes or no and a cumulative percentage of items marked with yes

Tab. 3.3. Stakeholder Power

Power	Financial	Technical	Position	Total
Stakeholder	Y/-	Y/-	Y/-	(...)%

B) (Perceived) Legitimacy

Legitimacy is about the norms and values of a stakeholder, and if they are in correspondence with the other stakeholders. de Vries et al. (2003), defines this attribute by acceptance and support between the different stakeholders. When stakeholders are accepted in a standardisation process, they are deemed legitimate. Therefore, the following questions were asked:

- How do the other stakeholders accept or support your participation in the technology?
- Which stakeholders do have the most legitimacy and why?

Result: Indication of legitimacy possession by yes or no.

Tab. 3.4. Stakeholder Legitimacy

Legitimacy	Accepted
Stakeholder	Y/-

C) Urgency

Urgency may be clarified by the recent actions of the stakeholder. (de Vries et al., 2003) If the stakeholder is committed and active in pursuing its goals, then urgency is evident. To determine the urgency, the following questions were asked:

- To what extend have you been active in pursuing your goals regarding this standardisation issue?
- Which stakeholders do have the most urgency and why?

Result: Indication of urgency possession by yes or -.

Tab. 3.5. Stakeholder Urgency

Urgency	Active
Stakeholder	Y/-

Step 6 Identifying stakeholder salience

The obtained information from the previous steps was used to list all the stakeholders and their attributes. With the attributes available, the stakeholder typology according to Mitchell et al. (1997) was found and placed in a list.

Result: List with stakeholder salience (Dormant, Discretionary, Demanding, Dominant, Dangerous, Dependent, Definitive, Non)

Tab. 3.6. Stakeholder Salience

Stakeholder	Description	Power	Legitimacy	Urgency
(. . .)	'Definitive, . . . '	Y/-	Y/-	Y/-

3.2.3 Part 3: Standardisation process

In addition to the original method of de Vries et al. (2003), a part 3: standardisation process, was designed. The goal is to create a standardisation map that shows actor dynamics and helps in identification bottlenecks. This is supported by combining all parts from the methodology.

Step 7 Mapping the standardisation process

van de Kaa et al. (2013) created a 'route' of standards passing through different institutions in China. They differentiated between corporate entities, approved standards groups and corporate entities on different levels (local, regional, international). All actors were divided in different phases of the

standardisation process, based on Lyytinen and King (2006). A similar approach was used for this step. To gain information about the process and actors, the following questions were asked to the interview participants:

- How are standards being developed in the maritime industry? (in this case the question was asked both for the maritime industry and for OCC in specific)
- Can you describe how your organisation is influencing maritime standardisation?

First, the map was divided in the four distinct standardisation phases as described in the literature: (1) idea/problem, (2) development/design, (3) approval/enforcement/selection, and (4) diffusion/implementation. Additionally, the main standardisation process was identified and the stakeholders with their connections and specific organisational types were included (NGO/IGO, Firms, Government bodies). In preparation for the next steps, which aims to identify bottlenecks, key decision moments were included in the standardisation map. Examples are, work group decision, document creation and committee meetings.

Result: Figure of the actors placed in the standardisation process, sorted in four phases: (1) idea/problem, (2) development/design, (3) approval/enforcement/selection, and (4) diffusion/implementation.

Step 8 Visualise actor dynamics

When barriers and actor dynamics are identified, a more substantiated choice of one of the strategies may be employed and barriers may be mitigated. There are a variety of barriers in a standardisation process, for example the lack of participation in a committee, or the lack of resources such as technical expertise and financing (Wiegmann et al., 2017). These barriers may be related to actors and their respective salience. For instance, a lack of financial resources may be linked to stakeholders with limited power. The lack of participation may be connected to the commitment of a stakeholder. Subsequently, when an actor without urgency is active in a standardisation process, it may have opposing goals to a committed stakeholder. Therefore, by plotting the different salience degrees in the standardisation map, bottlenecks may be identified. Consequently, a more comprehensive view of the actor dynamics in the process can be obtained. To facilitate a quick recognition of stakeholder salience in the process, the colour scheme in table 3.7 was designed.

Tab. 3.7. Stakeholder salience colour scheme

Colour	Salience degree	Power	Legitimacy	Urgency	Importance
	A. Definitive	Y	Y	Y	Very important
	B. Dominant	Y	Y	-	Important
	C. Dangerous	Y	-	Y	Important
	D. Dependent	-	Y	Y	Important
	E. Dormant	Y	-	-	Less important
	F. Discretionary	-	Y	-	Less important
	G. Demanding	-	-	Y	Less important
	H. Non-stakeholders	-	-	-	Not important

Result: Standardisation map with the stakeholders salience type indicated.

Step 9 Identify Bottlenecks

At last there is the identification of bottlenecks, of which there is a gap in the literature considering standardisation. In business process management and decision making literature there is more information available about the identification of bottlenecks in a process. In business process management, the determination of Key Performance Indicators (KPIs) is required to asses the overall process and know what are real bottlenecks or mere distractions, some metrics are: quality, speed, costs and service (Caeldries, 1994). In formal standardisation there are a few key principles that may be related to KPIs, transparency, inclusiveness, openness and reaching a consensus based solution.

The following KPIs are created based on the main principles and business process management literature.

1. Development time

2. Stakeholder engagement
3. Review and approval time
4. Revision cycles
5. Resource utilisation
6. Feedback loop and incorporation
7. Quality of the standard

By relating the KPIs to the process, potential red flag areas may be discovered. These areas have the potential to become a bottleneck in the process, for example, a constant repeating loop of revision cycles that delay the process. To visualise these bottlenecks, a red flag was placed in the process map.

Result: Standardisation map in which the bottlenecks are related to pre-defined KPIs and indicated with a red flag.

3.3 Interviews

The methodology in this thesis was further supported by the use of semi-structured interviews. The benefit of semi-structured interviews is the chance to build on given answers, get richer information and explore new insights. These discussions may help with identifying new stakeholders, stakeholder categories and to better understand the relations between stakeholders in the maritime industry. Eight interviews were conducted via Microsoft Teams and in-person. The interviews lasted for about 60 minutes per respondent and all were recorded. During the interview process, the following supportive documents were drafted:

- A. Interview participants (anonymous) (Appendix B.1)
- B. Informed consent Form (Appendix A.3)
- C. Interview questions document: A document with 23 questions which are divided in the three respective parts from the methodology. The questions form a guideline during the interviews however, when a topic seemed interesting to discuss deeper, deviations where allowed. (Appendix A.4)
- D. Interview guidance document: Introductory document with explanation of important concepts and guidance for the interview questions (Appendix A.5)

In Appendix table A.1, the data types, collection methods, processing method and storage locations are summarised. Additionally, a risk mitigation plan for the interviews and data management plan have been created (Appendix A.2,A.1) .

Interview participants

The interviewees required a specific profile to be applicable for this thesis and should fit one of the predefined categories from step 2 of the methodology. The interviewee should be an expert in its specific category (+- 5 years of experience). The interview participants were selected and approached through the external advisers and brainstorm participants, described in table 3.8.

Tab. 3.8. Brainstorm participants

Nr.	Company	Background
B1	Self-employed	Management support, energy transition
B2	OEM	Business Development Manager
B3	TNO/TU Delft	Maritime transition PHD candidate and science integrator

The interview participants are anonymised and shown in table 3.9. An elaborate description of the participants with background and experience can be found in appendix B.

Tab. 3.9. Interview participants

Nr.	Category	Function	Date	Appendix
I1	9. Representative Organisations	Sector Manager	19-04-2023	B.2.1
I2	1. Production Chain	Senior Business development manager	19-04-2023	B.2.2
I3	1. Production Chain 2. End users and related Organisations	Principal research engineer	24-04-2023	B.2.3
I4	3. Designers and Engineering 8. Research and consultancy	Lead naval architect	26-04-2023	B.2.4
I5	4. Inspection agencies 5. Regulators	Classification manager	03-05-2023	B.2.5
I6	3. Designers and Engineering 8. Research and consultancy	Naval architect R&D department	03-05-2023	B.2.6
I7	9. Representative Organisations	Project leader clean shipping	03-05-2023	B.2.7
I8	1. Production Chain	Management Support	03-05-2023	B.2.8

Interview analysis

To adequately analyse the obtained data from the interviews, three products where created per interview:

- Interview Notes
- Audio/video recording
- Transcriptions

At first, only interview notes and recordings where created. However, when progressing further in the research the choice was made to create transcriptions for the interviews. This was done because the conversations took 60 minutes which resulted in an overload of information. The program Atlas TI was used to analyse and code the transcriptions. With the software, trends can be identified and visually shown. With the transcriptions the analysis became more tangible and no information was lost. The various transcriptions have been stored in Atlas TI under the names I1 to I8. Subsequently, three distinct folders were created to correspond with the three parts of the methodology. Each part and corresponding codes have been assigned a specific colour to facilitate quick identification of data during the analysis. Several codes related to the interview questions were predefined and are described below. While reviewing the transcriptions, various synonyms were identified, which were primarily related to dutch translations of the words. The synonyms were added to the main codes. During the review process, codes were assigned to quotes which could thereafter by easily compared.

Part 1: stakeholder identification (Yellow)

- Location
- Organisation
- Project

Part 2: Stakeholder classification (Green)

- Power
- Legitimacy
- Urgency

Part 3: Standardisation process (Orange)

- Standards
- Policy
- Regulations
- Rules

Document Analysis

The objective of the document analysis was to expand and verify the data obtained from the interviews.

The documents were identified through directions in the interviews and by asking specifically if the interview participant had access to documentation about carbon capture in the maritime industry. Because the documentation provided by participants is potentially biased, an additional document search was conducted. The document types for the analysis are: company reports (because partnerships, strategies, and stakeholders are often described in these) and regulatory documents (the IMO and EU publish many documents about rules and regulations). The latest versions were obtained via: `https://puc.overheid.nl/nsi/`. In table 3.10, an overview of the obtained starting literature is shown.

Tab. 3.10. Preliminary obtained literature for the research project

Category	Title	Purpose	Source
Academic	Stakeholder identification in IT standardisation processes	Framework for stakeholder inventory	(de Vries et al., 2003)
Academic	How to decarbonise international shipping: Options for fuels, technologies and policies	Obtained by snowballing, and gives a solid overview of technology and policy barriers in the Maritime industry as a whole	(Balcombe et al., 2019)
Governmental Docs (IMO)	MEPC 76/7/17 Proposal to reflect onboard CO2 capture (CO2 removal) in the EEDI and EEXI frameworks	Example/request for Carbon Capture implementation in the rules and regulations	(MEPC, 2021)
Governmental Docs (IMO)	MEPC 75/7/15 Fourth IMO GHG Study 2020 – Final report	Background information about the GHG strategy of the IMO	(MEPC, 2020)
Governmental Docs (EP)	Review of the EU ETS 'Fit for 55' package	Background information about the maritime EU-ETS system	(EPRS, 2022)
Tech-report	The role of onboard carbon capture in maritime decarbonization	Background information about Onboard Carbon Capture Status	(MMKMC, 2022)
Tech-report	IMO Update: Marine environment protection committee - MEPC 79	Latest background information of IMO GHG Strategy discussions	(DNV, 2022)
Tech-report	CO2 Shipping Interoperability	Background information about Onboard Carbon Capture Status	(Parmiter, 2022)

3.4 Summarised research steps

Based on the previously described theory, research questions and research method, research steps have been summarised in a flowchart that is shown in figure 3.1.

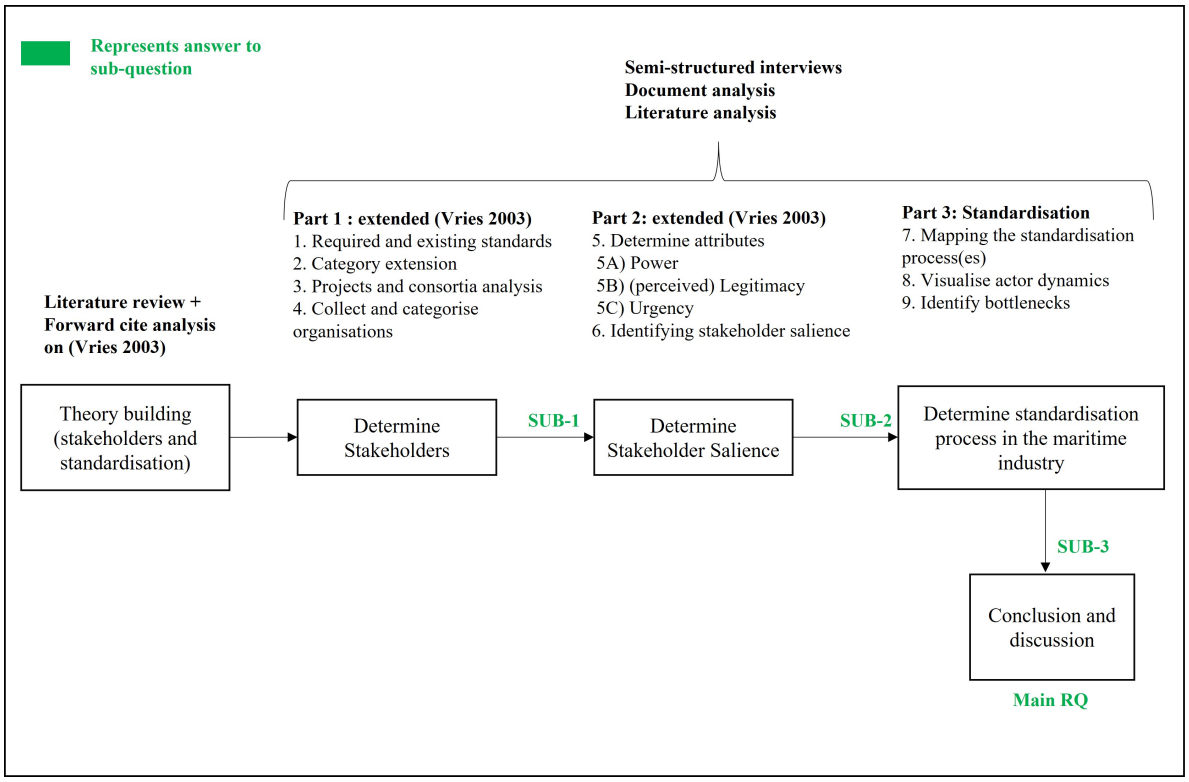

Fig. 3.1. Research flowchart

4 | Results

This chapter presents the main findings of the research divided into three different parts based on the previously described methodology. The end of every part (i.e. 1, 2, and 3) elaborates on the corresponding sub-question and is concluded with the findings that form an answer to the question. Before the parts are described, background information about the different carbon capture technologies is provided, to systematically assess the various carbon capture technologies. Subsequently, the required standards will be examined, which serve as a basis for the identification of standardisation processes.

4.1 Case background: Carbon capture technology

In addition to green fuels, one emerging technology aimed at mitigating CO2 emissions is onboard carbon capture (Balcombe et al., 2019)(MMKMC, 2022). This technology encompasses three types derived from land-based carbon capture methods: pre-combustion, oxy-fuel, and post-combustion (Bintoudi, 2021)(de Carvalho et al., 2023). In the case of oxy-fuel carbon capture, the incoming air mixture is filtered, resulting in a predominantly oxygen-rich environment that facilitates ignition and fuel mixing (Stanger et al., 2015). Pre-combustion involves pre-processing and conversion of the fuel into CO and H2. The gasified mixture is then transformed into CO2 and H2, with the CO2 being subsequently captured (Bintoudi, 2021)(de Carvalho et al., 2023). Post-combustion carbon capture, considered the most advanced technology (TRL level) in this field, is particularly suitable for retrofitting existing ships (de Carvalho et al., 2023). In relation to post-combustion carbon capture on ships, there are five associated technologies:

- Chemical absorption; an amine or ammonia solvent interacts with the CO2 in the exhaust gases, resulting in the absorption of CO2 in the fluid. Before this reaction can occur, the exhaust gases need to be pre-filtered because fossil fuels often contain heavy metals, sulphur, and particulate matter that disturb the CO2-amine reaction. The pre-cleaning of the exhaust gases is called stripping or scrubbing. This form of post combustion capture is the most advanced technology. However, it is seen as an expensive solution (Bintoudi, 2021) (de Carvalho et al., 2023).
- Chemical adsorption; With adsorption the CO2 does not dissolve and instead 'sticks' to the surface of the adsorbent (Bintoudi, 2021).
- Membrane separation: This technology uses a selective membrane where only CO2 can penetrate. The CO2 penetrates and is thereafter absorbed by a solvent that runs through the membrane. The technology is still at the pilot level for land-based plants (TRL 6) and therefore not yet commercialised (Bintoudi, 2021).
- Cryogenic separation: The flue gases are cooled to a certain temperature at which CO2 turns into liquid (liquefaction)
- CO2 mineralisation; Mineralisation is also referred to as carbonisation. The exhaust gases do react with a metal such as calcium to create a solid (calsiumcarbonate).

Onboard carbon capture may be divided into several parts: the system and corresponding equipment to capture carbon and the product the system produces, i.e., the degraded solvent or liquefied CO2, which are different per technology. To help understand the infrastructure around carbon capture, the value chain is shown in figure 4.1. With chemical absorption-based carbon capture, capturing is only one step of the CCUS process. When the chain is limited to the onboard part, de Carvalho et al. (2023) defines four steps; a) CO2 capture, b) CO2 liquefaction, c) on-board- storage, and d) CO2 offloading.

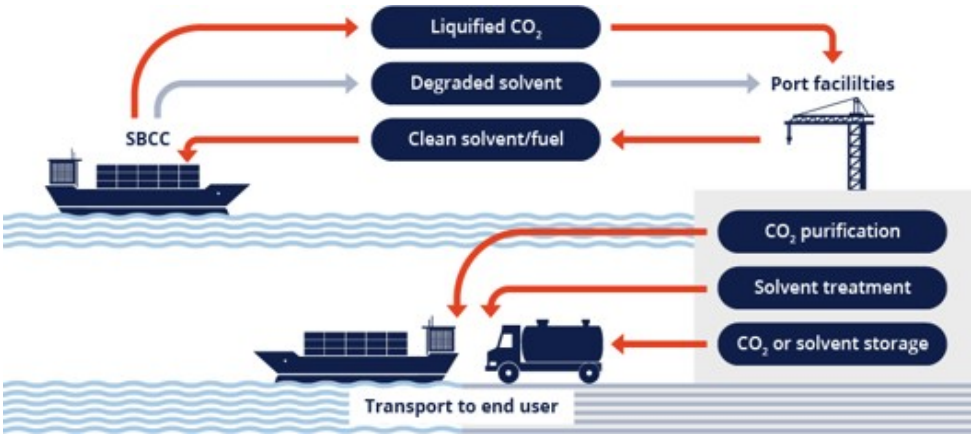

Fig. 4.1. EverLoNG Carbon capture value chain (de Carvalho et al., 2023)

Besides EverLoNG, Value Maritime created a value chain map based on their carbon capture system, which is called a 'filtree'. Using the filtree, CO2 can be captured and stored in an amine-based solvent in a CO2 battery, which is a special modified ISO tank container. When the battery is full of CO2, it can be exchanged with an empty battery via a port crane. The full battery is then transported to a greenhouse, where the CO2 is extracted from the solvent and used for plant growth. When the CO2 is completely dissolved, the container can be transported back to a vessel that requires new or more storage capacity. With this process, Value Maritime aims to create a supply chain in which CO2 is recycled. Besides the greenhouse application, CO2 can be temporarily stored or used to create methanol, steel, and beverages. Except for the liquefaction, the steps that Value Maritime follow are similar to figure 4.1.

4.2 Part 1: Stakeholder Identification

Part 1 is the first section of results based on the created methodology. First, existing and required standards were identified to delineate the case. Thereafter, ten search categories were used to not overlook any stakeholders in onboard carbon capture. A funnel approach was applied to narrow down the categories to the maritime industry; then, projects and consortia were identified as sources. The process continued by filling the categories with identified organisations.

4.2.1 Existing and required standards

Existing standards can potentially provide search directions for finding stakeholders as they are produced for specific end users. Therefore, existing standards must first be identified. Besides existing standards, required standards are described, which helps at a later stage to define the standardisation process.

Existing Standards

In line with expectations, the process of identifying existing standards for onboard carbon captures yielded limited results. Carbon capture onboard a vessel is new and innovative; therefore, the standards have yet to be produced. Based on the EverLoNG project, a first iteration of safety standards were identified with their respective stakeholders. Four classification societies, Burea Veritas, Lloyds Register, Class NK and ABS recently published these type of standards and requirements for onboard carbon capture (de Carvalho et al., 2023) (Interview I5, Appendix B.2.5). The users of these standards are shipowners and shipping companies (operators).

Besides classification societies, standard development organisations such as the NEN and ISO have been consulted. For the maritime industry, there is ISO/TC 8 - Ships and Marine Technology, which includes maritime pollution (ISO, n.d.-b). No standards have been dedicated to carbon capture as of the time of writing. The committee ISO/TC 265 - Carbon dioxide Capture, Transportation, and Geological storage, does include carbon capture. However, is solely for land applications and therefore not applicable to individual ship cases (ISO, n.d.-a)(Interview I4, B.2.4). During the aforementioned standardisation committee meeting of the NEN, a variety of stakeholders where identified. Due to privacy reasons, the participating stakeholders cannot be disclosed in this research. However, they align with the following categories: charterers (cargo owners), classification societies, and a significant portion of them are represented in the projects and identified during the interviews. CCUS considers the entire supply chain, as illustrated in Figure 4.1. Consequently, there are stakeholders within the standardisation committee who are not involved in any maritime activities but instead engage in land-based operations.

Emission Standards

Following the interviews there are a variety of standards required which can be categorised under, safety/functional, and emission standards (Hoogerbrugge et al., 2023). In the case of carbon capture, the necessary standards are primarily related to the GHG frameworks of the EU and the IMO. Six out of the eight interviews revealed the lack of any description, calculation or method to reflect onboard carbon capture in the Carbon intensity indicator (CII), Energy Efficiency Index for Existing Ships (EEXI), and the EU-ETS (See interviews I1, I2, I3, I4, I6, I8, Appendix B). Because carbon capture is not included, shipping companies now face uncertainty about the practical usability of carbon capture systems and hesitate in making investments. Technology developers face a similar perspective, while their business case depends on it. Figure 4.2 shows all the existing and upcoming frameworks.

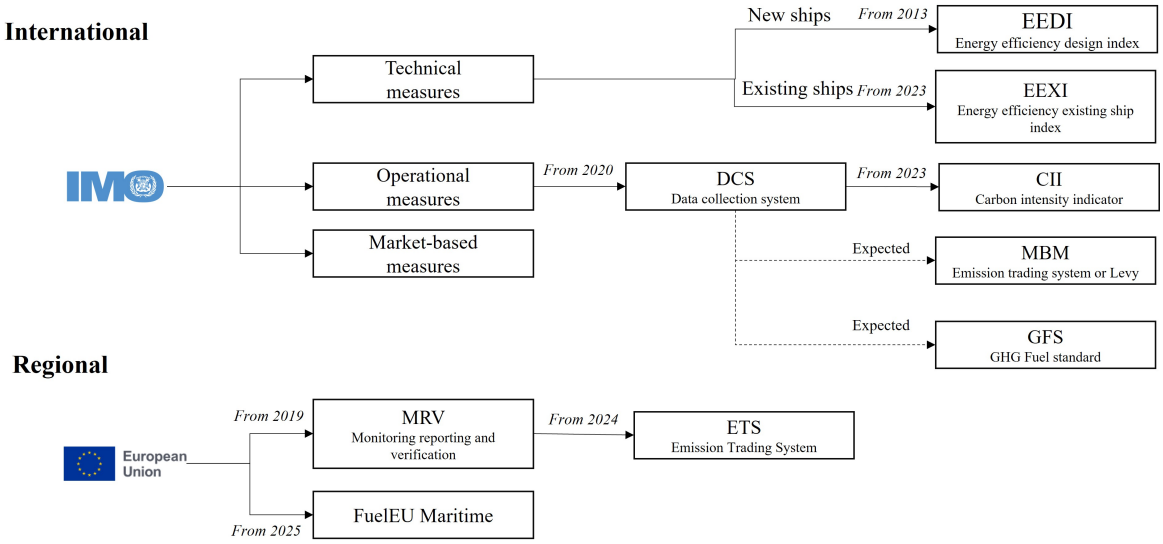

Fig. 4.2. Decarbonization frameworks of the EU and the IMO (Korean Register, 2022)

The purpose of the EEXI is to reduce emissions in the current maritime fleet, and encourage the adoption of environmentally friendly technologies such as air lubrication and wind propulsion (IMO, n.d.-a). It evaluates the transport efficiency by dividing the ship's emissions by its capacity (in ton-miles). The EEXI is assessed once during the vessel's lifetime, and ships are granted an operational license upon compliance. Whilst the EEXI focuses on the construction of a ship, the CII addresses its operational efficiency. The CII assigns an annual rating ranging from A to E, with increasingly stringent thresholds each year. If a ship receives a D or E rating, the Ship Energy Efficiency Management Plan (SEEMP) must be revised within one year to achieve a higher rating. This may involve opting for more efficient shipping routes, reducing speed or lowering the CO2 factor (Wagenborg, 2022). Both regulatory frameworks exist out of many standards that are used to calculate the CII and EEXI. An example, is the CO2 factor for fuels. For Heavy Fuel Oil (HFO), which is the conventional fuel type in the maritime industry this factor is 3.1. Carbon Capture is not included in this factor which makes CO2 accounting impossible. Besides the international level, the European Union created Monitoring Reporting and Verification (MRV), to set a first step in GHG reduction. This system differs slightly from Data Control System (DCS), as with MRV, carbon emissions were required to monitor. The MRV data is published in a distinctive database, whilst the IMO data is published anonymously. Ships in Europe now need to comply with both systems. The MRV data is subsequently utilised in the EU-ETS system, where emissions are traded and subject to an emission cap.

A CCUS kick-off meeting by the NEN, showed the need for CCUS standardisation (driven) from Europe. Therefore, the goal of the NEN is to arrange and intensify the Dutch CCUS standardisation committee (NC 310265) and thereafter establish the committee at the European Committee for Standardization (CEN). During the meeting three key standardisation pillars were discussed and further specified.

- CCS (Carbon Capture, Storage and transport)
- Utilisation of the carbon
- CO2 accounting

The stakeholders voted and the top two required standardisation topics where the measurement, monitoring and verification methodologies (MMV) for the CO2 in combination with certification, which are in line with the interviews. Especially the CO2 interface during the process of offloading CO2 to land does create complexity in CO2 accounting and the certification of it, as discussed by interview participant I4: *"If the captured CO2 eventually finds its way back into the atmosphere, a farmer might say, "No, this was CO2 captured from fossil fuel, it belongs to the ship owner." The ship owner might respond, "No, it does not belong to me because I gave it to the farmer for free. So, I haven't emitted it."*

Then both of them claim that they haven't emitted anything. However, in reality, something may have been emitted.". In summary, there is a specific need for CO2 accounting standards that include onboard carbon capture.

Safety/functional standards

Functionality and safety standards for onboard carbon capture systems are currently in development however, require further elaboration and/or specification (de Carvalho et al., 2023). After asking the question: What standards are required for OCC?, interviews I3, I5, I6 and I8 confirmed this view (See Appendix B).

4.2.2 Categories

During the brainstorm sessions with the three industry experts, specific maritime stakeholder literature was addressed (MMKMC, 2022; Stolper et al., 2022; Masodzadeh et al., 2022; Kim et al., 2020). Based on the literature, various actor maps were obtained, leading to the identification of 16 distinct (maritime) sub-categories. The descriptions of these sub-categories are provided below (Refer to: Appendix C.1 for the actor maps).

- 1. Production Chain: OEMs, shipyards, suppliers, ports and bunker stations
- 2. End Users: Shipping companies, charterers, ship owners
- 3. Designers and engineering:
- 4. Physical system:
- 5. Inspection agencies: Classification societies
- 6. Regulators:
- 7. Research and consultancy: Knowledge institutes
- 8. Education:
- 9. Representative Organisations: NGO's, Branch organisations (charterer, shipping, production)
- 10. Financial service providers: investors, financing, banks, insurers

The eight interviews did not result in any additional maritime search categories, which suggests that with the current overviews a suffcient level of saturation is achieved.

4.2.3 Projects

By analysing existing onboard carbon capture projects and consortia, 21 projects were collected and sorted based on their respective technologies (Appendix C.2). This thesis focuses on chemical absorption based carbon capture technology for fossil fuels, of which 11 projects were identified and summarised in table 4.1. There are many feasibility studies available concerning carbon capture. However, the focus of this research lies more on pilot projects and consortia because they provide a richer and more recent view of the active stakeholders.

1. The Norwegian SINTEF is in charge of the CCship Consortium, which has Wärtsilä's financial support. The goal of the project is primarily investigating the cost effectiveness of onboard carbon capture (Roussanaly, 2021)
2. REMARCCABLE: Realising Maritime Carbon Capture to demonstrate the Ability to Lower Emissions, led by a consortium of seven organisations that want to demonstrate the feasibility of onboard carbon capture, with a capture rate of 30%. The system was installed onboard a tanker from Stena Bulk by the scrubber OEM Alfa Laval (Laval, 2022).
3. LNG ZERO Consortium: The companies working on this project have created a budget of 6,1 million euros, of which the Dutch government accounts for 4,4 million euros. The project consists of three stages: capturing the carbon dioxide

(CO2); significant reduction of methane slip (CH4) / N-emissions; bringing the captured carbon to shore for new applications or directly offshore for permanent geological storage (Pekic & Pekic, 2021).

4. EverLoNG: The EverLoNG project/consortium aims to advance onboard carbon capture on two LNG-fuelled vessels from TRL 4 to 7. Besides the technology development, another goal is to create a CO2 Shipping Interoperability Industry Group (CSIIG), in which topics such as European value chains and off-loading networks are discussed (Parmiter, 2022).
5. DerisCO2: This is a Dutch-based onboard carbon capture pilot on the Sleipnir of Heerema Marine Contractors, one of the largest crane vessels in the world. The project builds upon the CO2AST feasibility study. It was funded by the Dutch ministry of economic affairs and aims to be commercially available in 2025 (TRL 9) (Ros, Skylogianni, et al., 2021) (Ros, Doedee, et al., 2021).
6. DMSE JDP In April 2022, Daewoo Shipbuilding & Marine Engineering (DSME) announced that they have received preliminary approval from ABS for a liquefied carbon dioxide (CO2) carrier. The proposed carrier will be equipped with an LNG propulsion engine and incorporate a carbon dioxide capture unit that utilises ammonia-water sorbent and mineral carbonation technology. The capture system and technology is developed by Hi Air Korea. GasLog, a prominent LNG tanker company, is also engaged in the project and intends to implement this technology on their new carriers manufactured by DSME starting from 2024 (CIMAC, 2022).
7. LINCCS: A project/consortium existing out of 13 influential actors in Norway that wants to develop and link all different steps in the CCUS value chain (LINCCS, n.d.-b). The project is owned by Aker Solutions which is an influential multinational that has been active in CCS projects since 1990. Aker Solutions is also part of the Longship project of the Norwegian Government, which is the first full scale CO2 transport and storage project in the world (LINCCS, n.d.-a). The primary stakeholder that will develop onboard carbon capture in the projects is the scrubber OEM Warsila (Bintoudi, 2021).
8. PureSOx: in collaboration with Japan's National Maritime Research Institute (NMRI), Alfa Laval, conducted a carbon capture and storage (CCS) pilot, providing practical validation of previously achieved laboratory results. The tests demonstrated the ability of a scrubber to capture CO2 onboard. Their modified PureSOx system effectively absorbed CO2 emitted by the auxiliary diesel engines while the vessel was in port, operating within a closed loop. Alfa Laval acknowledges that further development is required before CCS can be implemented at sea. Nonetheless, the advancements in carbon removal technology and the recent successful testing indicate promising potential for this approach (CIMAC, 2022).
9. Value Maritime: The Dutch based scrubber OEM has successfully implemented a pilot system on the containership Nordica, owned by Visser Shipping, which has demonstrated the ability to reduce carbon emissions with their 'filtree' product (CIMAC, 2022). Currently the company is already installing their carbon capture system commercially on several small container feeders. And in 2023, the first onboard carbon capture system with tank conversion was installed on the oil tanker The Pacific Cobalt of Eastern Pacific Shipping.
10. CC-Ocean: Mitsubishi Shipbuilding, in collaboration with K-line and Class NK (Japan), has been engaged in pilot testing of their carbon capture and storage (CCS) solution. The three organisations have conducted comprehensive tests using a small-scale demonstration plant, which was installed on the K-Line

bulker Corona Utility starting in August 2021. This initiative signifies their commitment to exploring innovative solutions for carbon reduction within the maritime industry (CIMAC, 2022) (MHI Group, 2022).

11. Compact Carbon Capture 3C technology : This technology is being developed by Compact Carbon Capture AS (Norway) and uses a patented RPB absorber with rotating elements to capture carbon more efficiently. Market readiness is expected in 2023 after running a successful demo in 2022. (Bintoudi, 2021)

The project analysis led to an amount of 53 unique participants (Table 4.1, Appendix C.3). Wärtsilä, Alfa Laval, Value Maritime, VDL AEC, and K-Air are all scrubber OEMs and are all actively participating in projects and developments. The OEMs have a leading role in at least the onboard carbon capture parts of the often larger CCUS projects and consortia. There are no direct collaborations visible between the different scrubber producers; as per project, only one manufacturer is included, which may be the result of competition. However, during the interviews, it was discovered that there is cooperation to a certain extent during discussions with the Dutch Government (Interview I1, I8, Appendix B.2.8). The projects all do have an international nature in terms of organisational collaborations; however, the countries where the technology primarily is being developed are: Norway, the Netherlands, Japan and South Korea, which are all rich and developed countries.

The research institutes TNO and SINTEF are both participating in at least three projects where a significant amount of research funding was allocated to their projects (> 1 million euros). This is an indication of the importance of carbon capture innovation in Norway and the Netherlands. The major classification societies: DNV GL, ABS, Bureau Veritas, Lloyd's Register, and Class NK are all participating in the projects.

Tab. 4.1. Onboard Carbon Capture projects (chemical absorption)

Project/consortia	Duration	Type	Participants	Technology type	Source
CCShip	(2021-2025) (Norway)	Modeling Knowledge-building Project for Industry	SINTEF Ocean, NTNU, University of Oslo, Seoul National University, Wärtsilä Moss, Klaveness and Calix Limited. Funded by: Wärtsilä Moss, Calix Limited, Klaveness, the Norwegian CCS Centre NCCS	Amine or ammonia	(Roussanaly, 2021)
REMARCCABLE	2022-ongoing (Interational)		GCMD, OGCI, Stena Bulk, Alfa Laval, the American Bureau of Shipping, Deltamarin and TNO	Amine	I2, (Laval, 2022)
LNG ZERO	Uknown (NL)		Shell, TU Delft, TNO, Anthony Veder, Heerema, Universiteit Twente, Lloyds Register, Conoship, Carbon collectors, carbotreat, PortXL (funder), VDL AEC. Lloyd's Register.	Amine or Ammonia	(Pekic & Pekic, 2021)
EverLoNG	(3 years)(NL)	onboard pilot and full CCUS chain (commercialisation) Demonstrating carbon capture on LNG-fuelled ships	TNO, Anthony Veder, Heerema, Bureau Veritas, Conoship, DNV, Jülich, Lloyds register, Carbotreat, Sintef, SCCS, MAN, VDL AEC, TotalEnergies, NexantECA, Bouman, AKP,	Amine or Ammonia	(Parmiter, 2022)
DERISCO2	2019- ongoing (NL)	Modeling/Lab (ship tilting effect)/New on board pilot project expected in the future Pilot on Sleipnir of Heerema	FME, TNO, Heerema Marine Contractors, Linde Gas Benelux BV	Amine or ammonia	Interviews, (Ros, Skylogianni, et al., 2021)(Ros, Doedee, et al., 2021)
DSME JDP	2022-2023 (KR)	Pilot test onboard LNG vessel	ABS, Daewoo Shipbuilding and Marine Engineering (DSME), Hi Air Korea and GasLog	Ammonia	Online search
LINCCS - Linking Carbon Capture and Storage'	(2016-2024) (NO)	On shore pilot project	Wärtsilä Marine Systems (Finland) (of sub-project); Aker Solutions (Norway)	Upgrading of existing sulfur scrubbers (with employment of different solvents) and designing of new scrubbers	(LINCCS, n.d.-b) (Bintoudi, 2021)
Carbon capture with Alfa Laval's 'PureSOx' commercial sulfur scrubber	2021 (JP)	On board pilot project (vessel at port)	Alfa Laval(Sweden) (NMRI)(Japan) Unspecified shipowner (Japan)	'PureSOx' commercial sulfur scrubber (hybrid system in closed-loop mode)	(Bintoudi, 2021)
CO2 Capture Module Within Value Maritime's 'Filtree' commercial multi-pollutant remover system	2021-ongoing (NL)	patented commercial product on operational vessel	Value Maritime (NL), Bureau Veritas, Visser Shipping (NL)	Amine or ammonia	(CIMAC, 2022)(Bintoudi, 2021), I8
CC-Ocean	2020-2022 (JP)	Modelling/On board pilot project	Mitsubishi Shipbuilding Co., Ltd, Kawasaki Kisen Kaisha, Ltd (K-Line), Nippon Kaiji, Kyokai (ClassNK)	amine chemical absorption	(CIMAC, 2022) (MHI Group, 2022)
Compact Carbon Capture - 3C' Technology	2020 - ongoing (commercial expected in 2023) (NO)	Modelling (results n/a yet)/C future/Commercial product e	Compact Carbon Capture AS (owner of technology) (Norway) & Baker Hughes Fjell Technology Group AS, Equinor ASA, CMR Prototech AS, SINTEF Tel-Tek	Amine or ammonia scrubber/thermal stripper with high-gravity rotating packed beds, with CO2 liquefaction on board storage of liquid CO2 in tanks	(Bintoudi, 2021)

4.2.4 Organisations

The interviews revealed a total of 47 organisations that are involved in the implementation of carbon capture technology in the maritime industry. Besides, twice the society as a whole was mentioned as stakeholder, because of the environmental impact carbon capture can have (Interviw I6, I8, Appendix B.2.6). The organisations are sorted per search category and described below:

OEMs or Technology providers:
OEMs are organisations that develop, manufacture, and provide onboard carbon capture technology solutions for the maritime industry. They are the first enablers of the product and value chain and play a critical role in advancing technological development and innovation, as well as facilitating the integration of carbon capture technology onboard ships. Sixteen OEMs were identified, with Value Maritime, Carbotreat, VDL AEC, Alfa Laval, and Wärtsïla being prominently mentioned and actively involved in the projects. VDL AEC, Alfa Laval, and Wärtsïla are multinational corporations that produce scrubber systems and are leading various pilots related to OCC. However, a fully functional product does not appear to be available yet. Value Maritime is a medium-sized company/start-up that sells 'filtrees' and claims to be the sole commercial OCC provider at present. Carbotreat, originally a land-based carbon capture organisation, collaborates on the LNG Zero project to capture CO2 emissions on LNG-fueled vessels. These entities are primarily active in the Netherlands and Norway; however, due to the international nature of shipping, a pilot program quickly becomes international. In addition to the aforementioned five OEMs, several other companies are involved in these initiatives.

Shipyards:
Shipyards are companies that build, repair, and maintain ships, with expertise in integrating advanced technologies. Shipyards are responsible for retrofitting existing vessels or constructing new vessels equipped with carbon capture technology. Shipyards can have their own engineering department and are therefore not solely bound to the production chain category. Thereby, large shipyards such as DAMEN are also active in research and development (Interview I3, Appendix B.2.3). Considering carbon capture, only two shipyards were identified in the 11 projects: Daewoo Shipbuilding and Marine Engineering (DSME) and Mitsubishi Heavy Industries. Which originate from South-Korea and Japan.

Ports and bunker stations:
Locations where ships load and unload cargo, serving as critical nodes for global maritime trade. Ports are active in the interoperability of onboard carbon capture technology, as they can provide the necessary infrastructure to support the technology, such as bunkering facilities for captured CO2 solvents or carbon capture utilisation facilities (figure 4.1. Major ports that have committed to zero-carbon shipping are Singapore, Hamburg, Algeciras, Valencia, Antwerp, Rotterdam, New York, Long Beach, Vancouver, and Housten (EDF & Center, 2022). The majority of the ports are rather focusing on alternative fuels than onboard carbon capture because onboard carbon capture is only one of the means for net zero in 2050 (MMKMC, 2022), (Interview I2, Appendix B.2.2).

Suppliers:
Companies that provide goods and services to the maritime industry, including amines, fuel, spare parts, complementary parts for the OCC system and maintenance services. The large multinationals Alfa Laval and Wärtsilä do provide these services. Further suppliers were not directly identified.

Engineering/design firms:
Companies that provide engineering and design services for ships, including optimisation of vessel performance and emissions reduction. They play an essential role in the adoption of onboard carbon capture technology, as they can design vessels that are optimised to use the technology effectively and efficiently. Design and engineering firms are also integrator of the different OEM systems and may provide insightful knowledge about standardisation because of their experience (Appendix B.2.6). One notable engineering firm actively involved in multiple projects is the Dutch company Conoship. Additionally, Deltamarin has been identified as another active stakeholder based on the projects. OCC OEMs often have their own in-house engineering departments responsible for the development and

integration of the carbon capture system. This may explain why there are relatively few identified engineering firms operating specifically in this area. Another contributing factor could be the relatively early stage of technology maturity in the field of onboard carbon capture (Interview I4, Appendix B.2.4).

Ship owners/Shipping companies:
Individuals or companies that own ships. Ship owners can play a critical role in the adoption of onboard carbon capture technology by investing in the technology and retrofitting their existing vessels or ordering new vessels equipped with the technology. They are the end users of a carbon capture system. Shipping companies can be hired by ship owners to operate their vessels, which includes system maintenance, crew provisioning, and other related services. Larger ship owners often have their own shipping companies, such as Eastern Pacific Shipping, which operates a fleet of 107 vessels. Eastern Pacific Shipping is the first company in the world to retrofit an onboard tank for storing CO2 using Value Maritime's filtree system. In total, 13 ship owners/shipping companies have been identified, including prominent names like Maersk, Stena, and Heerema. All of these companies operate internationally. There are also lesser-known names, primarily pilot implementers, such as the smaller-scale Visser Shipping in the Netherlands.

Charterers/cargo owners:
Companies or individuals that lease ships for a specific period or voyage, with an interest in ensuring vessel performance and emissions compliance. The cargo may belong to the charterer or to an individual cargo owner. Charterers can play a role in the adoption of onboard carbon capture technology by specifying the use of vessels with the technology in their contracts. Among the identified players in the field of oil chartering, leading companies include Shell, Total Energies, Equinor, and Aramco. The actors are active in full scale CCUS projects however, their exact role in onboard carbon capture besides funding remain unclear.

Governmental institutes:
National and international governmental institutes, such as the International Maritime Organisation (IMO), flag administrations, and European bodies like the European Commission (EC) and European Parliament, oversee the maritime industry, establish regulations, and promote sustainability. The IMO was mentioned in all interviews as one of the key stakeholders in maritime standardisation. The IMO is an international governmental body of the United Nations that is concerned with the maritime industry and promote themselves as: *"The global standard-setting authority for the safety, security and environmental performance of international shipping"*. Then there are flag states or flag administrations, which are responsible for all registered ships under their flag. In the Netherlands, the Ministry of Infrastructure and Water Management is partly responsible for this. In other countries a similar like department is responsible. Port State Control (PSC) is another identified stakeholder, as they are responsible for the inspection of foreign vessels in their respective national ports. They work closely together with the corresponding flag administration and their exact role is defined as following by the IMO: *"The primary responsibility for ships' standards rests with the flag State - but port State control provides a "safety net" to catch substandard ships."* (IMO, n.d.)

Classification societies:
organisations that establish and apply technical rules and standards for ships and offshore structures, with expertise in ensuring vessel safety and compliance. Classification societies can play a crucial role in the adoption of onboard carbon capture technology by providing guidelines and standards for the safe and effective use of the technology. A classification society has the mandate to act on behalf of the national government. Therefore, classification societies are not only inspection agencies but also regulators and therefore fit into two main categories. A classification society may also provide certificates and perform audits on behalf of the flag administration (Interview I5, Appendix B.2.5)

Education:
Educational institutions provide training and education for maritime seafarers, equipping them with the necessary skills and knowledge for their profession. While universities and educational institutions are

expected stakeholders in the adoption of onboard carbon capture technology, their involvement in training programs specifically focused on this technology is currently limited. Universities play a more active role in research and consultancy related to onboard carbon capture, rather than directly forming training programs or integrating the technology into their curricula. Therefore, universities are included in the subsequent category described as research and consultancy.

Research and consultancy:
Organisations that conduct research or provide consultancy services related to the maritime industry, with expertise in analysing industry trends and identifying opportunities for improvement. These organisations can play a role in the adoption of onboard carbon capture technology by providing information, guidance, and technical expertise to stakeholders interested in the technology.

Representative organisation's:
Industry associations that represent the interests of specific stakeholder groups in the maritime industry, with a focus on advocacy and collaboration. These organisations can play a role in the adoption of onboard carbon capture technology by promoting its benefits among their members and advocating for its adoption at a broader level. Branch organisations are found to be operating on a national, European and international level. For example, shipping companies and ship owners are represented on the Dutch national level by the KNVR, on the European level by the European Community Shipowners' Associations (ECSA) and on the international level by the International Chamber of Shipping (ICS) that represent 80% of the worlds merchant fleet. For technology providers there is the Dutch NMT and there is the European umbrella organisation Sea Europe. Most countries do have their own national representative organisation as stated by interview participant I1: *All the national associations are members of the European association, with each having their own individual members. Within the collective membership of these associations, there are a considerable number of entities that are involved in onboard carbon capture. These members contribute to the expertise and engagement in the field of carbon capture technology within the maritime industry.* Other representative organisations are climate movements as the European Transport & Environment and the international Clean Shipping Coalition. The final stakeholder is the International Association of Classification Societies (IACS), that represents the 11 biggest classification societies in the world, including the before described classification societies. Nearly every representative organisation seems to have their own umbrella organisation up to the international level.

Financial service providers
The category of investors, insurers, and banks encompasses entities that provide financial support for ships and the maritime industry. While specific investors were not directly identified in the projects overview, governments and charterers were mentioned in the project analysis. A notable insurer mentioned is Atradius, which also serves as the insurer for the Dutch state.

Banks play a role in investing in technologies, and for the maritime sector, the Poseidon Principles have been developed. The Poseidon Principles serve as a global framework adopted by major financial institutions in the shipping industry. These principles aim to promote sustainable shipping practices and align ship finance portfolios with the greenhouse gas reduction targets set by the IMO. Signatory banks commit to integrating climate considerations, openly disclosing the climate alignment of their portfolios, and leveraging their influence to drive emission reductions. The Poseidon Principles may offer support for onboard carbon capture, as certain banks pledge to invest in green solutions. NIBC is one of the identified banks that provides financing.

4.2.5 Conclusion

The main findings of part 1 have been summarised to form an answer to the first sub-question:

1. Who are the current stakeholders in onboard carbon capture?

A total of 87 unique stakeholders, divided into eight search categories, have been identified and are

presented in Table 4.2. Among the identified stakeholders, 17 stood out as they were mentioned in both the interviews and the projects/consortia. Five of these stakeholders were major classification societies, globally recognised and categorised within the inspection agencies category. The largest representation of stakeholders falls under the production chain category, with 16 specifically identified as original equipment manufacturers (OEMs). Many of these OEMs are prominent multinational companies such as Alfa Laval, VDL AEC, Wärtsilä, and K-Air. Additionally, several start-ups were identified within the OEMs category, including Seabound, Carbon Ridge, and Value Maritime. Engineering companies were relatively few in number and less prominent among the identified stakeholders.

The majority of the identified projects originated from Japan, the Republic of Korea, and Norway, which are all significant shipping nations and rank among the top 10 largest fleets globally. The Netherlands follows closely in 15th place. These countries are all economically developed nations that hold substantial influence in the global shipping industry. No stakeholders were identified in China and Greece, despite these countries being the two largest ship-owning nations.

The country of origin per stakeholder revealed that the highest number of stakeholders are based in the Netherlands (28), followed by Norway (11), which aligns with the origin of the projects (Appendix, Table C.6). International organisations, such as the International Maritime Organisation (IMO), Clean Shipping Coalition, International Association of Classification Societies (IACS), International Organisation for Standardisation (ISO), and the International Chamber of Shipping, accounted for nine stakeholders. Excluding these international and European-wide organisations, 72 stakeholders remain, with 57 of them being located in Europe. The remaining 15 stakeholders are dispersed across different continents outside the Europe. The representation of stakeholders from Japan and South Korea is relatively low when considering the number of projects and the size of their fleet register.

Tab. 4.2. Identified stakeholders sorted per search category

Category	**Stakeholders**
1. Production chain (25)	Aker Solutions, Alfa Laval, Andritz, Bouman Industries, Calix Limited., Carbon Collectors, Carbon Ridge, Carbotreat (Bouman), CMR Prototech, Compact Carbon Capture AS, Daewoo Shipbuilding and Marine Engineering (DSME), Damen, EcoSpray, Hi Air Korea , Ionada, MAN, Mitsubishi Heavy Industries, Panasia, Pureteq, ROG shipyard, Seabound, Value Maritime, VDL AEC, Wärtsilä, Yara
2. End Users (16)	Anthony Veder, CMA CGM, GasLog, Heerema, HMM, Samskip, JR Shipping, Kawasaki Kisen (K-Line), Klaveness , Maersk, Stena, Total Energies, Visser shipping
3. Designers and engineering (2)	Conoship, Deltamarin
4. Physical system (0)	
5. Inspection agencies (7)	ABS, Bureau Veritas, ClassNK, DNV GL, ISO, Lloyds Register, NEN
6. Regulators (7)	Europese Commissie, Europese Parlement, Flag State, IMO, INW, Marine Environmental Protection Committee (MEPC), Port State
7. Research and consultancy (14)	Forschungszentrum Jülich GmbH (FZJ) , Global Centre for Maritime Decarbonisation (GCMD), Maersk McKinney Moller institute, National Maritime Research Institute Japan (NMRI), NexantECA, Norwegian CCS Research Centre (NCCS), NTNU, Scottish Carbon Capture & Storage (SCCS), Seoul National University, SINTEF , TNO, TU Delft, Universiteit Twente, University of Oslo
8. Education(0)	
9. Representative Organisations (12)	Clean shipping coalition, European Community Shipowners' Associations (ECSA), FME, IACS, International Chamber of Shipping (ICS), KVNR, NML, NMT, Sea Europe, SGMF, Stichting de Noordzee, Transport & Environment
10. Financial service providers (4)	EBN, NIBC, PortXL, Atradius

4.3 Part 2: Stakeholder Classification

The stakeholder classification was primarily conducted at the category level, as there are many identified organisations that have the same attributes under the same category. Some international organisations were indicated as very influential and therefore described and shown at the detail level.

4.3.1 Salience

Table 4.3, shows the the degree of salience per stakeholder. Per type and attribute a rationale is given in the text below.

Tab. 4.3. Stakeholder Salience

Stakeholder	Colour	Type	Power	Legitimacy	Urgency
Classification societies		A Definitive	Y	Y	Y
International Chamber of Shipping		A Definitive	Y	Y	Y
IACS		A Definitive	Y	Y	Y
IMO		B Dominant	Y	Y	-
EC		B Dominant	Y	Y	-
Flag State		B Dominant	Y	Y	-
Port State control (PCS)		B Dominant	Y	Y	-
Ship owners		D Dependent	-	Y	Y
Shipping companies		D Dependent	-	Y	Y
Technology providers		D Dependent	-	Y	Y
Shipyards		F Discretionary	-	Y	-
Research and consultancy		F Discretionary	-	Y	-
Designers and engineering		F Discretionary	-	Y	-
Ports		F Discretionary	-	Y	-
ISO		F Discretionary	-	Y	-
Clean Shipping Coalition (CSC)		F Discretionary	-	Y	-
Charterers		H Non	-	-	-

The European Commission, the International Maritime Organisation, and the respective member states are all legislative bodies and are placed in the government category. All have legislative authority and therefore, substantial industry influence. As stated by interview participant I4: *"Pollution or cleaner transportation should be recognised and valued in economic terms. Those who have the power to influence this have the real authority. In my opinion, it lies with regulations that impose charges on polluting transportation and, on the other hand, with rewarding cleaner transport. This responsibility falls on the customers of shipowners and the regulations set by the maritime industry. For example, by the IMO and the EU"* An example is the EU-ETS, in which CO2 emissions from ships are certified and taxed. The governmental bodies are the ones who influence the business cases of the OEMs and the ship owners, giving the bodies an exceptional level of influence over the outcomes. All respondents individually indicated the EC, IMO and flag states as most powerful actors. The actors all can exert influence at the Marine Environmental Protection committee (MEPC), where worldwide maritime standards are being created concerning the environment. In terms of urgency, all bodies are subject to their own goals, such as 55% CO2 reduction in 2030 (Fit for 55); it is up to them to attain these goals. Onboard carbon capture may play a role in the equation however, the organisations may still reach their objectives without carbon capture. Consequently, urgency is lacking. An example is the Dutch government, that wants to create a roadmap for the decarbonization of shipping and created working groups, with ship owners shipping companies, ports, the NMT and KVNR. About the working groups, participant I1 stated the following: *"Different working groups were established, what is missing there in terms of subject is carbon capture. Despite the fact that I mentioned it several times in the beginning. I know for a fact that the shipowners have also indicated that."* The IMO and the EU are legitimate insofar as they are required to devise international standards and regulations for carbon capture onboard ships. Flag administrations do have authority because they interpret the IMO regulations and standards that the industry must adhere to

(IMO, n.d.-b). The flag states of the world are divided into distinct subsections. Panama, Liberia, the Marshall Islands, Hong Kong, the Bahamas, Singapore, Greece, Malta, China, and Cyprus have the most registered ships by tonnage (UNCTAD, 2022). Flag states may use tax incentives and other methods to entice ships to register with them (Balcombe et al., 2019). They have a pledge to the IMO and society in terms of auditing vessels and harnessing safety, which makes them legitimate (IMO, n.d.-b). The described attributes encompass power and legitimacy therefore, the EC, IMO, member states and port state control are ***Dominant*** stakeholders.

Classification societies are commercial businesses with a responsibility to society, the flag state and, have a recognised status within the IMO (IMO, n.d.-b). They have the authority to establish their own standards and regulations, which must be adhered to when a ship is classified under the classification society. The possession of regulatory power to devise these standards, coupled with their influential position within the network connecting the flag, society, and industry, as well as their technical expertise, grants classification societies a considerable degree of power. Additionally, they may certify the standards (IACS, 2023). When a ship owner complies and obtains this certificate, the classification society vouches for insurance. The urgency is high due to the fact that clients do request OCC standards and a classification society must remain competitive by keeping up with the market and innovations (Interview I5, Appendix B.2.5) Currently, a set of fundamental rules has been published and is now available for market development (Appendix B.2.5). IACS is one of 88 non-governmental organisations with consultative status with the IMO (Cariou & Randrianarisoa, 2023). They are the organisation that represents all major classification societies. The IACS does not possess any direct regulatory authority. However, based on the input of their members, they do technically advise the IMO. The larger classification societies, DNV GL, Bureau Veritas, ABS, Class NK and LR are all working on onboard carbon capture standards, so it is imperative that the IACS develops standards and advises the IMO (de Carvalho et al., 2023). Because IACS is an NGO that works for classification societies and society as a whole, its' perceived legitimacy is high, which also applies for classification societies themselves. In terms of urgency, the IACS has selected carbon capture as one of their priorities besides: hydrogen, ammonia and electrical energy storage systems (IACS, 2023). For this, they committed and established the Safe-Decarbonisation Panel (SDP) to collaborate with the industry (de Carvalho et al., 2023). According to the above description, classification societies and the IACS are all important in a standardisation process as they possess power, legitimacy and urgency, that corresponds to the ***Definitive*** stakeholder type.

On the Dutch National level, branch organisations such as the KNVR and NMT are actively pursuing onboard carbon capture, but only a small percentage of their members are involved in its' development (I1, Appendix B.2.1). As they are active representative organisation, we can speak of urgency and legitimacy. In terms of authority, it is more difficult to define branch organisations. On the one hand, neither the KNVR nor the NMT have any technical knowledge regarding carbon capture. However, they do seek guidance from their knowledgeable members, such as OCC OEMs (Value Maritime, VDL AEC and Alfa Laval) and end users (Anthony Veder, Heerema). Because they represent an entire industry, national administrations do take their advice seriously, which is confirmed by participant I1 (Appendix B.2.1) *'We have a strong presence and influence, especially here in the Netherlands, in Brussels, and at the IMO. When we advocate for important issues under the umbrella of our European associations, we are truly recognised as a significant knowledge source and a valuable conversation partner. While our recommendations may not always be immediately implemented, we are taken seriously, and our opinions are sought after. Governments ultimately make their own decisions, but they value our perspective as an organisation and the views of our members'*. Through their European counterpart, Sea Europe, NMT can influence the IMO and the EC with carbon capture recommendations. The same applies for the International Chamber of Shipping (ICS), who has a consultative role at the IMO (Cariou & Randrianarisoa, 2023). The ICS possess urgency as they submitted a proposal to the MEPC considering carbon capture implementation (MEPC, 2022b). This makes the above stakeholders, ***Definitive***.

Rare in the Netherlands are the stakeholders who are active in carbon capture from an engineering

standpoint. Only Conoship was identified in terms of urgency, as they are actively engaged in multiple initiatives (Projects table 4.1). The general consensus regarding carbon capture is that it is solely one option for achieving decarbonization. Therefore, there is no overall urgency among engineering firms (yet). However, engineering firms indicate that the technology might develop, at which point they are willing to continue developing and integrating the systems as confirmed by interview participant I4 (Appendix B.2.4): *"Our primary goal is to promote sustainability within the maritime industry, and Carbon Capture can play a role in achieving that. We aim to integrate it into our practices. However, it is important to note that this perspective is based on our perception and experience, and it may not represent the actual latest status. From our standpoint, Carbon Capture is not yet clear or mature enough to be widely implemented but there are developments ongoing"* Engineering firms are embracing collaboration and, in the Netherlands, view themselves more as collaborators than competitors (Interviews I4, I6, Appendix B.2.4, B.2.6). This collaborative nature and participation in OCC projects, makes the engineering firms legitimate. Ports, shipyards and bunker stations share a similar concept of urgency; in this stage, ports are more of a passive observer who may join the standardisation process more actively in the future (I2, Appendix B.2.2). However, they are frequently contacted by various CCUS actors for guidance during the development process, such as bunker locations for amines or interoperability between port facilities and ships with OCC. Research and consulting are still in their infancy however, notable organisations such as TNO and SINTEF are pursing onboard carbon capture standards. To summarise, only a small portion of research and consulting firms are active, however they are very much accepted in the standardisation process.

In general, environmental organisations or foundations, tend to have limited financial resources and possess less expertise compared to established businesses (I7, Appendix B.2.7). As a result, their level of influence or power is relatively low, as they have limited capacity to exert significant control or sway over other stakeholders. The same applies to the Clean Shipping Coalition (CSC), which do posses the power to hand in proposals at the IMO, however the resources are scarce and therefore certain focus areas are to be chosen, of which onboard carbon capture is none (I7, Appendix B.2.7). However, they are legitimate because the CSC is an association which exists out of many environmental protection organisations that represent a large part of civil society and the seas. Additionally, they are an active participant at the IMO. Besides the CSC, there is the Standard development organisation ISO, that do not posses power In the case of onboard carbon capture, ISO is a stakeholder because classification societies and the IMO may refer to their standards or partly implement them. Additionally, the ISO does have a consultative status at the IMO. Because ISO is a prominent standardisation organisation, their legitimacy is high. ISO does not have any objectives for onboard carbon capture and therefore lack urgency. All the previously described stakeholders only posses legitimacy and are ***Discretionary*** stakeholders.

All interviewees agreed upon the salience type of technology providers and shipping companies. As the inventors of the carbon capture system and participants in numerous initiatives, OEMs actively pursue standardisation, indicating their level of urgency. The same is true for shipping companies, as they conduct product evaluations and tests. Additionally, the parties are marked legitimate because they are already working together in many projects and consortia, which makes their participation accepted by others and thus legitimate. All possess some form of technical knowledge about the product and the implementation however, the actors rely significantly on regulatory bodies, such as flag administrations, that have the power to block or to make the overall business case of OCC work. Urgency and legitimacy are evident attributes of ship owners, shipping companies and technology providers. Power was currently not identified besides the component of technical knowledge, the stakeholders outcomes are currently dependent on regulatory bodies. This makes the stakeholders the ***Dependent*** type.

Charterers, investors, financiers, education, and bankers are indirect stakeholders as opposed to non-stakeholders. For instance, financiers and charterers may serve as technology enablers by committing to net zero and investing in carbon capture. However, they do not play a direct role in the standardisation procedure. The aforementioned Poseidon principles are an example of an incentive for investors and institutions to invest in green, sustainable solutions. Their lack of further participation

results in the ***non-stakeholders*** type.

4.3.2 Conclusion

Based on the stakeholder classification discussed in the previous section, it can be determined which parties should be involved in a standardisation process or at least define the major stakeholders by their attributes.

2. What are the positions of the stakeholders? (power, legitimacy, urgency)

Figure 4.3, presents the degree of salience per stakeholder in the context of onboard carbon capture standardisation. Among the definitive stakeholders, classification societies hold a central role as they develop standards, collaborate with the market, and have a unique position in representing the flag. In addition to the classification societies, the International Association of Classification Societies (IACS) and the International Chamber of Shipping (ICS) are also considered definitive stakeholders. These organisations operate at a broader scale, spanning both European and global levels, and hold an important consultative status at the International Maritime Organization (IMO). Their involvement is crucial in a maritime standardisation process. Ship owners, shipping companies, and technology providers were identified as dependent stakeholders. They heavily rely on governmental bodies to sustain a viable business case for onboard carbon capture technology.

Governments do promote decarbonization and establish specific goals and targets. However, there is limited sense of urgency concerning the implementation of onboard carbon capture technology. All the dominant parties, which only possess power and legitimacy are identified to be governmental bodies. No stakeholders were identified that possess solely power or urgency (i.e. E. Dormant or G. Demanding). In contrast, all stakeholders demonstrate legitimacy (excluding non-stakeholders) and 10 out of 16 stakeholders lack urgency. Among the stakeholders, those with only legitimacy constitute the largest group. They are discretionary and primarily serve as observers in the carbon capture process. However, they are willing to participate when called upon, indicating a high level of acceptance among the various stakeholders. Lastly, there are non-stakeholders who, despite playing a crucial role in providing financial incentives, do not contribute specific value to the standardisation process.

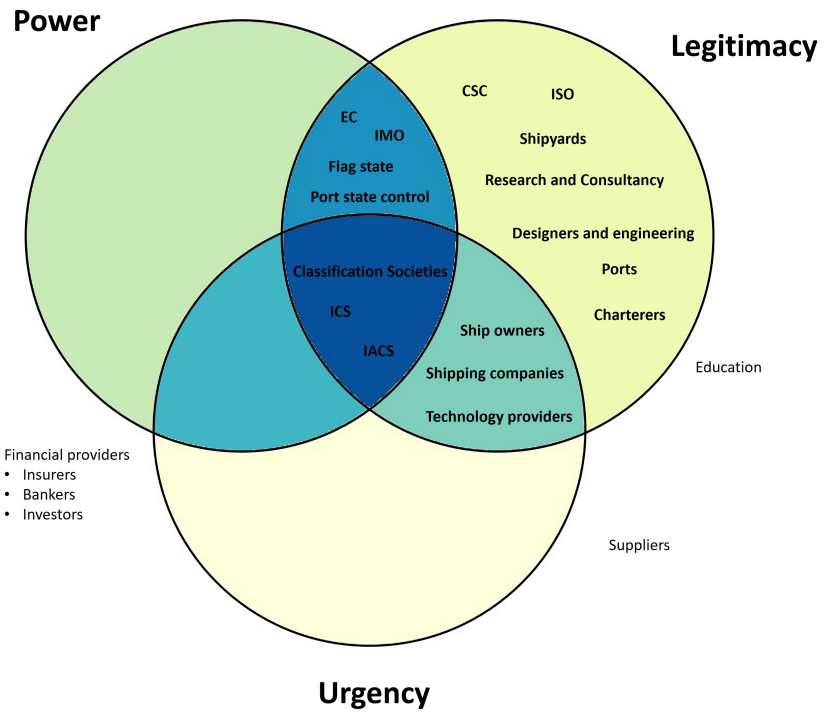

Fig. 4.3. Stakeholders in maritime carbon capture standardisation and their salience

4.4 Part 3: Standardisation

Based on the necessary CO2 accounting and safety/functional standards, two distinct standardisation processes have been identified: safety/functional standardisation and environmental standardisation. These processes are defined by four standardisation phases: (1) idea/problem, (2) development/design, (3) approval/enforcement/selection, and (4) diffusion/implementation.

4.4.1 Safety/functional standardisation

Regarding the carbon capture standardisation procedure, ship owners and shipping companies are the starting point. (1) Ship owners and shipping companies identify the need of functionality and safety standards for their crew to work safely with new technologies. This need is identified by the technology providers and consortia (Interview 8, Appendix B.2.8). (2) Subsequently, the technology providers request rules to comply with at their national classification society. The classification bureau then engages in internal discussions and determines, based on factors like timing and significance, whether standards should be established for the technology as stated by interview participant I5: *Technology providers come to us and request for standards. Together with the providers we then try to come to a set of requirements. And on that basis we will therefore create standards and rules that fits the existing systems. Additionally, we participate in the EverLoNG project.* (3) If there is enough traction, the classification society collaborates with the industry to develop the standards. For example, the EverLoNG consortium in which the classification societies: Lloyds Register, Bureau Veritas and DNV facilitate the exchange of knowledge pertaining to standardisation (de Carvalho et al., 2023).

(3a) During the development of the new standards, a classification society may optionally refer to ISO standards (Interview 5, Appendix B.2.5). This approach helps to avoid duplication of effort and ensures that standards are more robust when presented to external authorities.

(3b) When a specific new technology is not yet established and the design is in an early stage, a risk-based qualification approach can optionally be employed to acquire an Approval In Principle (AIP) (Interview 3, Appendix B.2.3). This AIP serves as a temporary validation to demonstrate the feasibility of the system to project partners, customers, and governmental bodies (ClassNK, n.d.). During the process, the classification bureau collaborates with the technology provider to develop standards that prioritise safety and functionality, employing a systematic and evidence-based methodology. This methodology entails evaluating the risks associated with the technology, where OEMs do provide a significant amount of advice.

(4) After consulting with the industry, the classification bureau independently determines the standards and whether they should be voluntary or mandatory (i.e. class notation). In the case of carbon capture, these standards have been made mandatory (de Carvalho et al., 2023). New or adjusted standards are published periodically on the platform of the specific classification society. Rulefinder and Veristar Erules are online examples of these platforms (Lloyd's Register, n.d.). (5) The standards are subsequently implemented and imposed on every eligible ship registered with the specific classification bureau (Interview 5, Appendix B.2.5).

An initial set of standards in the form of rules now has been established, All phases of the corresponding process have been completed. The issued standards are focusing on safety and functionality standards, specifically for chemical absorption amine-based systems. However, the standardisation process is iterative, which means that when new technologies enter the market, a revision of the existing standard is conducted. As stated by participant I5, *"So now it is up to the market to apply the standards and see if any issues arise or if there are emerging technologies that do not align with what we have written. In such cases, we will actively assess and adjust our rules as necessary."* This allows for the inclusion of parties with new innovative technologies and ensures that the standards remain up to date and relevant. This prevents the market to run in a technological lock-in an early phase (Leiponen, 2008).

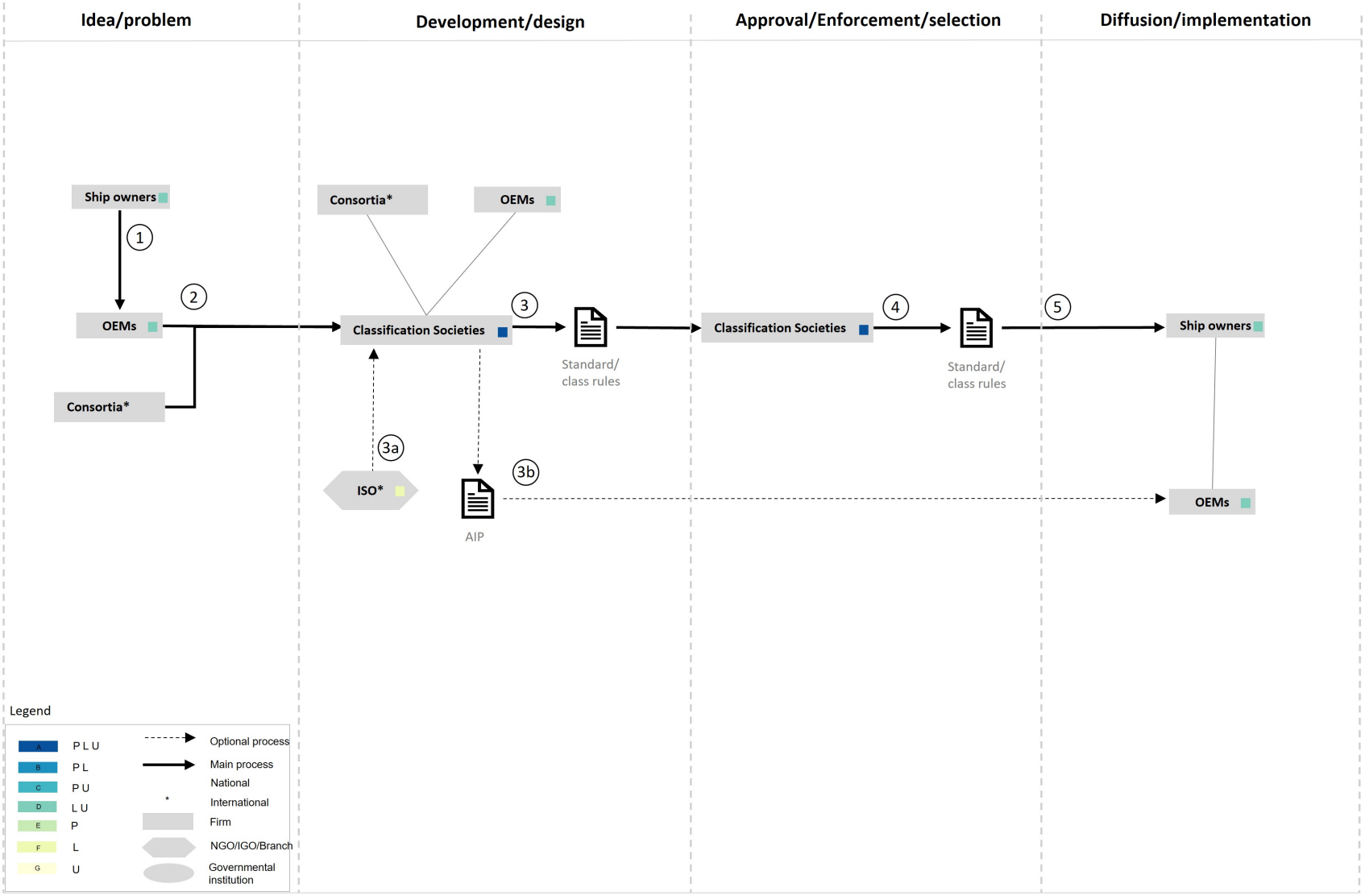

Fig. 4.4. Standardisation process concerning functional/safety standards for onboard carbon capture in the maritime industry

4.4.2 Environmental quality standardisation

Environmental standards are internationally being developed at the IMO. The IMO develops and enforces major conventions such as the International Convention for the Safety of Life at Sea (SOLAS) and the convention for the Prevention of Pollution from Ships (MARPOL). Specialised committees are active which are related to the key conventions. Figure 4.5, shows the committees and their sub-committees. The Marine Environment Protection Committee (MEPC), is composed out of 175 member states and the place to discuss carbon capture related standardisation (ClassNK, 2023b).

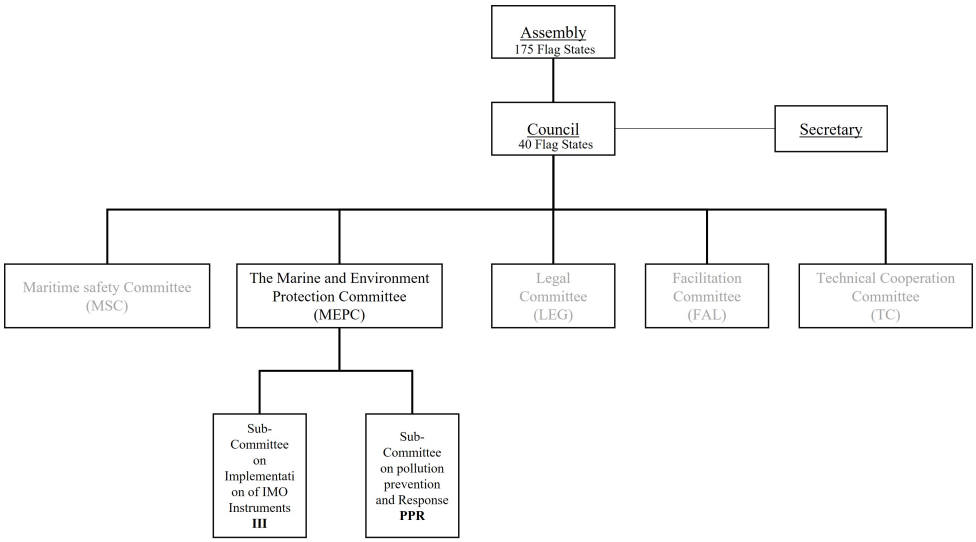

Fig. 4.5. IMO organisational structure (ClassNK, 2023b)

(1) At the national level the industry presents an idea or problem to the flag state. By submitting a proposal, one can have it included on the MEPC's agenda, which may lead to subsequent decision-making processes at a later stage. The flag state is more inclined to address the problem promptly if the stakeholder holds sufficient power. In the case of the Netherlands, branch organisations such as the Netherlands Maritime Technology (NMT) or the Royal Association of Netherlands Shipowners (KNVR) are involved. (2) Once there is enough traction, the flag state collaborates in the form of a working group with port authorities, shipowners, technology producers, and classification bureaus. Based on different perspectives, EU policies, and national interests, an overall position is established for the flag state. This perspective, along with any potential proposals, is then brought into international discussions within the IMO (Interview 5, Appendix B.2.5). The proposals predominantly originate from wealthy flag states with a keen interest in international trade and high political accountability (Cariou & Randrianarisoa, 2023). In the case of the the working groups in the Netherlands, participant I1 stated the following: *"Different working groups were established, what is missing there in terms of subject is carbon capture. Despite the fact that I mentioned it several times in the beginning and I know for a fact that the shipowners have also indicated this topic"* . Therefore, no view or proposal about onboard carbon capture has been taken or created, which is indicated in the flowchart with a red flag.

(2a) Besides flag administrations, proposals can be submitted by one of the 88 non-governmental organisations (NGOs) or one of the 66 intergovernmental organisations (IGOs) that own the consultative status at the IMO. Shipowners and shipping-related associations have historically played a prominent role, representing almost 50% of the proposals between 2002 and 2019 (Cariou & Randrianarisoa, 2023). Which makes The International Chamber of Shipping (ICS) a very active stakeholder. Because, the IACS, EC and the Clean Shipping Coalition were classified in the previous chapter, they have been placed in the process flow. The Safe-Decarbonisation Panel (SDP) of the IACS, created a consultative status for technology providers, ship owners, shipyards and insurers to collaborate and

create recommendations, or propose submissions (de Carvalho et al., 2023). Additionally, the NGOs and IGOs may optionally collaborate with OEMs, shipping companies or Flag administrations to create a proposal. Table 4.4, shows all proposals to the MEPC concerning onboard carbon capture. These proposals all have been submitted to the MEPC which is shown in figure 4.6

Tab. 4.4. Carbon Capture related submissions at the MEPC

MEPC meeting	Submission title	Submitted by	Source
MEPC 76-7-17	Proposal to reflect onboard CO2 capture (CO2 removal) in the EEDI and EEXI frameworks	Republic of Korea	(MEPC, 2021)
MEPC 79-7-4	Proposal for including carbon capture technologies in the IMO regulatory framework to reduce GHG emissions from ships	Liberia, ICS	(MEPC, 2022b)
MEPC 79-7-6	Proposed amendments to EEDI calculation Guidelines to incorporate Carbon Capture system for Ship Exhaust gas (CCSE)	China	(MEPC, 2022d)
MEPC 79-7-7	Proposed amendments to EEDI Survey and Certification Guidelines to incorporate a Carbon Capture system for Ship Exhaust gas (CCSE)	China	(MEPC, 2022e)
MEPC 79-7-16	Carbon capture and storage on board ships	Norway	(MEPC, 2022a)
MEPC 79-7-22	Proposal to include onboard CO2 capture system in the IMO GHG regulatory framework (Republic of Korea)	Republic of Korea	(MEPC, 2022c)
MEPC 80-7-7	The use of onboard carbon capture systems within IMO's regulatory framework	Republic of Korea, China, Japan, Liberia, Norway, ASEF	(MEPC, 2023)

(3) The approval of a proposal is based on consensus among all flag states. Every flag state and consultative organisation may send delegates to a MEPC meeting. These delegates may be appointed from the industry instead of solely working for their respective government. Based on the input of the committee, a new proposal may be requested and proposed to discuss in a new meeting. During the consideration of proposals, both the IMO and the European Union (EU) can refer to existing ISO standards to avoid duplicating efforts. An existing standard can be adopted for the maritime sector by the IMO or the EU. When either organisation adopts such a standard, they can impose its mandatory application, which is in the EU referred to as harmonised standardisation.

There have been several attempts to influence the standardisation process at the IMO, considering carbon capture. For instance, the Democratic Republic of Korea, proposed in 2021 to: *"reflect onboard CO2 capture (CO2 removal) in the EEDI and EEXI frameworks"* by adjusting the conventional calculation standard (MEPC, 2021). (3a) For this proposal no consensus was reached, because there was not enough time during the meeting to discuss the detailed submission. Therefore, the submission was postponed and discussed at MEPC 78. At MEPC 78 no consensus was reached because several flag states had diverging views about the regulatory and technical aspects. The MEPC, requested for more detailed proposals for the next meeting MEPC 79. The Republic of Korea, Liberia, China and Norway followed up with four unique proposals. Again at MEPC 79 there were time constraints and the proposals were not considered in detail. The committee again requested for more proposals and postponed the discussion of the MPEC 79 proposals to MEPC 80. The before mentioned flag states created a new submission, this time all together with Japan (MEPC, 2022b). As shown in the last row of table 4.4. The latest discussion during MEPC 80 did not led to any standard or amendment however, carbon capture now has been added to the agenda of the ISWG-GHG 16 workgroup. This workgroup of the IMO is requested to develop a regulatory framework for carbon capture during intersessional MEPC meetings (ClassNK, 2023a).

If no consensus is reached and a decision must be made, the MEPC may use voting. at least 2/3 of the flag states need to agree for a proposal to be approved. For the proposal to implement Existing Efficiency Design index (EEDI) and SEEMP this unique situation happened in 2011. Brazil, China, India and Saudi Arabia were resistant because, they thought the measures were unfair considering their developing country status. Something similar happened recently during MEPC 80, China and Brazil appeal to their developing country status and their respective carbon budget and blocked the consensus process around

new decarbonization targets at the IMO. In figure 4.6 , a red flag is placed as indicator when no consensus is reached.

(4) The proposal is approved based on consensus among all flag states, after which a document is drafted or modified accordingly. The interpretation of the standard is done per flag state: *Each flag state must incorporate the IMO standards into its own national legislation to ensure compliance for its registered ships.* (Interview I5, Appendix B.2.5) The flagstate is free to do this by its own interpretation which complicates comparison.

(5) The last step in the process is, the implementation of the new standard. Where, OEMs adjust their product based on the standard, which for example could be specific CO2 measurement systems. Ship owners need to comply with the new standard and therefore adjust their ways of working and classification societies perform audits, depending on how the flag state implemented the new standards. the same applies for port state control. A revision of the standard is possible overtime, however with the standard captured in nation specific legislation a revision may take long to be finally implemented.

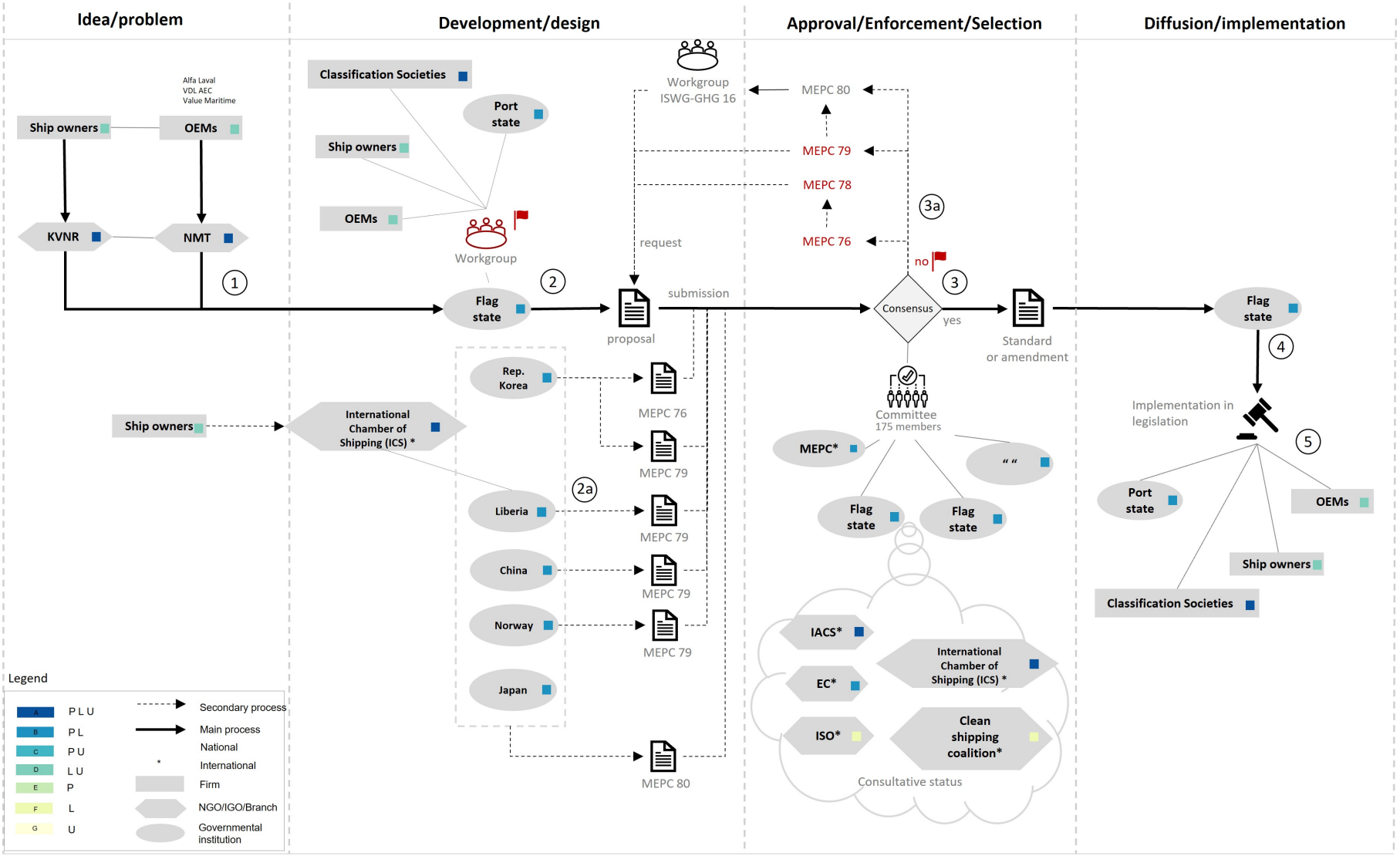

Fig. 4.6. Standardisation process concerning environment standards for onboard carbon capture in the maritime industry

4.4.3 Conclusion

The last sub-question of this research is:

3. How are standards being developed in the maritime industry?

Upon initial examination, the maritime sector demonstrates a distinct approach to standardisation compared to well-established institutions such as ISO, CEN, and NEN. Instead of relying on traditional standardisation bodies, the maritime sector places significant emphasis on industry initiatives and consortia, rather than actively reaching out for stakeholders. Two distinct standardisation processes have been identified: safety/functional standardisation and environmental standardisation.

In the safety/functional standardisation process, dependent industry stakeholders play a crucial role. Classification societies dominate this process, particularly in the approval phase where they have sole authority. Their involvement is required during the development stage, and their approval ultimately determines the finalisation of a standard document. Stakeholders such as OEMs collaborate closely with classification societies due to their dependent salience nature. This process can be relatively swift as it does not require consensus or voting, with for-profit firms largely dominating the entire process, excluding ISO.

On the other hand, environmental standardisation operates on a more international scale. opposed to functional standardisation, this process involves fewer for-profit organisations and is primarily led by governmental bodies. Dependent stakeholders initiate the process by identifying environmental issues, and engage their respective representative organisations to gain traction with the flag state. In the subsequent development phase, flag states and international organisations with consultative status to the IMO play a dominant role, as they can produce submissions to discuss at the MEPC committee meetings. Within the national working group which might be established by the flag state, three of the five stakeholders posses urgency. After the development phase, the proposal is discussed in a committee lead by the MEPC, involving 175 member states, NGOs and IGOs. Consensus under flag states must be achieved to enter the next phase. The flag states in this process are all dominant stakeholders. In the case of carbon capture, the IACS, ICS, EC, ISO and CSC are all stakeholders that own a consultative status and may provide advice during the meetings. Once consensus is reached, the standard can become final and implemented by flag states through legislation, thereby making the standard mandatory. In the whole process, the following decision moments in the process were identified: working group discussions, proposal developments, consensus building and the implementation in the legislation. The working group discussions in at least the Netherlands did not consider onboard carbon capture. No consensus was reached considering the onboard carbon capture proposals. The discussion of the proposals in detail was postponed several times from 2021 until the next session of the MEPC in 2024.

5 | Discussion

5.1 Interpretation of results and comparisons

part 1 The majority of the identified stakeholders are located in the Netherlands. These results may be somewhat biased as the nationality of all interview participants is Dutch and therefore, they may be more familiar with Dutch companies and stakeholders. On the other hand, it is also the Netherlands that aims to establish the first CCUS (Carbon Capture, Utilisation, and Storage) committee in Europe through the NEN. Additionally, there are numerous Dutch projects related to carbon capture. The involved countries are predominantly developed and wealthy nations, which is in line with literature that describes the amount of resources and knowledge which is required for standardisation (Wiegmann et al., 2017). The absence of stakeholders from China during the identification is notable because, in other sectors such as the LED industry, standardisation was widely applied in China (van de Kaa & Greeven, 2017a). Additionally, China is active in creating standardisation proposals at the IMO. A potential explanation for this absence can be found in the more ambitious decarbonisation targets of the European Union compared to those of the IMO. Alternatively, it is a possibility that information regarding the standardisation process in China is not publicly available. The limited number of engineering companies stands out and could be attributed to the relatively early stage of technology development. It is possible that a higher Technology Readiness Level (TRL) needs to be achieved first. This argument was partly confirmed by interview participant 4: *"Our primary goal is to promote sustainability within the maritime industry, and Carbon Capture can play a role in achieving that. We aim to integrate it into our practices. However, it is important to note that this perspective is based on our perception and experience, and it may not represent the actual latest status. From our standpoint, Carbon Capture is not yet clear or mature enough to be widely implemented but there are developments ongoing"*

part 2 Before determining the attributes of the stakeholders in part 2, the following question was asked to participants: Who are the key stakeholders in onboard carbon capture? Firstly, key stakeholders were identified - but these initially differed from the definitive stakeholders. This is not all that surprising considering the participants had yet to be informed about part 2 of the methodology. It is evident from the results that the process would not be set in motion without any of these key stakeholders. Furthermore, it was observed that governments primarily possess power and legitimacy but lack urgency. This is likely due to the large group they represent and the broad responsibility carried by governments. For instance, the government may have decarbonization goals; however, there are numerous approaches to achieve the targets, making it challenging to focus entirely on one technology.

There were no demanding and dormant stakeholders identified (i.e. stakeholders with only urgency or legitimacy). This may have a variety of causes. First, the interviewees described the maritime industry as a collaborative oriented industry. There is a focus on clusters and collaboration to develop new technologies, which is especially evident in Norway and the Netherlands. In this way, a stakeholder could be accepted earlier due to the nature of the industry and giving the stakeholder the legitimacy attribute, as they are accepted by others. Another reason could be a double agenda or not yet determined agenda of particular stakeholders. For example, ports that are now legitimate and observing the process as a whole however, they may change their objectives when more information is available and the market is more mature. A legitimate stakeholder therefore, may change overtime and become an opponent of the technology as a whole. The same applies for the attributes power and urgency. When for example many ship owners do install a carbon capture system, bunker infrastructure is required which a port may facilitate and gives them suddenly a hard incentive to support carbon capture. In short, many stakeholders are open for collaboration and want to help by advising however, the overall technology and in specific the onboard implementation is still immature. Only Value Maritime was identified to have a working commercial product, other parties such as Wärtsila, Ecospray and Alfa Laval are still in

the development phase and running pilots. When the technology is further developed, stakeholders may have a better understanding about their own position and become powerful by allocating resources such as time, money and hire more knowledgeable people.

A second explanation could be the use of broad categories instead of specific organisations. For example, now ship owners are dependent stakeholders however, when looking at the organisational level there are different decarbonization pledges under ship owners. Flag states are a comparable example. Flag states are dominant stakeholders however, on the detail level, China, The Republic of Korea, Norway and Liberia are all actively creating new carbon capture implementation proposals for the MEPC. Whilst actively working on the standardisation of carbon capture, there is a sense of urgency that would alter their salience type. Regardless of the exact reason's why specific stakeholder types are scarce or unidentified, there could be a variety of effects on the standardisation process. The lack of demanding stakeholders may result in a less active or slower approach of the stakeholders during the standardisation process. Because, there are no actors "buzzing, in the ears of the managers" (Mitchell et al., 1997) On the other side, purely demanding stakeholders may slow down the standardisation process, by focusing on small topics which are not important overall, as they lack legitimacy (de Vries et al., 2003).

part 3 Unlike ISO and NEN, the maritime industry mandates the private classification societies to handle standardisation. This is noteworthy, because these companies operate commercially and can facilitate the standardisation of new technologies relatively easily. They resemble accredited firms that, for example, issue and enforce GHG certificates on land (Hoogerbrugge et al., 2023). No direct bottlenecks were identified however, one could argue that a potential red flag could lay in convincing the classification society to develop the standards. Classification societies do have a powerful position as they are creator of the standards and inspector. When assessing the safety/functional process, all active stakeholders in the main process flow do posses urgency which may be the reason why safety standards have been created relatively fast. The environmental standardisation process progresses slower than safety/functional standardisation, which can be explained by looking at the type of involved stakeholders and the key decision moments. Environmental standardisation is driven by consensus and mainly involves bureaucratic government agencies.

Additionally, a flag state without urgency needs to hand-in a submission, this may form a bottleneck as committed stakeholders need to convince the flag state. Because the flag state is a government institute, stakeholders can only exert influence over flag state decisions through lobbying efforts' (Wiegmann et al., 2017). Therefore, dependent stakeholders such as ship owners and OEMs have few options and are practically required to approach their national representative organisation. Additionally, the flag state could be bypassed by ship owners going directly to the International Chamber of Shipping who is a definitive stakeholder and can directly hand-in agenda items to the committee. However, this only helps the dependent stakeholders through the development stage, while in the approval stage consensus must be reached by flag states. Again only lobbying through NGOs or IGOs with consultative status may succeed. The IACS and ICS would in this case be the main targets as they are definitive and are probably willing to support the case.

Influencing the process

The first one to submit a proposal about implementing onboard carbon capture was the Republic of Korea in 2021. In 2022 they tried again without success. By working together with Japan, Norway, China and Liberia in 2023, some success was finally booked as onboard carbon capture was added to the agenda of the MEPC ISWG- GHG 16 working group however, it is guessing if this success is booked because all the flag states worked together or because of the other submissions that were handed in since 2021. It is interesting to see that China and Liberia are working against new decarbonization targets by blocking the consensus process, however do create submissions for onboard carbon capture, which is a measure to decarbonize. Carbon capture could be a way to still use fossil fuel based ships, which may be their main motive. Notable is the flag administration of Norway who is in favour of strict decarbonization targets however, still works together with china and Liberia on onboard carbon capture proposals. This may be

linked to the already large carbon capture and utilisation industry in Norway, with companies as Aker Solutions and Equinor.

While Norway, Japan, and the Republic of Korea actively contribute to submissions at the IMO and projects related to onboard carbon capture, the involvement of the Netherlands raises questions. The Dutch industry is notably engaged in onboard carbon capture projects such as EverLoNG and LNG Zero, along with the commercial company Value Maritime. However, the Netherlands' lack of collaboration on the MEPC proposals remains puzzling. During interviews, participant 3 stated: *"I'm not sure if CO2 capture is necessarily the optimal solution. In that regard, one could argue against it, stating that it serves as a plea to continue relying on fossil fuels. That serves as a counterargument to consider"*. The potential association of carbon capture with sea-polluting devices like scrubbers might contribute to the Dutch flag state's indecisiveness or lack of clear commitment to carbon capture initiatives at the IMO. To influence members such as the dutch government, it should be made very clear that a carbon capture system is not always connected to a polluting open loop scrubber. Other options for companies in European countries could be to work together in Norwegian companies and research institutes such as SINTEF, as they seem active in projects and MEPC proposals. Additionally, Norway does pledge for strict decarbonization targets at the IMO which shows some conformity with the European Union.

Apart from flag states, representative organisations play a crucial role in influencing IMO decisions. For example, the KNVR (Royal Association of Netherlands Shipowners) discusses its position within the ICS, and the ICS, in turn, is simultaneously influenced by numerous shipowners. It is worth noting that the ICS is not solely active in onboard carbon capture but is, in fact, the most active in generating submissions among all consultative organisations at the IMO (Psaraftis & Kontovas, 2020). Japan and the International Chamber of Shipping (ICS) have faced accusations of intentionally blocking decarbonization targets through lobbying, leveraging their positions to exert influence over other countries. Non-ship owners, such as the OEM Value Maritime are attempting to influence the Dutch flag to support their agenda, specifically by approaching organizations like the NMT (Netherlands Maritime Technology). It could be argued that their commercial product has given them leverage in negotiations, as ship owners who have purchased their system are aligned with their cause. This alignment is believed to expedite the decision-making process for classification societies, given that ship owners are the primary customers of such entities. In short, the key organisations to exert influence over flag states and potentially the MEPC (Marine Environment Protection Committee) are the IACS (International Association of Classification Societies), ICS (International Chamber of Shipping), and classification societies. These entities play a crucial role in shaping decisions and policies within the maritime industry.

One challenge during the research was the closed nature of the IMO. Cariou and Randrianarisoa (2023) also highlighted the lack of delegate accountability and the fact that the public, and also NGOs, are often unable to find out their national delegation's position in debates and negotiations. this was encountered first handed, while in the summaries and IMO documents no names were provided with reactions on the proposals. Because of this non-transparant ways of working, it could not be identified who is against carbon capture at the MEPC. There was only stated that careful assignment of the topic is required.

Comparison with other cases

Due to the method being renewed and expanded, a full comparison with other research is not immediately possible. However, the identification (Part 1) and classification (Part 2) have been carried out by other authors on multiple occasions (Willemse et al., 2003) (Gottlieb et al., 2003)(Karaöz et al., 2004)(Jorritsma & Vries, 2003). The case studies mainly focused on the IT field, making it challenging to draw comparisons. Nevertheless, there was a case study conducted on paint systems for ships, which is the closest case available to the maritime sector (Gottlieb et al., 2003). Despite the difference in cases, primarily governmental stakeholders were indicated to be dominant. Therefore, the aforementioned explanation seems to hold. Another similarity between the different cases is the importance of branch organisations and certification companies, as they are primarily described to

be definitive stakeholders. Another interesting finding is the overall lack of demanding and dormant stakeholders. In five case studies a total of 111 stakeholders were identified of which only 13 were dormant or demanding (Willemse et al., 2003) (Gottlieb et al., 2003)(Karaöz et al., 2004)(Jorritsma & Vries, 2003)(Hoogerbrugge et al., 2023). In total only seven dormant and six demanding stakeholders were found in the other case studies. All the case studies are looking back on already completed standardisation efforts, which could be an explanation for the identification of the stakeholder types. When looking back on a completed process more information is available about the real motives or strategies of the stakeholders, which they may hide in an earlier stage to get a competitive advantage or to prevent other stakeholders from getting this advantage. In developing countries van de Kaa and Greeven (2017a) discovered that governmental institutions are able to be definitive stakeholders and can contain urgency, which may be an interesting topic for future research.

Comparison with theoretical standardisation modes

Committee-based standardisation involves committees shaping and documenting solutions collectively. This mode aligns with classification societies that collaborate with the industry to develop inclusive technical standards. The key concepts of inclusiveness and openness are reflected in classification societies, where standards should be applicable to all parties and not favour specific technologies or producers. However, classification societies ultimately choose and impose the standards, resembling a government-based approach. Market-based standardisation occurs when individual companies compete in the market based on decisive factors. This mode primarily takes place during the diffusion phase of a standard. While there is currently only one commercially active company, the classification society adjusts standards when multiple technologies exist to prevent technological lock-in. This form of standardisation does not fit into the predominant modes. Government-based standardisation involves lobbying efforts to influence the standardisation process. This mode is dominant in the approval phase of a standard, however the lobbying activities already start at the problem/idea phase. For environmental standardisation, the approval phase is dominated by government institutes, which would indicate a government based mode. However, it seems that all the flag states come together and join in a consensus driven meeting, which is in line with a committee based mode.

The described processes all represent multi-mode standardisation in general. Depending on the phase of the process, different standardisation modes are identified. In the case of carbon capture in the maritime sector, the influence can primarily be exerted through lobbying, especially regarding standardisation processes where government agencies play a significant role. Consortia play an important role in this context, as they bring together key stakeholders to align standards with each other. Once a new technology is developed, traction is gained by engaging with a classification society, enabling them to organise rapid temporary approval of the technology and allowing companies in the development phase to adhere to standards in the market. This initiates a market-based standardisation process and potentially offers an early advantage for actively lobbying companies such as Value Maritime.

5.2 Validity

As described in the theory section and supported by the citation analysis, the initial stakeholder identification and classification method proposed by de Vries et al. is mostly reliable with only a few criticisms. Additionally, this research is limited to the single case study of onboard carbon capture, and therefore, the results cannot be directly generalised. Nevertheless, the role of certain stakeholders such as the IMO and classification societies in the maritime sector has been highlighted in a manner that suggests its applicability to other sustainability cases within the maritime sector. Particularly, Part 3: standardisation presents findings that are expected to hold true for similar cases such as biofuels since the identified approaches and dynamics of the IMO and classification societies are expected to remain consistent. Regarding the sources used, it can be argued that company and industry reports may exhibit bias, and the same applies to the interviews conducted mainly with commercial entities. However, by incorporating government reports such as IMO published documents and identifying trends across the various interviews, the selected sources can still be considered valid. Yet it is somewhat regrettable that

no organisations that are operating exclusively outside of Europe were consulted, as their perspectives would have provided additional insights into the overall trends surrounding carbon capture.

5.3 Reflection

Assessment of the methodology

The methodology of de Vries et al. (2003) was relatively easy to apply which was also confirmed by other authors (Willemse et al., 2003) (Gottlieb et al., 2003)(Karaöz et al., 2004)(Jorritsma & Vries, 2003) . The search categories from part 1 were clear and only required a little tweaking for the maritime industry. The first parts were sometimes somewhat broad, which resulted in a non-chronological working order. After creating part 3 and adding an extra step to identify existing and required standards, it was found that this should be the first step of the whole methodology. One of the reasons why this happened was an agile way of working during the writing of this thesis. The dependency on the response and planning of the interview participants are an example why agile working was required. Therefore, the chronological ordering of all steps were sometimes challenging. However, by adding the very detailed approach per step, now the methodology seems easy applicable and less thinking is required in the early stages.

Because the international nature of the research, Part 1 led to a very extensive list of actors worldwide. This complicated part 2: stakeholder classification in a way that there was to much information required to classify all identified actors. This could be improved by scoping and put focus on one country. During this research this challenge was solved by using categories such as ship owners, instead of detailed organisations.

Part 3 of the methodology was a completely new and challenging aspect, requiring significant effort because it involved the development of a novel iterative method during the thesis writing. Step 9 aimed to identify bottlenecks in the process, which proved particularly difficult due to the goal of creating a generic methodology applicable to various types of standardisation. Mapping the process underwent several iterations, with the main finding being the importance of initially mapping an overall main process to gain a comprehensive understanding. However, to pinpoint bottlenecks, it was necessary to visualise time components or recurring activities. After multiple attempts, a detailed level of sub-processes involving various organisations was required to effectively identify the bottlenecks. No bottlenecks related to the quality of the documents or feedback topics have been identified. Although the process has been deemed slow, it could be argued that the constant revision of proposals leads to an overall improvement in quality, regardless of the time it takes. To gain a better understanding of metrics, further research into the relationship between standard development time, standard quality, and their mutual influence would be highly beneficial. Additionally, there are more Key Performance Indicators (KPIs) that remain untested due to the current stage of the process. The future development of linking KPIs, identifying bottlenecks, and connecting them to strategies would enhance the methodology and present an intriguing avenue for exploration.

Master programme MOT

This thesis was written in accordance with the requirements of the master Management of Technology at the Technical University Delft. The program's emphasis on the intersection of management and technology provides a fitting framework to understand the strategic importance of standardisation and its implications for especially sustainable environmental innovation. Moreover, the program's focus on fostering leadership skills and technological expertise equips graduates with the ability to drive transformative change in industries, which in this case is the maritime sector. The thesis shows the impact of standardisation on environmental innovations and gives firms insights in how to influence these processes, which may lead to competitive advantage and the useful utilisation of their resources. This strategical positioning for innovation is in line with one of the main criteria of the Master: Using technology as a corporate resource. This all was executed by using a scientific based methodology based on academic standardisation theory, that forms another link with the program.

Within the Master's program, two specific courses hold considerable relevance to this thesis: "Technology Battles" and "Digital Business Process Management." The "Technology Battles" course provides a comprehensive introduction to market-based standardisation, where companies compete to establish a dominant design that becomes the prevailing industry standard. This course played a pivotal role in kickstarting the ideation phase of the thesis. On the other hand, the "Digital Business Process Management" course, offered during the first year of the MOT-program, proved invaluable in refining the developed methodology and culminating in the final step of Part 3. This course delved deeply into the analysis and visualisation of business processes that gave tools to effectively map existing standardisation processes. Moreover, the academic literature from this course played a crucial role in identifying bottlenecks within these processes.

Academic contributions

This study makes a substantial contribution to the existing body of literature on standardisation, as well as to the field of stakeholder theory. The replication of the existing method proposed by de Vries et al. (2003) enhances its validity and offers researchers a framework for further investigations, while simultaneously allowing for necessary improvements. The theory was tested in the Maritime industry, which had previously not been explored in standardisation literature.

Where, (de Vries et al., 2003) (2003) created a useful methodology, some adjustments were made to facilitate the use in sectors beyond the IT industry. By creating intermediate steps for Part 1: identification and Part 2: classification together with model questions, the methodology has become even easier to replicate. Aside from these small adjustments, the real contribution lies in part 3: standardisation process. This part introduces a novel methodology for systematically mapping the standardisation process across different phases. A notable gap in the existing literature is the lack of a clear visual representation illustrating the various phases of standardisation, the dynamics of the involved stakeholders and bottlenecks. While different phases have been described, a comprehensive visual overview that encompasses the entire standardisation process and highlights the roles played by different actors is currently absent. To compose this complex standardisation map, Part 1 identification, part 2 classification and part 3 standardisation process, were all combined. Due to the process used in part 1 (identification), stakeholders could be sorted on their organisational type such as NGO's, firms and government bodies, which helped in a later stage to identify the specific mode and selecting appropriate strategies to influence the respective stakeholders. By adding the degree of salience from part two and through the use of a specific colour schemes, relations between stakeholders could be identified in the standardisation map. This additionally helps with identifying bottlenecks such as, non-urgent stakeholders that are gatekeepers in a consensus process.

Implications

A manager can utilise this research to identify and classify important stakeholders in a standardisation process, following a relatively simple step-by-step approach. Additionally, by mapping out the standardisation process based on academic fundamentals, the manager can gain valuable insights into stakeholder dynamics within the standardisation process. Based on the stakeholders and their dynamics, a company can choose specific strategies such as lobbying to work more effectively. This enables more accurate identification of the necessary resources and personnel dedicated to the lobbying process. Additionally, mapping out the standardisation process can identify potential bottlenecks at an early stage, such as consensus-based processes involving government institutions.

Given the crucial role of inclusiveness and openness in standardisation, and the lack of adequately represented or overlooked stakeholders, this research could be beneficial for Standard Development Organisation. The proposed method in this thesis can play a significant role in ensuring the participation of the appropriate stakeholders, by identifying and classifying them. For policymakers, this research provides insights into the stakeholders who are genuinely impacted by a standard, enabling them to produce more targeted policies.

Limitations

One limitation of the applied methodology is the assessment of power. Power, as defined, refers to the capacity to influence outcomes for other stakeholders (Mitchell et al., 1997)(de Vries et al., 2003)). The current determination of power is based on factors such as financial resources, technical expertise, and position within the network. However, it should be noted that certain stakeholders, such as legislative bodies, may hold a unique form of power through their authority to shape processes via regulations and laws. In this context, these authorities may possess an absolute power, which was not identifiable by following the pre-defined resource based view.. Consequently, the methodology's limitation arises from the possibility that a stakeholder could receive a lower combined score in terms of financial resources, technical expertise, and network position, even though they possess significant power in reality.

Another limitation of part 2: classification is the assignment of attributes to broad categories. This practice can potentially lead to a distorted understanding of the significance of specific organisations. For instance, it is generally assumed that research and design entities possess legitimacy, while the firm Conoship indicated possessing both legitimacy and a sense of urgency. This may lead researchers to false assumptions and or conclusions.

A final limitation identified in this study is the anonymity of the interview participants. Replicating this research would have been more convenient if the participants were identified by name and affiliated organisation. However, due to the presence of sensitive information, and the participant preferences, alternative options were not viable. Given the novelty and emerging nature of onboard carbon capture, strategic information was deemed of considerable importance and expected to be classified. Nevertheless, the experiences and categories of the participants are extensively described, making replication in our opinion feasible.

6 | Conclusion & Future research

Main research question

This research aimed to get insights in stakeholders dynamic within the standardisation process of carbon capture in the maritime industry. To find an answer, the following question was created:

"How do onboard carbon capture stakeholders influence the standardisation process in the maritime industry?"

To find a concise answer three different aspects of standardisation where investigated:

1) Identification. there where 87 unique stakeholders identified across eight categories. The production chain category had the highest representation, with multinational companies and start-ups identified. Projects were primarily concentrated in Japan, the Republic of Korea, Norway, and the Netherlands. The majority of stakeholders were located in Europe, with a smaller representation from other continents. International organisations accounted for nine stakeholders. Stakeholders from Japan and South Korea were relatively low compared to their project and fleet sizes.

2) Classification: The stakeholder analysis of onboard carbon capture standardisation reveals important stakeholders, including governmental bodies, classification societies, shipping companies, ship owners, and technology providers. Ship owners, shipping companies, and technology providers are dependent stakeholders relying on governmental support. Despite government efforts, there is limited urgency in implementing onboard carbon capture technology. Stakeholders primarily demonstrate legitimacy, with some serving as observers. Non-stakeholders provide financial incentives but do not contribute directly to standardisation.

3) Standardisation process: The maritime sector has a distinct approach to standardisation compared to established institutions like ISO, CEN, and NEN. Instead of relying on traditional bodies, the sector emphasises industry initiatives and consortia. Two standardisation processes are identified: safety/functional and environmental standardisation. In safety/functional standardisation, classification societies dominate the approval phase and collaborate with dependent stakeholders such as OEMs. This process is swift and largely influenced by for-profit firms, excluding ISO. The iterative nature of the process allows for the inclusion of new technologies, ensuring the standards' ongoing relevance and preventing market lock-in. Environmental standardisation involves fewer for-profit organisations and is led by governmental bodies. Dependent stakeholders initiate the process and rely on representative organisations to engage with flag states. Flag states and international organisations with consultative status to the IMO play a key role, while stakeholders with only legitimacy are underrepresented. The approval phase in this process is consensus-driven, involving multiple stakeholders and leading to a slower process compared to safety/functional standardisation. During key decision moments, the stakeholders that acted as gatekeepers lacked urgency. This was identified as major bottleneck. The distinct approach of the maritime sector highlights the significance of industry initiatives and consortia, with variations between safety/functional and environmental standardisation processes.

The described processes exhibit multi-mode standardisation. Lobbying plays a significant role in influencing standardisation processes involving government agencies, especially in the maritime sector's carbon capture context. Consortia facilitate stakeholder alignment while, engagement with classification societies allows for rapid approval and adherence to market standards, benefiting actively lobbying companies like Value Maritime. The Republic of Korea submitted the first onboard carbon capture proposal in 2021. Collaborating with Japan, Norway, China, and Liberia in 2023, they achieved success with its inclusion in the MEPC ISWG-GHG 16 working group. China and Liberia oppose new decarbonization targets but support onboard carbon capture, potentially to continue using fossil

fuel-based ships. Representative organizations like ICS and IACS play influential roles at the IMO. The closed nature of the IMO hinders transparency, posing a challenge in identifying opposition to carbon capture at the MEPC. Therefore, a simplified answer to the main question would be: by lobbying at OEM and shipping branch organisations and setting up early collaborations with classification societies and consortia.

Future research

One direction for future research could be extending the designed methodology and test it on different cases. Alternative fuels are heavily discussed by all interviewees. They compare onboard carbon capture with the fuels because all are relative new innovative technologies with the goal to decarbonize. Standardisation for alternative fuels seems also to be lacking in the maritime industry. The implementation of an alternative fuel could be an example of an interesting case to test the methodology on.

Further research into the relation between stakeholder salience and bottlenecks in a standardisation process would be an interesting topic. This research primarily identified the lack of urgency as obstacle to further proceed in a process. However, it would be interesting to know how this applies to other standardisation processes. The link between the three different parts could be further enhanced, so that managers can even easier establish appropriate strategies to influence a standardisation process. A bottleneck was now identified in the process however, the exact solution to overcome this bottleneck is not directly verified. How to overcome identified bottlenecks and possibly find the root cause of these bottlenecks would be very interesting to know, especially for managers who want to influence a standardisation process efficiently.

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A | Interview documents

A.1 Data management Plan

Data storage locations and methods.

Tab. A.1. Data overview of interviews

Type of data	File format(s)	How will data be collected?	Purpose of processing	Storage location	Who will have access to the data
Anonymous Interview notes of stakeholder information on maritime carbon capture	.docx	Handwritten on paper or/and PC	To map all stakeholders in maritime carbon capture	Onedrive of TU Delft	The researcher, G. van de Kaa
Preparation document with interview questions	.docx	Based on standardisation and stakeholder literature, Written on PC	For consistent interviews	Onedrive of TU Delft	The researcher, G. van de Kaa
List of interview participants	.csv	Via an external advisor, proffessional network and myself	For traceability purposes and organising the interviews	Onedrive of TU Delft	The researcher, G. van de Kaa
Consent document	.docx	From TU Delft Template	Obtaining proof of consent	Onedrive of TU Delft	The researcher, G. van de Kaa
Audio recordings	.rec	Via Teams recording and mobile phone	To map all stakeholders in maritime carbon capture	Onedrive of TU Delft	The researcher, G. van de Kaa
transcriptions	.docx	Via Teams recordings and mobile phone	For interview analysis	Onedrive of TU Delft	The researcher, G. van de Kaa

Plan Overview

A Data Management Plan created using DMPonline

Title: Master Thesis: Carbon Capture in the Maritime Industry, Stakeholders setting standards

Creator: Tim van den Eertwegh

Principal Investigator: Tim van den Eertwegh

Data Manager: Tim van den Eertwegh

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2021)

Project abstract:

The primary purpose of this research is to investigate the influence of stakeholders on standardisation processes. In specific, in the maritime carbon capture industry, where currently no clear regulations are available. A sub-goal is to explore stakeholder relevance and their relationships. Another sub-goal is the clarification of the current standardisation process (mode) within the maritime industry.

ID: 118630

Start date: 13-02-2023

End date: 03-07-2023

Last modified: 12-04-2023

Master Thesis: Carbon Capture in the Maritime Industry, Stakeholders setting standards

0. Administrative questions

1. Name of data management support staff consulted during the preparation of this plan.

My faculty data steward, Nicolas Dintzner, has reviewed this DMP on 03-03-2023.

2. Date of consultation with support staff.

2023-03-03

I. Data description and collection or re-use of existing data

3. Provide a general description of the type of data you will be working with, including any re-used data:

Type of data	File format(s)	How will data be collected (for re-used data: source and terms of use)?	Purpose of processing	Storage location	Who will have access to the data
Anonymous Interview notes of stakeholder information on maritime carbon capture	.docx	Handwritten on paper or/and PC	To map all stakeholders in maritime carbon capture	Onedrive of TU Delft	the researcher, G. van de Kaa
Preperation document with interview questions	.docx	Based on standardisation and stakeholder literature, Written on PC	For consistent interviews	Onedrive of TU Delft	the researcher, G. van de Kaa
List of interview participants	csv.	Via an external advisor, proffessional network and myself	For traceability purposes and organising the interviews	Onedrive of TU Delft	the researcher, G. van de Kaa
Consent document	.docx	From TU Delft Template	Obtaining proof of consent	Onedrive of TU Delft	the researcher, G. van de Kaa
Audio recordings	.rec, .mp4	Via microsoft Teams and iphone	To map all stakeholders in maritime carbon capture	Onedrive of TU Delft	the researcher, G. van de Kaa

4. How much data storage will you require during the project lifetime?

- < 250 GB

II. Documentation and data quality

5. What documentation will accompany data?

- Methodology of data collection

III. Storage and backup during research process

6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?

- OneDrive

IV. Legal and ethical requirements, codes of conduct

7. Does your research involve human subjects or 3rd party datasets collected from human participants?

- Yes

8A. Will you work with personal data? (information about an identified or identifiable natural person)

If you are not sure which option to select, ask your Faculty Data Steward for advice. You can also check with the privacy website or contact the privacy team: privacy-tud@tudelft.nl

- Yes

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

If you are not sure which option to select, ask your Faculty Data Steward for advice.

- No, I will not work with any confidential or classified data/code

9. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question. If this is not the case, you can use the example below.

This is an internal TU Delft Master project, which is only supported by Value Maritime.

10. Which personal data will you process? Tick all that apply

- Other types of personal data - please explain below
- Data collected in Informed Consent form (names and email addresses)

Quotes and audio recordings from the experts

11. Please list the categories of data subjects

Maritime industry experts

12. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?

- No

15. What is the legal ground for personal data processing?

- Informed consent

16. Please describe the informed consent procedure you will follow:

Template 1 of TU Delft, with providing a broad explanation

17. Where will you store the signed consent forms?

- Same storage solutions as explained in question 6

18. Does the processing of the personal data result in a high risk to the data subjects?

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply).
If two or more of the options listed below apply, you will have to complete the DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to receive support with DPIA.
If only one of the options listed below applies, your project might need a DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to get advice as to whether DPIA is necessary.
If you have any additional comments, please add them in the box below.

- None of the above applies

22. What will happen with personal research data after the end of the research project?

- Other - please explain below
- Anonymised or aggregated data will be shared with others

Personal data will be preserved for 2 years inside TU Delft on a secure storage. Personal data: list of participants with contact information.

23. How long will (pseudonymised) personal data be stored for?

- Other - please state the duration and explain the rationale below

Personal data stored up to three years.

24. What is the purpose of sharing personal data?

- Other - please explain below

Personal data not to be shared.

25. Will your study participants be asked for their consent for data sharing?

- Yes, in consent form - please explain below what you will do with data from participants who did not consent to data sharing

Only store the data and put this in a non-share folder.

V. Data sharing and long-term preservation

27. Apart from personal data mentioned in question 22, will any other data be publicly shared?

- I do not work with any data other than personal data

29. How will you share research data (and code), including the one mentioned in question 22?

- My data will be shared in a different way - please explain below

Interview preperation document, interview notes and ICF will be shared in Master Thesis.

30. How much of your data will be shared in a research data repository?

- < 100 GB

31. When will the data (or code) be shared?

- As soon as corresponding results (papers, theses, reports) are published

32. Under what licence will be the data/code released?

- CC BY

VI. Data management responsibilities and resources

33. Is TU Delft the lead institution for this project?

- Yes, leading the collaboration - please provide details of the type of collaboration and the involved parties below

The research is partly completed at the company Value Maritime.

34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?

Chair of graduation committee: Dr. G. van de Kaa

35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

No additional financial resources are required. It will be the data of about 10 experts, wherein data processing time is included during the Thesis period.

A.2 HREC

A.3 B. Informed consent form

"Carbon Capture in the Maritime Industry, the role of stakeholders in standardisation."

You are being invited to participate in a research study titled 'Carbon Capture in the Maritime Industry, the role of stakeholders in standardisation'. This study is being done by T. van den Eertwegh from the TU Delft, supervised by Dr. G. van de Ka and made in collaboration with Value Maritime.

Consent Form

I, _____, hereby freely and voluntarily give my consent to participate in the interview about carbon capture stakeholders and their relationships, in the maritime industry.

I understand that my participation in this study is entirely voluntary and I can withdraw at any time without any penalty.

I understand that the interview may be recorded with both audio and video. All recordings of the meeting will be treated as confidential by the research team and will only be accessed by the research team (Dr. G. van de Kaa, and Tim van den Eertwegh)

I understand that I have the right to consult, rectify, and request the deletion of any and all personal data about my participation. I can consult with the principal investigator should I have any further questions about the handling of personal data during this project.

I understand that the information/quotes I provide will be used as part of a Master Thesis.

I understand that my name and contact information will be stored in internal TU Delft databases for 3 years. We may use this information to contact you for clarification or more research activities in standard implementation and development in the maritime industry.

Interview notes of the interview will be produced, and such non-personal data will be made available publicly via the TU Delft Repository. I understand I have the right to review the interview notes before its publication.

Date: _____
Participant's signature: _____

Researcher: Tim van den Eertwegh
Email: t.vandeneertwegh@student.tudelft.nl

Thesis Supervisor: Dr. G. van de Kaa
Email: G.vandeKaa@tudelft.nl

A.4 C. Interview questions

Interview Questions: Carbon Capture in the Maritime Industry, the role of stakeholders in Standardisation.

Research topic description: The purpose of this research is to add to stakeholder and standardisation theory by studying the complex maritime stakeholder environment concerning standardisation for chemical absorption based carbon capture on ships. The research tries to find an answer for the following question:

"How do onboard carbon capture stakeholders influence standard development in the maritime industry?"

Introduction

1. Have you seen and accepted the Informed Consent Form? [*Ref: B. Informed Consent Form]*
2. What is your e-mail address?
3. What is your name?
4. At what organisation do you work?
5. What is your function?

Part 1: Stakeholder Identification

6. What is your organisations relationship with onboard carbon capture technology?
7. Under which category do you classify your organisation? (show the predetermined categories and specifically ask if there may be any other category)
8. In your opinion, who are the key stakeholders in the maritime carbon capture industry, and what role do they play?

Part 2: Stakeholder Classification

Power:

9. As a stakeholder in the maritime carbon capture industry, what are your main priorities and goals in relation to this technology?
10. What is your financial position according to onboard carbon capture? (availability of funds)
11. Who are your direct partners? (Onboard Carbon Capture stakeholders)
12. Who are your direct competitors? (Onboard Carbon Capture stakeholders)
13. How is/was the power divided between your partners?
14. Which stakeholders do have the most power and why?

Legitimacy:

15. How do the other stakeholders accept or support your participation in the technology?
16. Which stakeholders do have the most legitimacy and why?

Urgency:

17. To what extend have you been active in pursuing your goals regarding this standardisation issue?
18. Which stakeholders do have the most urgency and why?
19. How do you see the role of stakeholders evolving in the maritime carbon capture industry over the next 5-10 years, and what impact do you expect this to have on the industry as a whole?

Part 3: Standardisation

20. How are standards being developed in the maritime industry?
21. What kind of standards do you believe are necessary for onboard carbon capture?
22. How are standards being developed for Onboard Carbon Capture?
23. Can you describe how your organization is influencing maritime standardisation?

Finalization

24. Can you share any relevant research or analysis on the potential benefits and challenges of OCC for the maritime industry?
25. May we contact you in the future after processing the interview by phone, email or otherwise and present the results of the interview to correct misinterpretations or other details?

A.5 D. Interview guidance document

Interview Guidance: Carbon Capture in the Maritime Industry, the role of stakeholders in Standardisation

goal

The goal of this document is to provide information and guidance for the interview questions about the roles of stakeholders in maritime standardisation. The semi-structured interview consists out of 3 parts:

Part 1: Stakeholder identification
Part 2: Stakeholder classification
Part 3: Standardisation

Background

There is a strong desire to meet decarbonisation targets in a technically short period of time. Especially with the implementation of the EU-ETS system, the maritime industry needs guidance from policy and standards now. The creation of new standards is a time consuming process. Some stakeholders in onboard carbon capture technology want to speed up standardisation. An example of a stakeholder is the company Value Maritime. Value Maritime claims to already have a functional CO2 capture system in use, so it is critical for their business and customers that rules and regulations align as soon as possible. Together with shipping companies and other stakeholders, they are now trying to speed up the creation of maritime standardisation. Standardisation however is a complex process and in the maritime industry concerned with many stakeholders. Due to the unique operational and technical characteristics of ships, land-based standards cannot directly be applied. Therefore, action is required from relevant stakeholders to develop carbon capture standards in the maritime context. However, who the stakeholders are, where to find them and how standardisation exactly works in the maritime industry are not clear.

Part 1: Stakeholder identification

Because search categories within standardisation may vary significantly, the first step is to investigate if there are missing categories besides the nine categories as defined by Vries et al. (2003). For this research the context is defined by: chemical absorption based carbon capture for sea going vessels. The search categories have been discussed with three experts and the below was extracted.

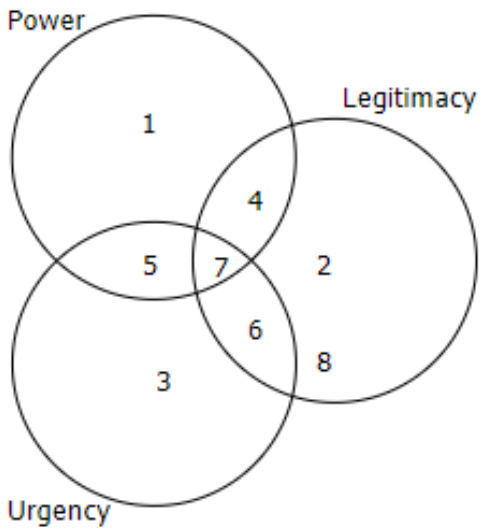
Category	Description	Examples (maritime)
Production Chain	suppliers, trans-porters, and trade companies	Suppliers, Ports, OEM, Shipyards
End Users and related organizations	large companies, small-and medium sized enterprises, public organizations and individual employees	Shipping companies, Charterers
Designers & engineering	designers of the product the standards relates to, such as specialized companies	Engineering firms,
Physical system	producers to ensure compatibility with other technical systems	
Inspection agencies	dedicated organizations, certification bodies, testing laboratories or government enforcement agencies	Classification societies
Regulators	governmental bodies	IMO, flag state, port state
Research and consultancy	universities, research institutes, and consultants	
Education	educational programs for student sand professionals	
Representative Organisations	labor unions, consumer organizations, professional organizations and branch of business organizations	Charterer, associations, Climate institutes, NGO
Service providers (financial)		Investors /bankers/insurance companies

Part 2: Stakeholder classification

To help managers assess stakeholder relationships Mitchell et al. (1997) created a salience model based on three possible stakeholder attributes: power, legitimacy, and urgency.

- **Power:** Power refers to the power of a stakeholder to influence a firm (or in this case, the standardisation process or the success of the resulting standard). Power is concerned with the level of authority or the ability to influence the outcomes by having specific resources. The main identified resources are: Financial resources, Time available, technical expertise, position in the network of firms.
- **Legitimacy:** The appropriateness of the involvement (socially accepted structures or behaviours)
- **Urgency:** Need for immediate attention, either time-constrained or relating to the stakeholders' high stakes outcome (time sensitive, critical)

There are different combinations of the attributes available which are defined by 8 typologies as shown in figure 1. Together they form the stakeholder salience. Definitive (nr 7) stakeholders do have the highest salience and form important stakeholders in the standardisation process.



De stakeholders worden als volgt benoemd:

1. Dormant Stakeholder
2. Discretionary Stakeholder
3. Demanding Stakeholder
4. Dominant Stakeholder
5. Dangerous Stakeholder
6. Dependent Stakeholder
7. Definitive Stakeholder
8. Non-stakeholder

Figure 1, Stakeholder salience (Mitchell 1997)

Part 3: Standardisation

There are different types of standards and standardisation processes. The literature defines three modes: Committee based, market based and Government based. A combination of the modes is referred to as: multi-mode standardisation. The characteristics of the modes are shown in the figure below.

Ideal-typical modes of standardisation – characteristics (source: authors' own summary of literature).

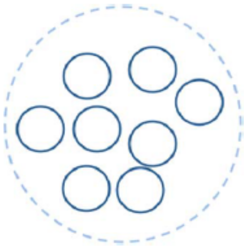
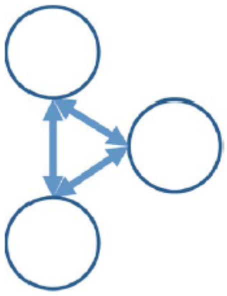
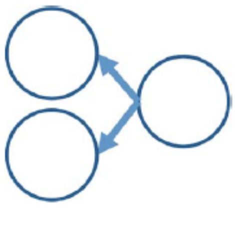
	Committe-Based Standardisation	Market-Based Standardisation	Government-Based Standardisation
Relationships between actors			
Coordination mechanism	Coordination through *cooperation* between stakeholders. Standards are developed in committees and only diffused if members agree on a common solution.	Solutions intended as a standard can be developed by anyone. Coordination through *competition* between solutions in the market, leading often (but not always) to one de-facto standard.	Solutions intended as a standard can come from various sources. Coordination through governments using their *hierarchical position* to impose these standards' use on others.
Timing of coordination	Coordination takes place during standard *development* – only one solution is chosen to enter the market.	Coordination takes place during *diffusion* – different standards are developed and compete with each other.	Governments can intervene in development or mandate using an already developed standard.
Main actors driving the standardisation process	Predominantly private Stakeholders cooperating in committees; SDOs providing a platform for standard development.	Predominantly private Individual market actors influencing the outcome of the market competition with their actions.	Predominantly public Governmental bodies developing standards and/or enforcing their use.
Avenues of influence	Participating in committees to influence standards' contents.	Engaging in the market to influence battles' outcomes by influencing decisive factors.	Influencing government decision-making through lobbying or parliamentary representatives.
Inclusiveness in standard development	High, any interested party can join a commitee.	Varies, some standard development venues are open; access to others is restricted.	Medium, lobbying may require high effort.
Examples of empirical research	Leiponen (2008), Mattli and Büthe (2003), Tamm Hallström and Boström (2010), Tate (2001)	den Uijl (2015), Schilling (2002)	Farina et al. (2005), Schmidt and Werle (1998)

Figure 2, Standardisation modes (Vries 2003)

B | Interview documents

B.1 Interview participants

Tab. B.1. Interview participants

Nr.	Category	Function	Experience
I1	Representative organization	Sector Manager	Advocate for the Dutch maritime manufacturing industry, in the areas of environment and climate. Dealing with policy development, regulation, development at three levels actually, in the Netherlands, in the EU, and at the IMO.
I2	Port	Senior Business development manager	Business economics background and worked at a major storage tank company in the Netherlands, worked as an account manager for different commodity segments and developed many digital solutions at the port. Now senior business development manager with focus on the maritime energy transition.
I3	Shipyard	Principal research engineer	The participant possesses a solid background of ten years of engineering experience at a prominent shipyard, of which five years in the role of principal research engineer. Currently, endeavours are directed towards the decarbonization efforts and the transition away from fossil fuels. Additionally, explores simulation packages and model-based system engineering to enhance skills in dealing with emerging technologies.
I4	Engineering	Lead Naval architect	In the lead of sustainability within the organisation, which encompasses both research and development activities as well as commercial aspects, including sales. Additionally, the participant serves as the coordinator and supervisor for internship and handles a portion of quality management and administration.

I5	Classification Society	Classification manager	Functioning as liaison between the classification society and various flag administrations. Thereby, responsible for the continuation of the development of international standards as part of the delegation of the Netherlands at IMO meetings. Before, the participant had experience as senior policy advisor and was responsible for the development, implementation and interpretation of both national and international legislation for construction, stability and fire safety for all seagoing vessels.
I6	Engineering	Naval Architect at R&D Department	At this organisation the primary focus lies on developments related to sustainability in the maritime industry. This includes various aspects such as CO2 capture, wind propulsion, hydrogen, and other forms of emission-free or low-emission propulsion methods. The focus of the participant lies mainly on CO2 capture and wind propulsion. Additionally, the participant has a background in designing carbon capture systems.
I7	NGO	Project leader (clean shipping)	The participant has a background in environmental policy and gained experience at the Clean Shipping Index in Sweden, which functions as an independent and comprehensive labelling system that evaluates the environmental performance of ships. Daily business in the participant's current position is working towards a more sustainable shipping industry – i.e. trying to reduce shipping emissions to both air and water.
I8	Technology producer	Regulatory management adviser, maritime energy transition	This participant has experience at sea as a Maritime Officer, and thereafter held various (management) positions in the maritime sector, both at a classification society and a shipping company/maritime service provider.

B.2 Interview summaries

B.2.1 I1

Interview Questions: Carbon Capture in the Maritime Industry, the role of stakeholders in Standardisation.

Research topic description: The purpose of this research is to add to stakeholder and standardisation theory by studying the complex maritime stakeholder environment concerning standardisation for chemical absorption based carbon capture on ships. The research tries to find an answer for the following question:

"How do onboard carbon capture stakeholders influence standard development in the maritime industry?"

Introduction

1. **Have you seen and accepted the Informed Consent Form? [*Ref: B. Informed Consent Form*]**
   Yes
2. ~~**What is your e-mail address?**~~
3. ~~**What is your name?**~~
4. **At what organisation do you work?**

Representative organization in the Dutch Maritime industry

5. **What is your function?**

Advocate for the Dutch maritime manufacturing industry, in the areas of environment and climate. Dealing with policy development, regulation, development at three levels actually, in the Netherlands, in the EU, and at the IMO.

Part 1: Stakeholder Identification

6. **What is your organisations relationship with onboard carbon capture technology?**

Serving the interests of members that do focus on Onboard Carbon Capture, which comes up regularly in the work I do. I'm trying to make it a hot topic because not everyone is aware of it yet.

7. **Under which category do you classify your organisation? (show the predetermined categories and specifically ask if there may be any other category)**

Representative Organisation 100% fit

8. **In your opinion, who are the key stakeholders in the maritime carbon capture industry, and what role do they play?**

Technology providers, shipping companies, regulators and financing. Because these four stakeholders need to be aligned to quickly develop a technology.

Part 2: Stakeholder Classification

Power:

9. **As a stakeholder in the maritime carbon capture industry, what are your main priorities and goals in relation to this technology?**

> Serving interests of our members and facilitating business opportunities. Lobbying on a national, European and International level to influence regulation and policy development for Onboard Carbon Capture. We are actively involved in the discussions and promoting topics related to climate, including Carbon Capture. It's commendable that we are actively engaged in promoting such initiatives. In Europe there is a scrubber manufacturers working group, which quite actively discusses carbon capture.

10. **What is your financial position according to onboard carbon capture? (availability of funds)**

> The income of the organization comes from members, every decision needs to represent members and time should therefore be adequately divided. Relatively speaking there is more time allocated to carbon capture.

11. **Who are your direct partners? (Onboard Carbon Capture stakeholders)**

> Three members: Alfa Laval, Value Maritime, VDL AEC. And thereby we talk a lot to shipping companies and the KNVR, actually they talk with the whole maritime industry.

12. **Who are your direct competitors? (Onboard Carbon Capture stakeholders)**

> No competitors, however organizations as Transport and Environment (T&E) which is an international environmental organization with about 20 IMO seats, do sometimes give opposite reactions to our stakes. For example discussions about the environmental effect of scrubbers.

13. **How is/was the power divided between your partners?**

> The organization provides networking for organizations in the maritime industry and are active in the maritime cluster. Within this cluster the organization plays a key role as they form a bridge between regulators, members and other organization. If you look at all branch organisations we are the one with the most power.

14. **Which stakeholders do have the most power and why?**

> In the Netherlands the KNVR as they represent shipping companies, the Government, in Brussel there are the European commission and Parliament and international there is the IMO. At last there are the ship financiers. Ship financing is very complex:
>
> "Certainly at the European level a compelling regulation is simply announced. And the financiers determine... What is a healthy business case and what is not? And that's where the... Suppliers and shippers... Rely on."

Legitimacy:

15. **How do the other stakeholders accept or support your participation in the technology?**

> If the members want it we facilitate, therefore acceptance is high. There is a lot of trust as we serve our members. There could however be some competition between members which may lead to less acceptance in specific .
>
> 'We have a strong presence and influence, especially here in the Netherlands, in Brussels, and at the IMO. When we advocate for important issues under the umbrella of our European associations, we are truly recognized as a significant knowledge source and a valuable conversation partner. While our recommendations may not always be immediately implemented, we are taken seriously, and our opinions are sought after. Governments ultimately make their own decisions, but they value our perspective as an organization and the views of our members'.

16. **Which stakeholders do have the most legitimacy and why?**

> Unknown, hard to answer

Urgency:

17. **To what extend have you been active in pursuing your goals regarding this standardisation issue?**

> Urgent on the agenda. The Dutch Government wants to create a fuel transition roadmap to 2050, together with input from all stakeholders in the maritime industry. Different working groups have been established of which carbon capture is not yet one. However, when sitting in the working group, carbon capture is advocated by us. The NMT was asked for advice and to join the working groups.

18. **Which stakeholders do have the most urgency and why?**

> Technology Providers as they invest money in the product and development. Shipping companies, because of the EU-ETS shipping companies are going to pay for their CO2. Therefore Carbon capture or another solution is pressing for their business case.

19. **How do you see the role of stakeholders evolving in the maritime carbon capture industry over the next 5-10 years, and what impact do you expect this to have on the industry as a whole?**

> The technology will probably develop without to many problems, however the process around it seems interesting. The CO2 utilization should be certified and should find a good solution. Thereby should it be made acceptable in the regulations.

	Financial	Technical expertise	Position in Network	Power to influence	Legitimacy	Urgency
NMT	N	(Indirect) Y	Y	Y	Y	Y
	Members pay, only 3 members are active	~ This is double, they act and collaborate with their members who do share their knowledge.	Networking organisation with not only national but also international ties.	Influences regulation and authorities	Acceptance is high due to representative function	Urgent on the agenda
KNVR	…	…	…	Y	...	…
Technology providers	N	Y	x	N	Y	Y
	Business case is still not fully viable	Inventor of the OCC systems		Dependent on regulation and investors		High because they put money in the development
Shipping companies (Users)	…	…	…	N	Y	Y
				Dependent on regulation	End user that must work together with the technology provider	EU-ETS make the companies pay for their CO2 emissions
Flag (the government)	…	…	…	Y	…	N
				Legislative authority		Primarily focus on fuel transition without OCC

Part 3: Standardisation

20. **How are standards being developed in the maritime industry?**

> On the national level at the Imo makes the most sense. An example from the scrubber industry, some countries prohibited open loop scrubbers and some don't. This results in an unbalanced playing field.

21. **What kind of standards do you believe are necessary for onboard carbon capture?**

> We want IMO to deliver or at least include onboard carbon capture in the environmental standard frameworks such as CII and EEXI. IMO doesn't' deliver, therefore the EU now takes its own measures such as the EU-ETS and FUEL EU maritime. 2 important things: Certification of the CO2 and how it should be processed. And the processed CO2 should be made available and allowed to utilize in all regions.

22. **How are standards being developed for Onboard Carbon Capture?**

> For carbon capture all three modes are required, at the moment of certification, an ISO or classification society would be required to determine the technical details in some sort of committee. Thereafter the market should embrace the technical details and then form some sort of consensus or choose how to proceed. There is some overlap because the market parties are also members of the previously described committees. And at last there is government based standardization, the government should be the final step and create regulations based on the input from the market. They use trusted organisations to advise them about the issues, and that is exactly what we are.

23. **Can you describe how your organization is influencing maritime standardisation?**

> Lobbying for the stakes of our members. Therefore, we regularly hold meetings to assess what is achievable, understand the perspectives of various stakeholders, and evaluate the state of technology. These discussions helps the government (EU, Dutch) determine feasible goals and gather input on preferences and positions.

Finalization

24. **Can you share any relevant research or analysis on the potential benefits and challenges of OCC for the maritime industry?**

> ...

25. **May we contact you in the future after processing the interview by phone, email or otherwise and present the results of the interview to correct misinterpretations or other details?**
Yes

Extra:

- We are affiliated with Sea Europe, a European umbrella organization that advocates for the interests of the European sector in Brussels. While we also engage independently, we collaborate closely with our European umbrella organization. Within this broader European network, numerous organizations are involved in Carbon Capture, including notable companies like Yara and EcoSpray. These companies are represented through their respective Associations (Danish). The membership base as a whole comprises various organizations actively engaged in Carbon Capture initiatives.
- Connection between scrubber OEMS and carbon capture providers, scrubber providers are discussing the possibilities. Mix between different countries, some have many green shipyards and other many scrubber providers, Sometimes this clashes and is representation on a European level hard.
- Process IMO: 184 members, NGO's, IGO's and member states can submit documents and talk during the gatherings. In the end the flag states (members) determine via consensus if submission may be approved or not. It is a very slow process
- At the International Maritime Organization (IMO), there are officially three types of entities. Firstly, there are the member states who ultimately make decisions. The number of member states varies, but it is estimated to be around 180 to 182. Secondly, there are non-governmental organizations (NGOs), which have their own seat within their respective umbrella organizations. Shipping companies also have their own organizations with seats, and there are environmental organizations with their own representation as well. Finally, there is a third category called intergovernmental organizations (IGOs).
- The workings of the IMO involve discussions among member states, and NGOs have the opportunity to participate actively. They can submit proposals and documents to suggest modifications or introduce new measures. However, it is ultimately the member states that have the authority to determine the outcomes. Voting does not take place at the IMO; instead, the emphasis is placed on achieving consensus. Agreement must be reached among the majority. In my eight years of involvement, I have never witnessed a voting process, although it is known to occur on occasion. Nevertheless, this topic may be better suited for casual conversation rather than academic discourse. The consensus-based approach is inherently logical and central to the IMO's functioning.

B.2.2 I2

Interview Questions: Carbon Capture in the Maritime Industry, the role of stakeholders in Standardisation.

Research topic description: The purpose of this research is to add to stakeholder and standardisation theory by studying the complex maritime stakeholder environment concerning standardisation for chemical absorption based carbon capture on ships. The research tries to find an answer for the following question:

"How do onboard carbon capture stakeholders influence standard development in the maritime industry?"

Introduction

1. **Have you seen and accepted the Informed Consent Form? [*Ref: B. Informed Consent Form*]**
   Yes
2. ~~**What is your e-mail address?**~~
3. ~~**What is your name?**~~
4. **At what organisation do you work?**

   A port

5. **What is your function**?

   Senior business development manager with a focus on the energy transition

Part 1: Stakeholder Identification

6. **What is your organisations relationship with onboard carbon capture technology?**

   We find ourselves in a position of following in terms of development. Consequently, we do not have a say in the activities that should take place aboard ships. Ultimately, our goal is to play a facilitating role. This entails being prepared as a port in terms of legislation and infrastructure to accommodate the potential implementation of technology at scale. This would allow for the discharge of captured CO2 in a port. Subsequently, it is up to the market to determine the course of action.

7. **Under which category do you classify your organisation? (show the predetermined categories and specifically ask if there may be any other category)**

   Production chain we unquestionably serve as a vital partner in the production chain.

8. **In your opinion, who are the key stakeholders in the maritime carbon capture industry, and what role do they play?**

   On the one hand the legislative powers: IMO and EU with their fitfor55 package. Technology providers, the technical development. Ship owners, they follow the legislators and have more options as long as the business case stands (this in collaboration with ship financiers). Alternate fuels also could be chosen by some of them. A fifth could be the ports to facilitate all activities. Certification and standardization is in this process also key which is done by classification societies.

Part 2: Stakeholder Classification

Power:

9. **As a stakeholder in the maritime carbon capture industry, what are your main priorities and goals in relation to this technology**?

   For now observing and advising whenever requested however, when the technology is more mature the organization will may have a facilitating role.

10. **What is your financial position according to onboard carbon capture? (availability of funds)**

    No direct financing is provided for onboard carbon capture

11. **Who are your direct partners? (Onboard Carbon Capture stakeholders**)

    Advising in the Everlong project and partner in the GCMD study with NPA and Singapore. Are active in many projects but mainly as observers.

12. **Who are your direct competitors? (Onboard Carbon Capture stakeholders)**

    …

13. **How is/was the power divided between your partners?**

    …

14. **Which stakeholders do have the most power and why?**

    IMO, EC, because they create the laws and regulations. Technology providers and Ship owners in the end need to follow IMO and the EC so are subject to them**.**

Legitimacy:

15. **How do the other stakeholders accept or support your participation in the technology?**

    Frequently gets request to advise and help thinking in developing the needed infrastructure. Public opinion is also important, the goal is a sustainable future.

16. **Which stakeholders do have the most legitimacy and why?**

    The different governments, as they represent society.

Urgency:

17. **To what extend have you been active in pursuing your goals regarding this standardisation issue?**

> The end goal is urgent and that is a more sustainable future and fulfilling the EU and IMO target (fitfor55 and more). We are reliant on achieving the ultimate goal of carbon neutrality. However, we are less dependent on the specific means by which we accomplish it.

18. **Which stakeholders do have the most urgency and why?**

> ...

19. **How do you see the role of stakeholders evolving in the maritime carbon capture industry over the next 5-10 years, and what impact do you expect this to have on the industry as a whole?**

> In my personal estimation, I believe that within the next five years, we will witness a combination of old and new methods. However, it is between 2040 and 2050 that I anticipate the real transition or significant leap taking place. This is purely a subjective assessment. Currently, when I observe shipbuilding programs, a portion of them is still being developed or equipped to operate on low-sulfur fuel oil. If we calculate the lifespan of these vessels, which is typically around 20 to 25 years, it brings us to the year 2050. It aligns with the established goals, which are also set for 2050. On the other hand, there is the emergence of Maersk's first methanol-powered vessel this year, indicating a contrasting outlook. I believe that over the next 25 years, we will be in a phase where various approaches diverge significantly. This complexity arises from the fact that the advancements in technologies, the required infrastructure, whether it's for bunkering new fuels or capturing CO2, or ensuring sufficient availability of biofuels or fully renewable fuels, will make the playing field considerably intricate over the next two decades.

	Financial	**Technical expertise**	**Position in Network**	**Power to influence**	**Legitimacy**	**Urgency**
Port	N	N	Y	N	Y	N
		Not concerning carbon capture	Crucial in supply chain	While we do not have the power to enforce, we do serve as a crucial link in the potential chain that emerges.	Other organizations often request for collaboration or advice	We benefit from achieving carbon neutrality, regardless of the specific means by which we accomplish it.

Part 3: Standardisation

20. **How are standards being developed in the maritime industry?**

> Not that familiar with.

21. **What kind of standards do you believe are necessary for onboard carbon capture?**

that is certification, both for technology and product. At some point, the EU-ETS (European Union Emissions Trading System) should also include provisions regarding onboard carbon capture, as land-based carbon capture is already recognized as a reduction measure. However, there is currently no mention or documentation regarding carbon capture at sea.

22. **How are standards being developed for Onboard Carbon Capture?**

…

23. **Can you describe how your organization is influencing maritime standardisation?**

…

Finalization

24. **Can you share any relevant research or analysis on the potential benefits and challenges of OCC for the maritime industry?**

Some projects and stakeholders: TNO, The Remarkable project (Shell and Aramco) And a study of the GCMD in Singapore

25. **May we contact you in the future after processing the interview by phone, email or otherwise and present the results of the interview to correct misinterpretations or other details?**
yes

Extra:

• Open loop scrubbers not accepted

B.2.3 I3

Interview Questions: Carbon Capture in the Maritime Industry, the role of stakeholders in Standardisation.

Research topic description: The purpose of this research is to add to stakeholder and standardisation theory by studying the complex maritime stakeholder environment concerning standardisation for chemical absorption based carbon capture on ships. The research tries to find an answer for the following question:

"How do onboard carbon capture stakeholders influence standard development in the maritime industry?"

Introduction

1. **Have you seen and accepted the Informed Consent Form? [*Ref: B. Informed Consent Form*]**
2. ~~**What is your e-mail address?**~~
3. ~~**What is your name?**~~
4. **At what organisation do you work?**

Major shipyard

5. **What is your function?**

Principal research engineer

Part 1: Stakeholder Identification

6. **What is your organisations relationship with onboard carbon capture technology?**

Observed and investigated the possibilities to integrate carbon capture on ships. Technology seems hard to implement so only tracking the technology now.

7. **Under which category do you classify your organisation? (show the predetermined categories and specifically ask if there may be any other category)**

Production chain, Design & Engineering and physical system

8. **In your opinion, who are the key stakeholders in the maritime carbon capture industry, and what role do they play?**

Shipping companies/owners (our customers), Technology needs to be available therefore technology providers also.

Part 2: Stakeholder Classification

Power:

9. **As a stakeholder in the maritime carbon capture industry, what are your main priorities and goals in relation to this technology?**

   No clear goals, only the target to become one of the most sustainable organisations in the maritime industry in 2030

10. **What is your financial position according to onboard carbon capture? (availability of funds)**

    Depends primarily on research subsidiaries and (RDM-subsidiary)

11. **Who are your direct partners? (Onboard Carbon Capture stakeholders)**

    Some suppliers asked for advice and information for the integration of carbon capture

12. **Who are your direct competitors? (Onboard Carbon Capture stakeholders)**

    No direct competitors because there is no direct link to carbon capture, but this could be a Conoship or other shipyards

13. **How is/was the power divided between your partners?**

    …

14. **Which stakeholders do have the most power and why?**

    A shipyard, can leverage power towards its customers, expressing preferences regarding the installation or non-installation of certain components. For instance, you may choose to install or not to install a specific technology based on perceived risks. This decision, of course, has implications for the acceptance of the technology as a whole.

    Implementing certain measures can involve significant costs, and therefore, there is a need for enforcement. In this context, the EU plays a crucial role as it strives to ensure that the IMO's efforts align with their expectations. As EU members, we are obligated to comply with the regulations set by the EU, and we cannot escape this responsibility.

Legitimacy:

15. **How do the other stakeholders accept or support your participation in the technology?**

    There have been requests for information by suppliers, and we are a large shipyard who is in most of the cases somehow involved.

16. **Which stakeholders do have the most legitimacy and why?**

…

Urgency:

17. **To what extend have you been active in pursuing your goals regarding this standardisation issue?**

Not active, only did explorative research into the topic

18. **Which stakeholders do have the most urgency and why?**

It seems that our competing shipyards are more actively engaged in these matters, and I am curious as to why they show greater enthusiasm or proactivity compared to us.

19. **How do you see the role of stakeholders evolving in the maritime carbon capture industry over the next 5-10 years, and what impact do you expect this to have on the industry as a whole?**

…

Part 3: Standardisation

20. **How are standards being developed in the maritime industry?**

> The approach being observed can be characterized as a combination of the left-leaning and moderate approaches. However, it is important to note that the regulatory framework lags behind these developments. The current regulations tend to respond to existing circumstances and determine the most suitable course of action. Subsequently, they are established based on those considerations.
>
> The classification societies have their own process for that, known as risk-based design. It is a process that they tailor to their own standards and levels, down to the detailed level

21. **What kind of standards do you believe are necessary for onboard carbon capture?**

> - I believe there are many aspects to consider, actually. Firstly, concerning CO2 accounting, how does the counting process work?
> - At second there is the onboard installation. So, how is CO2 handled in that context? I'm unsure. How is it stored, and in what form?
> - When it comes to CO2, certain safety measures need to be implemented. This includes considerations such as single-wall or double-wall containment systems. Another aspect is, if you want to dispose of the CO2, you would require a standard procedure. How and where would you store it in that case?

22. **How are standards being developed for Onboard Carbon Capture?**

> ...

23. **Can you describe how your organization is influencing maritime standardisation?**

> We are often involved in lobbying activities. There are various maritime clusters that one can join. We have a fairly prominent position and are typically present at the initiation stage of discussions and proposals. Consequently, we have the opportunity to provide valuable input and contribute to the refinement of the proposal

Finalization

24. **Can you share any relevant research or analysis on the potential benefits and challenges of OCC for the maritime industry?**
25. **May we contact you in the future after processing the interview by phone, email or otherwise and present the results of the interview to correct misinterpretations or other details?**
    Yes

Extra:

- We primarily work on European projects, as well as some Dutch projects. The RDM-subsidiary is a unique case in that regard. It has been quite some time since the Dutch government has utilized this type of funding approach.
- Here's how it works: a call for proposals is opened, and as companies, we need to form a consortium with other like-minded entities to respond to that call. Essentially, it relies on our existing network. However, if there are certain stakeholders that are not part of our network or if we are not familiar with a specific area or aspect of the project, it becomes more challenging to find suitable representatives for that particular part. Consequently, it is often observed that a relatively small inner circle of established connections is involved in these projects. However, efforts are made to actively search for stakeholders, as seen in the case of the Green Maritime Methanol initiative, for instance. They actively seek out and engage with relevant stakeholders.
- I'm not sure if CO2 capture is necessarily the optimal solution. In that regard, one could argue against it, stating that it serves as a plea to continue relying on fossil fuels. That serves as a counterargument to consider.

B.2.4 I4

Interview Questions: Carbon Capture in the Maritime Industry, the role of stakeholders in Standardisation.

Research topic description: The purpose of this research is to add to stakeholder and standardisation theory by studying the complex maritime stakeholder environment concerning standardisation for chemical absorption based carbon capture on ships. The research tries to find an answer for the following question:

"How do onboard carbon capture stakeholders influence standard development in the maritime industry?"

Introduction

1. **Have you seen and accepted the Informed Consent Form? [*Ref: B. Informed Consent Form*]**
   Yes
2. ~~**What is your e-mail address?**~~
3. ~~**What is your name?**~~
4. **At what organisation do you work?**

Design/engineering company (maritime industry)

5. **What is your function?**

Lead naval architect. In terms of my responsibilities, I am in the lead of sustainability within the organization, which encompasses both research and development activities as well as commercial aspects, including sales. We have had several spin-off projects related to sustainability. Additionally, I serve as the coordinator and supervisor for internships. I also handle a portion of quality management administration.

Part 1: Stakeholder Identification

6. **What is your organisations relationship with onboard carbon capture technology?**

Ship designer and equipment integrator. Carbon capture systems could be an example of a system that may be integrated on a ship. However carbon capture is still perceived as not developed sufficiently yet and there are too many unknowns such as the effectivity of the system.

7. **Under which category do you classify your organisation? (show the predetermined categories and specifically ask if there may be any other category)**

Research and consultancy, Designers and engineering

8. **In your opinion, who are the key stakeholders in the maritime carbon capture industry, and what role do they play?**

Technology providers, Classification societies end users: ship owners, engineering firms, may play a crucial role in integrating and combining all together.

Part 2: Stakeholder Classification

Power:

9. **As a stakeholder in the maritime carbon capture industry, what are your main priorities and goals in relation to this technology?**

> *"Our primary goal is to promote sustainability within the maritime industry, and Carbon Capture can play a role in achieving that. We aim to integrate it into our practices. However, it is important to note that this perspective is based on our perception and experience, and it may not represent the actual latest status. From our standpoint, Carbon Capture is not yet clear or mature enough to be widely implemented but there are developments onging"*

10. **What is your financial position according to onboard carbon capture? (availability of funds)**

> The financial power stops at the power of the client. Some research money can be allocated however no system is going to be produced or developed by the organization itself.

11. **Who are your direct partners? (Onboard Carbon Capture stakeholders)**

> Technology providers could play a prominent role. Or consortia partners, these include shipowners, shipyards, research institutions, and classification societies.

12. **Who are your direct competitors? (Onboard Carbon Capture stakeholders)**

> Other engineering firms, however it is not per se that they are competitors we see them more as partners in The Netherlands. To keep the Dutch name high.

13. **How is/was the power divided between your partners?**

> *"Our influence is limited to the point where the economic feasibility of our clients' operations ends. As much as we may desire to transition everyone to sustainable fuel propulsion, we lack the power to enforce it. We understand that a viable business case is essential. The added value of cleaner transportation or the additional costs associated with pollution need to find their way into the market. Unfortunately, we have almost no power in that regard. We can propose ideas, make suggestions, and pitch solutions, but we cannot adopt them at a national or higher level, or enforce them. We are not legislators. Furthermore, we have no authority. I often mention that classification societies or regulations can impose fees on pollution, and on the other hand, the customers of shipowners can be willing to pay more for clean transport.. We are neither of those entities. However, once a decision is made, we can technically make it possible. We strive to ensure it is as economically attractive as possible, but our influence ends where our technical domain ends."*

14. **Which stakeholders do have the most power and why?**

> Pollution or cleaner transportation should be recognized and valued in economic terms. Those who have the power to influence this have the real authority. In my opinion, it lies with regulations that impose charges on polluting transportation and, on the other hand, with rewarding cleaner transport. This responsibility falls on the customers of shipowners and the regulations set by the maritime industry. For example, the IMO, the EU

Legitimacy:

15. **How do the other stakeholders accept or support your participation in the technology?**

> ...

16. **Which stakeholders do have the most legitimacy and why?**

> Those organizations that truly embrace a vision of sustainability.

Urgency:

17. **To what extend have you been active in pursuing your goals regarding this standardisation issue?**

> Sustainability is deeply embedded in our mission and vision, driving our sense of urgency to take action. We are committed to making a positive impact and actively pursue innovative solutions for a greener and more sustainable future. We are willing to contribute and collaborate on standards, but within the context and relevance of our specific needs and operations.

18. **Which stakeholders do have the most urgency and why?**

> Technology suppliers, because they make a living of it.

19. **How do you see the role of stakeholders evolving in the maritime carbon capture industry over the next 5-10 years, and what impact do you expect this to have on the industry as a whole?**

> ...

	Financial	Technical expertise	Position in Network	Power to influence	Legitimacy	Urgency
Organisation	N	Y	N	N	Y	N (Y indirect)
		Once a decision is made, we can technically make it possible. We strive to ensure it is as economically attractive as possible, but our influence ends where our technical domain ends.		Our influence is limited to the point where the economic feasibility of our clients' operations ends.		There is urgency, however this is primarily based on input from clients and linked to their sustainable future vision instead of OCC

Part 3: Standardisation

20. **How are standards being developed in the maritime industry?**

In order to establish standardization, various international organizations such as SGMF (Society for Gas, Marine Fuel) play a crucial role. It is beneficial for shipowners to be the first to adopt these standards, as well as for suppliers of the corresponding connections. Once a common standard is established and widely adopted, it benefits everyone involved. It's like trying to fit a triangular connector into a circular socket, and the goal is to align them for the benefit of all stakeholders.

21. **What kind of standards do you believe are necessary for onboard carbon capture?**

Implementation in CII and EEXI, because there is a need for standardization in the interpretation and definitions of various fuel types, such as grey hydrogen, green hydrogen, grey methanol, green methanol, and even blue fuels in the context of CCS.

22. **How are standards being developed for Onboard Carbon Capture?**

...

23. **Can you describe how your organization is influencing maritime standardisation?**

Although we are familiar with these issues, we do not directly engage in standardization efforts ourselves. However, we strongly emphasize to shipowners, industry associations, and classification societies the importance of addressing these issues. By highlighting the shortcomings and the need for action, we aim to raise awareness and place these matters higher on the agenda. Our involvement helps reinforce the significance and urgency of the required changes.

Finalization

24. **Can you share any relevant research or analysis on the potential benefits and challenges of OCC for the maritime industry?**
25. **May we contact you in the future after processing the interview by phone, email or otherwise and present the results of the interview to correct misinterpretations or other details?**
    Yes

Extra:

- Extension of fossil fuel usage when newbuilds are going to apply carbon capture and build HFO ships
- Investors may require certain preconditions of ship owners and shipping companies, like green investments etc.
- it is not feasible or necessary to standardize everything, as there is a significant amount of customization involved. When dealing with assets worth millions to hundreds of millions, they must meet the specifications of the shipowner, which may differ from those of neighboring vessels. However, at the core, there are certain aspects that can be standardized, including emissions. It is crucial to establish standardization at that level. Additionally, I find it important to draw a parallel with another relevant aspect.
- Carbon Capture can play a role in achieving our primary goal which is promoting sustainability within the maritime industry. We aim to integrate it into our practices. However, it is important to note that this perspective is based on our perception and experience, and it may not represent current developments.

B.2.5 I5

Interview Questions: Carbon Capture in the Maritime Industry, the role of stakeholders in Standardisation.

Research topic description: The purpose of this research is to add to stakeholder and standardisation theory by studying the complex maritime stakeholder environment concerning standardisation for chemical absorption based carbon capture on ships. The research tries to find an answer for the following question:

"How do onboard carbon capture stakeholders influence standard development in the maritime industry?"

Introduction

1. **Have you seen and accepted the Informed Consent Form? [*Ref: B. Informed Consent Form*]**
   Yes
2. ~~**What is your e-mail address?**~~
3. ~~**What is your name?**~~
4. **At what organisation do you work?**
   Major classification society
5. **What is your function?**

Manager classification

Part 1: Stakeholder Identification

6. **What is your organisations relationship with onboard carbon capture technology?**

The organization is responsible for issuing rules for steel ships, known as NR467. These rules are structured into parts A through F, with parts B through F encompassing the technical specifications, while part A covers class notations and all survey requirements. Examples of class notations are scrubbers or onboard carbon capture. Thereby does the organisation inspect and certification of carbon capture systems on ships. *'We create the standard ourselves. And that standard is essentially the notation.'*

7. **Under which category do you classify your organisation? (show the predetermined categories and specifically ask if there may be any other category)**

Inspection agency, regulator. You may voluntary choose at which classification society you register, however you must comply with the requirements/standards of the specific classification society.

8. **In your opinion, who are the key stakeholders in the maritime carbon capture industry, and what role do they play?**

Technology providers, because from the ship owner perspective there is not enough economic pressure such as a bunker levy.

Part 2: Stakeholder Classification

Power:

9. **As a stakeholder in the maritime carbon capture industry, what are your main priorities and goals in relation to this technology?**

   The priority is to have a safe system on board that just works. Safety is a broad concept wherein the protection of the environment is included.

10. **What is your financial position according to onboard carbon capture? (availability of funds)**

    The company is in the end commercial with a mandate to the Flag. So money comes from clients such as shipping companies.

11. **Who are your direct partners? (Onboard Carbon Capture stakeholders)**

    Technology providers come to us and request for standards. Together with the providers we then try to come to a set of requirements. classification society creates then standards and rules. And on that basis we will therefore create standards and rules that fits the existing systems. Thereby doe BV participate in the EverLoNG project.

12. **Who are your direct competitors? (Onboard Carbon Capture stakeholders)**

    Other classification societies.

13. **How is/was the power divided between your partners?**

    Classification societies are commercial companies with a mandate to society and Flag. They do have the power to create their own standards and rules which must be followed when a ship is a customer of the classification society.

14. **Which stakeholders do have the most power and why?**

    IMO/Flag

Legitimacy:

15. **How do the other stakeholders accept or support your participation in the technology?**

    …

16. **Which stakeholders do have the most legitimacy and why?**

    …

Urgency:

17. **To what extend have you been active in pursuing your goals regarding this standardisation issue?**

Active because clients did request OCC standards and a classification society needs to stay competitive by keeping up with the market and innovations. At the moment the basis rules have been published and it is to the market to further develop.

'As I mentioned, we have created our own rules. So now it is up to the market to apply them and see if any issues arise or if there are emerging technologies that do not align with what we have written. In such cases, we will actively assess and adjust our rules as necessary.'

18. **Which stakeholders do have the most urgency and why?**

Technology providers

19. **How do you see the role of stakeholders evolving in the maritime carbon capture industry over the next 5-10 years, and what impact do you expect this to have on the industry as a whole?**

…

	Financial	**Technical expertise**	**Position in Network**	**Power to influence**	**Legitimacy**	**Urgency**
Organisation		Y	Y	Y	Y	Y
Technology providers				N		Y
				A producer cannot impose requirements on their own. They can bring a product to the market, but they cannot enforce its purchase.		

Part 3: Standardisation

20. **How are standards being developed in the maritime industry?**

In the maritime industry, there are essentially three types of standards: classification societies, flag states, and market-driven standards. For instance, the offshore and gas industry imposes its own set of requirements to ensure safety and competitiveness. Additionally, industry professionals often refer to ISO standards or develop their own standards specific to their professional community.

Flag states and the IMO can be seen as closely related entities. The IMO acts as a forum where flag states come together to collectively establish standards. For example, the IMO develops and enforces major conventions such as MARPOL, SOLAS, and load line requirements. However, it is important to note that these conventions do not automatically become law for flag states. Each flag state must incorporate the IMO standards into its own national legislation to ensure compliance for its registered ships.

Before participating in IMO discussions, a flag state, such as the Netherlands, typically invites national stakeholders to gather their input on further developments. This includes port authorities, shipowners, producers, and classification bureaus like us. These stakeholders provide their perspectives, which the Dutch government takes into consideration along with European policies and national interests. Based on these inputs, the government then determines the Netherlands' position within the IMO.

21. **What kind of standards do you believe are necessary for onboard carbon capture?**

...

22. **How are standards being developed for Onboard Carbon Capture?**

I believe that each classification bureau will establish its own set of rules, including our competitors. Additionally, ISO is likely to contribute to standardization efforts, considering its broad focus on both maritime and land sectors. Consequently, some discrepancies may arise due to these diverse perspectives. Furthermore, regarding IMO, I mentioned earlier that the initial focus will likely be on the imposition of a CO2 tax. As for scrubbers, for instance, there are currently no specific requirements from IMO. While emission values are taken into account, the focus is not on the underlying technology.

23. **Can you describe how your organization is influencing maritime standardisation?**

Ultimately, I would categorize us largely under government-based standardization, with the understanding that government-based standardization is not overly prescriptive but rather takes into consideration existing market standardization and committee input before imposing a standard.

Finalization

24. **Can you share any relevant research or analysis on the potential benefits and challenges of OCC for the maritime industry?**
25. **May we contact you in the future after processing the interview by phone, email or otherwise and present the results of the interview to correct misinterpretations or other details?**

Extra:

- you must have a class notation on a ship. And in addition, we have a number of additional notations, which are voluntary, but we also have a number that we actually impose. We call that the Service Feature, other classification societies call it differently. And with us, onboard carbon capture is classified under a mandatory notation. So if you put a system onboard, you have to comply.
- Notations should be not to technology specific, then you may give a monopoly to certain technology providers
- Internal committee discusses the broad market requests such as Onboard Carbon capture and then vote on importance. When issues are voted for, time will be allocated and the development department will further develop the standards in detail.
- Because their legitimacy, which actually depends, I think, more on what a ship needs to operate in this case. And those are a number of certificates. They have to comply with them. And those are the flag state certificates and the class certificates. Flag states don't impose anything yet. We do now, but a producer cannot impose it on their own. They can bring a product to the market, but they cannot force you to buy it.
- In the end, we ultimately issue a certificate or a class certificate, which is basically a declaration towards an insurer. Yes, to assure an insurer that a ship is safe enough for the transportation of, well, whatever. So there is a certain legitimacy behind it in that way as well.

B.2.6 I6

Interview Questions: Carbon Capture in the Maritime Industry, the role of stakeholders in Standardisation.

Research topic description: The purpose of this research is to add to stakeholder and standardisation theory by studying the complex maritime stakeholder environment concerning standardisation for chemical absorption based carbon capture on ships. The research tries to find an answer for the following question:

"How do onboard carbon capture stakeholders influence standard development in the maritime industry?"

Introduction

1. **Have you seen and accepted the Informed Consent Form? [*Ref: B. Informed Consent Form*]**
   Yes
2. ~~**What is your e-mail address?**~~
3. ~~**What is your name?**~~
4. **At what organisation do you work?**

   Ship design and engineering office

5. **What is your function?**

   Naval architect at the research and development department

Part 1: Stakeholder Identification

6. **What is your organisations relationship with onboard carbon capture technology?**

   We are always very much looking for ways to make shipping more sustainable, where are the opportunities in that regard. In any case, especially our research department. And then we also look at wind and also at all other technologies, hydrogen and CO2 capture is also one of them and that is a big one and I really believe that CO2 capture will or should actually be a large part, whether it will be know I don't, but it should be from the transition to, zero emissions

7. **Under which category do you classify your organisation? (show the predetermined categories and specifically ask if there may be any other category)**

   Designers & Engineers And Research Development

8. **In your opinion, who are the key stakeholders in the maritime carbon capture industry, and what role do they play?**

   In the first place the governments: IMO, Port state, Flag state. When looking very broad society as a whole. This because they have the power to adjust frameworks such as EEDI, EEXI and CII and give carbon capture economical value for ship owners and shipping companies. Other important stakeholders would be technology providers and shipping companies/charterers as they need to implement the system. When looking very broad it starts with society as a stakeholder

Part 2: Stakeholder Classification

Power:

9. **As a stakeholder in the maritime carbon capture industry, what are your main priorities and goals in relation to this technology?**

   Contributing to the development, being at the forefront in terms of knowledge about it, and actively participating in shaping various aspects such as regulations and technology to make it as feasible as possible, including cost reduction, so that ship owners find it feasible and appealing to implement such technology. This applies to all technologies not solely carbon capture.

10. **What is your financial position according to onboard carbon capture? (availability of funds)**

    Primarily money from research subsidies

11. **Who are your direct partners? (Onboard Carbon Capture stakeholders)**

    Participant in the research project EverLoNG. It is important that an ecosystem will be created to compete with other countries such as china. Therefore, competitors in the Netherlands quickly become a sort of partner. Important partners from the projects are: Stena, Carbotreats (bouman industries) and VDL AEC

12. **Who are your direct competitors? (Onboard Carbon Capture stakeholders)**

    No direct competitors in carbon capture ship design.

13. **How is/was the power divided between your partners?**

    In the consortium the power is divided equally, everyone has their own work package to focus on and shares all their findings during meetings.

14. **Which stakeholders do have the most power and why?**

    Governments as they have authority and can ban or allow issues

Legitimacy:

15. **How do the other stakeholders accept or support your participation in the technology?**

> Tolerating each other however sometimes questions appear such as what does the organization really want with the technology and what do partners want. Some partners are more focusing on scrubber clients. Currently we are working together in the research projects and share all data with every member (EverLoNG)

16. **Which stakeholders do have the most legitimacy and why?**

> **…**

Urgency:

17. **To what extend have you been active in pursuing your goals regarding this standardisation issue?**

> We are actively participating in the EverLoNG project, the project is also about standardization of production lines or what formats the system should have. Currently this part is on hold because first some more research into engines is required in our project.

18. **Which stakeholders do have the most urgency and why?**

> See 19

19. **How do you see the role of stakeholders evolving in the maritime carbon capture industry over the next 5-10 years, and what impact do you expect this to have on the industry as a whole?**

> In terms of utmost urgency, I believe the primary responsibility lies with the regulators, who aim to reduce emissions. Perhaps the technology providers also share some responsibility, but in practice, progress in this regard has been relatively slow. Over the next five to ten years, a significant portion of the fleet is expected to operate without implementing CO2 capture, considering the current regulatory landscape. However, there are numerous shipping companies eager to adopt such measures. Therefore, although five to ten years may be considered a relatively short timeframe in the maritime industry, which does not undergo frequent changes, I anticipate considerable developments in this area.

	Financial	Technical expertise	Position in Network	Power to influence	Legitimacy	Urgency
Designers/engineering	N	Y	N	N	Y	Y
				No power to influence a shipping company for example	Legitimate decarbonisation goal and participant in consortia shows that acceptance of the stakeholder is evident	Our goal is to design ships that achieve net-zero emissions. We believe it is crucial to take action now rather than waiting for technologies that may become available in the next decade.

Part 3: Standardisation

20. **How are standards being developed in the maritime industry?**

> Classification societies are frontrunners in the case of carbon capture, by releasing rules and standards. The IMO has decarbonization targets and goals, however not dedicated for carbon capture. From the classification societies a higher level can be achieved such as the IMO.

21. **What kind of standards do you believe are necessary for onboard carbon capture?**

> Implementation of CO2 capture in CII, EEDI, EEXI, ETS and similar like frameworks. Quality and safety standards for the system (by classification societies). Standard production lines or standard equipment so that it could be easily implemented onboard on a wide variety of vessels, to decrease costs significantly (amine based systems are expensive)

22. **How are standards being developed for Onboard Carbon Capture?**

> Lloyds is now developing performance based standards and risk mitigation plans in our research consortium. The classification societies are now releasing carbon capture standards or did recently release them. A product standard advise comes forth out of the research which could be a public paper and then the manufacturer can choose what to develop or standardize. Then some sort of market based standardization could result in competition. When there are enough market parties and there are standards then in the final stage the IMO does implement it internationally

23. **Can you describe how your organization is influencing maritime standardisation?**

> By collaborating in the EverLoNG project, for example discussing the lessons learned from case studies with a manufacturer so they can create standard equipment.

Finalization

24. **Can you share any relevant research or analysis on the potential benefits and challenges of OCC for the maritime industry?**
25. **May we contact you in the future after processing the interview by phone, email or otherwise and present the results of the interview to correct misinterpretations or other details?**
    Yes

Extra:

- Yes, for us as Conoship itself, I think power is not really there. We have little power in that regard, to make ship owners do what we want them to do. Making good choices. I do think that legitimacy and urgency, well, they're both there for us as. Im looking mainly for our department, and we just want to design ships that emit net zero. And we should actually do that now and not wait for the development of technologies that may be ten years from now. That is for us and we also advertise with it. So in that respect, the urgency is there. And the legitimacy, yes, you could argue about that. What you say, everything is legitimate in itself in this case. So yes, I find it difficult to do exactly what to do with it.
- Number 6 salience (depend on legislative bodies and shipping companies)

B.2.7 I7

Interview Questions: Carbon Capture in the Maritime Industry, the role of stakeholders in Standardisation.

Research topic description: The purpose of this research is to add to stakeholder and standardisation theory by studying the complex maritime stakeholder environment concerning standardisation for chemical absorption based carbon capture on ships. The research tries to find an answer for the following question:

"How do onboard carbon capture stakeholders influence standard development in the maritime industry?"

Introduction

1. **Have you seen and accepted the Informed Consent Form? [*Ref: B. Informed Consent Form*]**
   Yes
2. ~~**What is your e-mail address?**~~
3. ~~**What is your name?**~~
4. ~~**At what organisation do you work?**~~
5. **What is your function?**

Project leader, Clean Shipping

Part 1: Stakeholder Identification

6. **What is your organisations relationship with onboard carbon capture technology?**

With our organization we are working on clean and healthy seas. An important aspect to achieve this, is to aim for emission-free ships.

7. **Under which category do you classify your organisation? (show the predetermined categories and specifically ask if there may be any other category)**

Representative organization, environmental organization (NGO)

8. **In your opinion, who are the key stakeholders in the maritime carbon capture industry, and what role do they play?**

Not that familiar with carbon capture specific stakeholders however, for the maritime industry as a whole the following actors may be key: • Ship owners because they need to reduce their emissions because of regulations, • Society as they exert influence on the ship owners and bear the consequences of pollution • Charterers/cargo owners as they want to have a green supply chain, and then choose for greener ship owners • Technology providers as they develop clean technologies/carbon capture systems

Part 2: Stakeholder Classification

Power:

9. **As a stakeholder in the maritime carbon capture industry, what are your main priorities and goals in relation to this technology?**

Rather an indirect stakeholder then direct stakeholder.

10. **What is your financial position according to onboard carbon capture? (availability of funds)**

No funds

11. **Who are your direct partners? (Onboard Carbon Capture stakeholders)**

We are not directly concerned with carbon capture

12. **Who are your direct competitors? (Onboard Carbon Capture stakeholders)**

No competitors

13. **How is/was the power divided between your partners?**

Only the exchange of information

14. **Which stakeholders do have the most power and why?**

-

Legitimacy:

15. **How do the other stakeholders accept or support your participation in the technology?**

• *Our role is to provide information and represent specific interests, with the aim of influencing parties that have the practical impact to make choices that are ultimately best for the environment. This applies to policies as well, so we also engage in discussions with e.g. the government, and the IMO, as they are involved in what we believe should be done. However, in the end, they are the ones who put it into practice, not us.*

16. **Which stakeholders do have the most legitimacy and why?**

-

Urgency:

17. **To what extend have you been active in pursuing your goals regarding this standardisation issue?**

- *Our role is to provide information and represent specific interests, with the aim of influencing parties that have the practical impact to make choices that are ultimately best for the environment. This applies to policies as well, so we also engage in discussions with e.g. the government, and the IMO, as they are involved in what we believe should be done. However, in the end, they are the ones who put it into practice, not us.*

18. **Which stakeholders do have the most urgency and why?**

-

19. **How do you see the role of stakeholders evolving in the maritime carbon capture industry over the next 5-10 years, and what impact do you expect this to have on the industry as a whole?**

Yes, I always hope that there are still shipowners who feel their social responsibility and have taken action on that, but it's more expensive. And in the maritime industry, that's also the problem; it's so competitive that they always have to be mindful of money because, well, if their neighbor offers something cheaper, customers might choose them instead, so it's all quite logical. So that's a bit of what I've observed now with those scrubbers. And if you then ask, how do you see that in the next five to ten years, I think the same principle will come into play again, for example, with Carbon Capture. Now there will be a price on CO2 emissions, well, that CII from the IMO is also coming into play, yes, it's starting now. And now CO2 will finally be priced and hopefully somewhat reduced as well. And I think maritime stakeholders will once again assess what rules are coming. How can we most cost-effectively comply? What do we need for that? How much will it cost us? What are our competitors doing? And I believe that as long as such a Carbon Capture system onboard is affordable and a viable alternative to other potential actions they could take, it will simply continue to increase, although the ultimate goal should be to not produce CO2 instead of producing CO2 and storing it.

Part 3: Standardisation

20. **How are standards being developed in the maritime industry?**

'there are numerous maritime matters at hand, our focus lies particularly with regards to the environment. As far as my knowledge extends, it is possible to submit proposals in this regard. By doing so, one can have their proposal placed on the agenda of the International Maritime Organization (IMO), and subsequently, this could result in decision-making processes at a later stage.'

21. **What kind of standards do you believe are necessary for onboard carbon capture?**

…

22. **How are standards being developed for Onboard Carbon Capture?**

…

23. **Can you describe how your organization is influencing maritime standardisation?**

'In our efforts, we engage in both informing and lobbying. This entails disseminating information to the general public and advocating towards policymakers. However, our informative activities extend beyond the broader public. We also engage in direct dialogue with commercial entities, such as port authorities, and engage in discussions with stakeholders in the shipping industry, including frequent interactions with the KVNR (Koninklijke Vereniging van Nederlandse Reders) or the NMT, Netherlands Maritime Technology. We strive to persuade them to consider certain actions or collaborate with them to explore potential improvements. While we possess substantial knowledge and ideas, it is ultimately these stakeholders who can influence decision-making. Therefore, we encourage their engagement and actively communicate with them. Our aim is to raise awareness among the general public, as greater attention to the issues at hand can impact policy outcomes. Moreover, we often encourage commercial entities to go beyond existing regulations and take steps in the right direction. We emphasize the potential benefits they could gain from distinguishing themselves in this regard. Sometimes, it is necessary to provide a gentle push or prompt them to think more deeply about the long-term implications of their actions.'

Finalization

24. **Can you share any relevant research or analysis on the potential benefits and challenges of OCC for the maritime industry?**

Scrubber video website: *https://www.noordzee.nl/lozing-van-scrubberwater-vervuilt-de-noordzee/*
Questions in the house of representatives about scrubbers: *https://app.1848.nl/document/kamervraag/101106*
NOS: *https://nos.nl/artikel/2455605-kabinet-wil-internationaal-onderzoek-naar-vervuilende-schepen-op-zee*

25. **May we contact you in the future after processing the interview by phone, email or otherwise and present the results of the interview to correct misinterpretations or other details?**
Yes

Extra:

- *Our role is to provide information and represent specific interests, with the aim of influencing parties that have the practical impact to make choices that are ultimately best for the environment. This applies to policies as well, so we also engage in discussions with e.g. the government, and the IMO, as they are involved in what we believe should be done. However, in the end, they are the ones who put it into practice, not us.*

B.2.8 I8

Interview Questions: Carbon Capture in the Maritime Industry, the role of stakeholders in Standardisation.

Research topic description: The purpose of this research is to add to stakeholder and standardisation theory by studying the complex maritime stakeholder environment concerning standardisation for chemical absorption based carbon capture on ships. The research tries to find an answer for the following question:

"How do onboard carbon capture stakeholders influence standard development in the maritime industry?"

Introduction

1. **Have you seen and accepted the Informed Consent Form? [*Ref: B. Informed Consent Form*]**
   Yes
2. ~~**What is your e-mail address?**~~
3. ~~**What is your name?**~~
4. **At what organisation do you work?**

Value Maritime

5. **What is your function?**

Regulatory advisor

Part 1: Stakeholder Identification

6. **What is your organisations relationship with onboard carbon capture technology?**

The organization sells the worlds first commercial onboard carbon capture systems

7. **Under which category do you classify your organisation? (show the predetermined categories and specifically ask if there may be any other category)**

Technology Provider

8. **In your opinion, who are the key stakeholders in the maritime carbon capture industry, and what role do they play?**

   - Society; requiring / driving change
   - Legislators/IMO; translate change request to regulatory goals and requirements
   - Flag/memberstates; translate regulatory goals into statutory laws
   - Charterers; translate change to specific maritime requirements, creating business cases / opportunities for clients
   - OEMS; Creating products for maritime OCC
   - Shipowners, seizing opportunities to comply with regulations and/or creating business cases
   - Offtakers & end users; Seizing opportunities / create business cases with captures carbon
   - Financial institutes; enablers

Part 2: Stakeholder Classification

Power:

9. **As a stakeholder in the maritime carbon capture industry, what are your main priorities and goals in relation to this technology?**

   Market a mature CC product for maritime industry which is commercially viable and has it's place in the decarbonization regulatory pathways

10. **What is your financial position according to onboard carbon capture? (availability of funds)**

    …

11. **Who are your direct partners? (Onboard Carbon Capture stakeholders)**

    - Clients; shipowners / charterers
    - Regulatory bodies; Class & Flag states
    - Financial institutes
    - Offtakers; greenhouses

12. **Who are your direct competitors? (Onboard Carbon Capture stakeholders)**

    VDL, Alfa Laval
    In General; scrubber manufacturers are working on OCC solutions

13. **How is/was the power divided between your partners?**

    …

14. **Which stakeholders do have the most power and why?**

    Regulatory bodies; Acceptance within EU ETS and / or CII, EEXI will powerful stimulate the market entry of OCC

Legitimacy:

15. **How do the other stakeholders accept or support your participation in the technology?**

    Shipowners support in their early involvement / purchase of OCC systems

16. **Which stakeholders do have the most legitimacy and why?**

    Also the regulatory bodies -> Dominant stakeholder

Urgency:

17. **To what extend have you been active in pursuing your goals regarding this standardisation issue?**

Very active; AIP for on board OCC, development of OCC certificate for offtake process, Initiated voluntary independent verification in accordance with ISO standards

18. **Which stakeholders do have the most urgency and why?**

Shipowners; needing to comply with climate goals / regulations. Willing to invest however business case not fully clear with multiple dependencies

19. **How do you see the role of stakeholders evolving in the maritime carbon capture industry over the next 5-10 years, and what impact do you expect this to have on the industry as a whole?**

Regulations will enter into force / standards will be developed changing the landscape.

Part 3: Standardisation

20. **How are standards being developed in the maritime industry?**

Society wants change -> small business cases are developed -> early adoption by shipowners / charterers -> class is involved, creation of additional class rules, notations -> National regulations could be defined -> Regional reg's could be defined (EU) -> International regulations (IMO)

21. **What kind of standards do you believe are necessary for onboard carbon capture?**

Class rules for structure / safety etc. IMO (MEPC) & EU for OCC functioning (emission reduction) and market based instruments, ISO standards for landbased process

22. **How are standards being developed for Onboard Carbon Capture?**

In line with no. 20

23. **Can you describe how your organization is influencing maritime standardisation?**

Bringing first functioning CCS on the market. Discussion with Class societies, flag states, IMO and EU. Have landbased process for independently verified.

Finalization

24. **Can you share any relevant research or analysis on the potential benefits and challenges of OCC for the maritime industry?**
25. **May we contact you in the future after processing the interview by phone, email or otherwise and present the results of the interview to correct misinterpretations or other details?**

Extra:

C | Part 1

C.1 Stakeholder categories

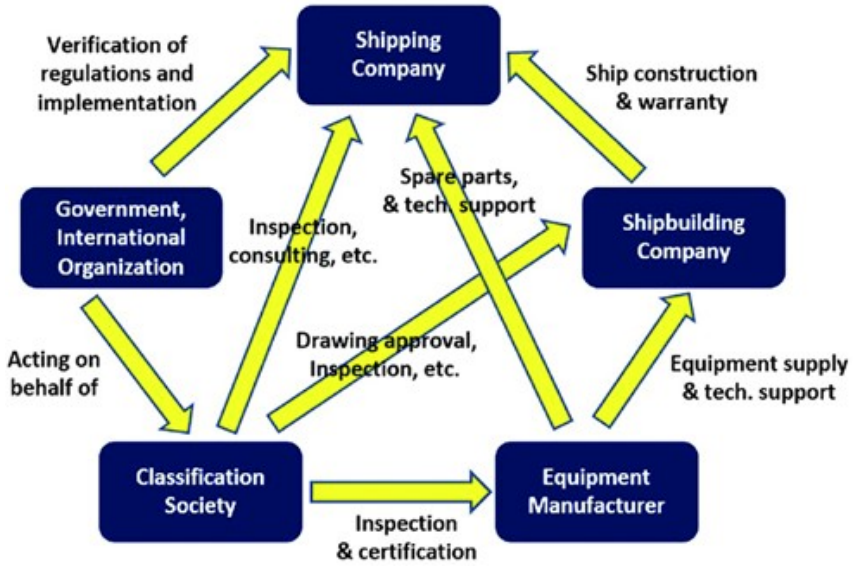


Fig. C.1. Main stakeholders for ships (Kim et al., 2020)

Fig. C.2. (MMKMC, 2022)

CHAPTER 2

The ask: How key players in shipping can drive emissions reductions

Among the many players with a role in the maritime sector, two types of market participants play a central role influencing the pace of decarbonization. These are: 1) ship owners and operators, referred to in this report as **maritime shipping providers (MSPs)**, and 2) users of shipping such as cargo owners and charterers, referred to as **maritime shipping users (MSUs)**. Each has key leverage over the sector's energy transition due to its central placement in the network of shipping operations and shipping demand, respectively (see Figure 3).

FIGURE 3

The shipping ecosystem

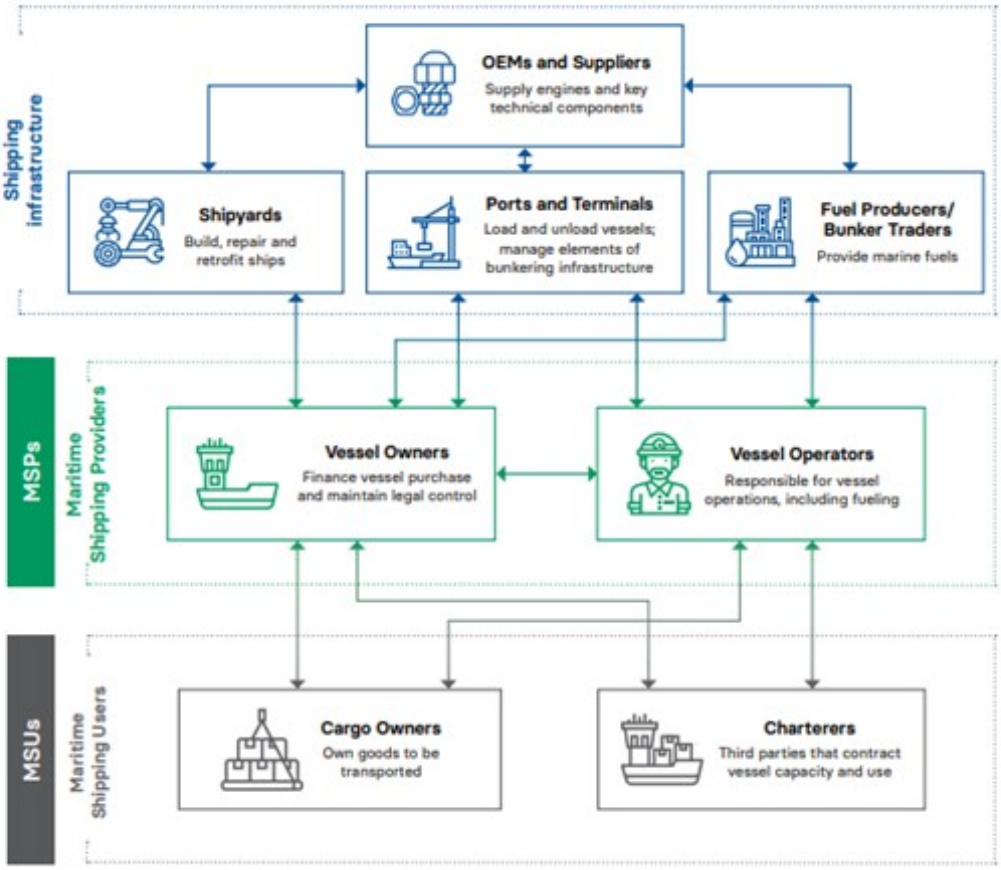


Fig. C.3. (EDF & Center, 2022)

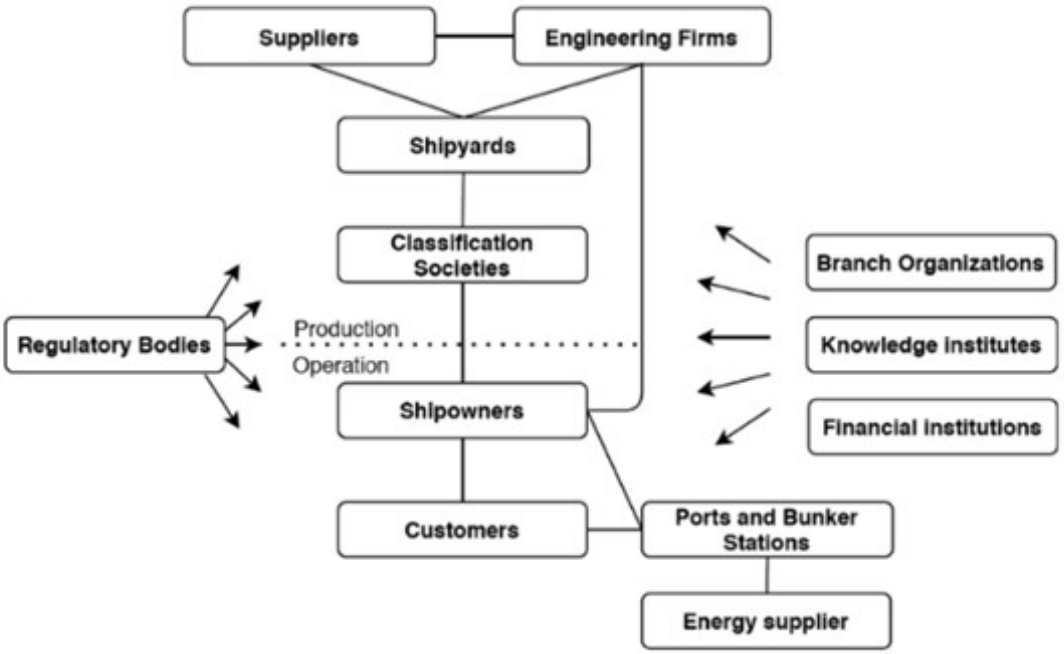


Fig. C.4. (Stolper et al., 2022)

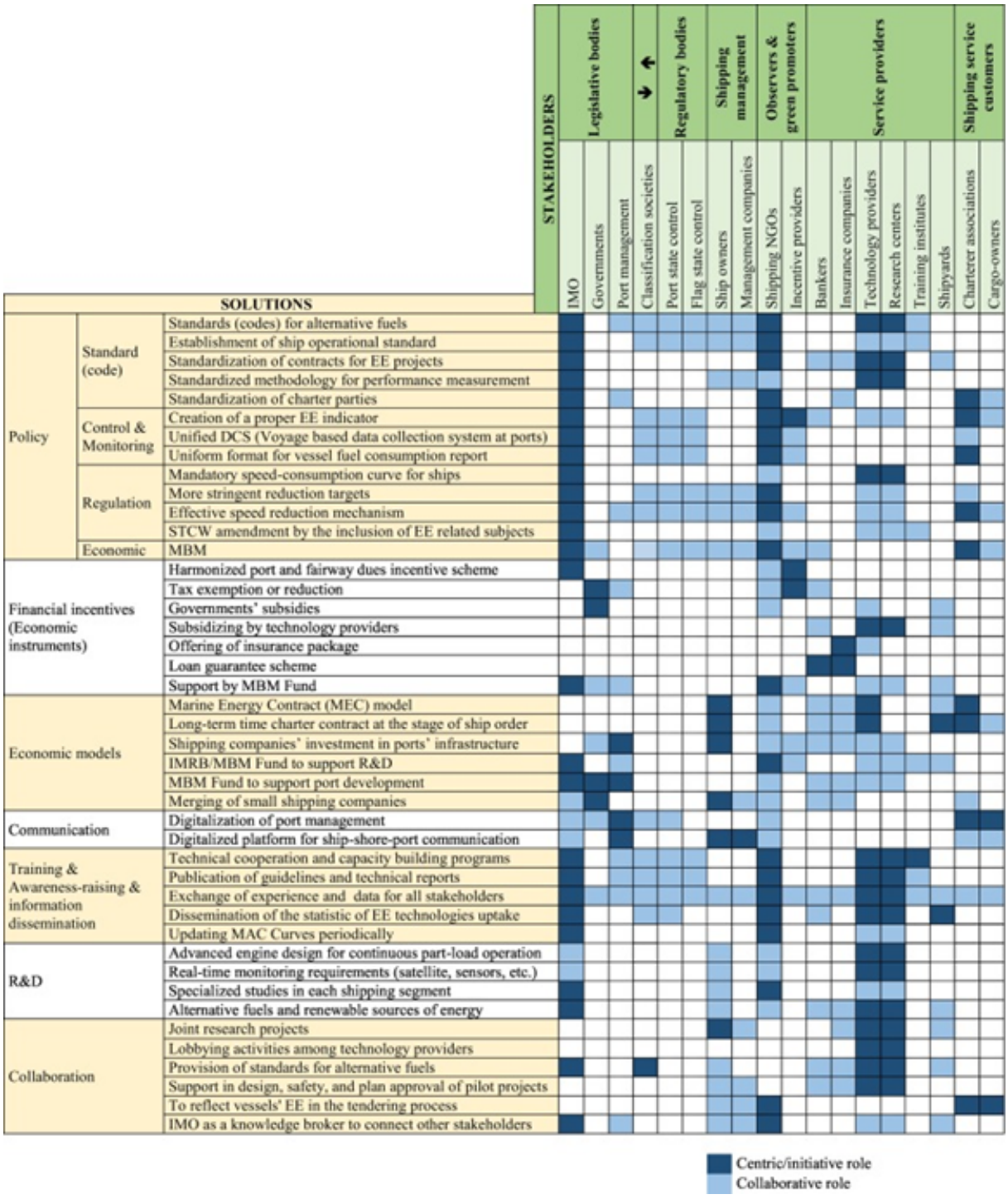


Fig. C.5. (Masodzadeh et al., 2022)

C.2 Projects

Part 1					
Project	Duration	Type	Description	Participants	Technology type
CCShip	(2021-2025) (Norway)	Modeling	Knowledge-building Project for Industry in Norway	SINTEF Ocean, NTNU, University of Oslo, Seoul National University, Wärtsilä Moss, Klaveness and Calix Limited. Funded by: Wärtsilä Moss, Calix Limited, Klaveness, the Norwegian CCS Centre NCCS	Amine or ammonia
REMARCCABLE	2022-ongoing (Interational)			GCMD, OGCI, Stena Bulk, Alfa Laval, the American Bureau of Shipping, Deltamarin and TNO	
LNG ZERO	Uknown (NL)			Shell, TU Delft, TNO, Anthony Veder, Heerema, Universiteit Twente, Lloyds Register, Conoship, Carbon collectors, carbotreat, PortXL (funder), VDL AEC. Lloyd's Register.	
EverLoNG	Uknown (NL)	onboard pilot and full CCUS chain (commersialisation)	Demonstrating carbon capture on LNG-fuelled ships	TNO, Anthony Veder, Heerema, Bureau Veritas, Conoship, DNV, Jülich, Lloyds register, Carbotreat, Sintef, SCCS, MAN, VDL AEC, TotalEnergies, NexantECA, Bouman, AKP,	
lomarlabs (joint project)(seabound carbon capture technology)	2023-ongoing (UK/DK)	onboard pilot	Start-up	Seabound, lomar shipping	Quicklime pebbles
MerVent 2025 project	ongoing-2025 (FR)	Commercial vessel ready in 2025	Construction of the first hybrid sail/synthetic fuel powered container ship with OCC for LNG	GTT, Zéphyr & Borée, Centrale Nantes University, OSE Engineering	2 types
DERISCO2	2019- ongoing (NL)	Modeling/Lab (ship tilting effect)/New on board pilot project expected in the future	Pilot on Sleipnir of Heerema	FME, TNO, Heerema Marine Contractors, Linde Gas Benelux BV	Amine or ammonia
DecarbonIce	2019-2020	IMO approval and feasibility	carbon negative shipping byusing dry ice to store co2 on the sea bottom	NYK, Sovcomflot, Knut-sen OAS, Ardmore, Daewoo Shipbuilding and Marine Engineering, Vale, MDC, DNV GL	Dry ice and dumping in sea
DSME JDP	2022-2023 (KR)	Pilot test	onboard LNG vessel	ABS, Daewoo Shipbuilding and Marine Engineering (DSME) and GasLog	Ammonia
MemCCSea	(GR)	Feasability and pilot	CO2 capture via membrame for LNG		
Carbon Capture and Storage systems on ships	(2021- ..)	Modeling/On board pilot project		DNV (international), Altera Infrastructure, Daphne Technology (Switzerland) - Equinor (Norway) - Total S. A. (France) - Moss Maritime AS (Norway) - Wärtsilä (Finland) - Brevik Engineering AS (Norway) - DFDS (Denmark) - NorSea Group AS (Norway)- Norwegian Maritime Directorate	high-energy electrons technology
LINCCS - Linking Carbon Capture and Storage'	(2021-2024)	On shore pilot project		Wärtsilä Exhaust Treatment of Wärtsilä Marine Systems (Finland) (of sub-project); Aker Solutions (Norway)	Upgrading of existing sulfur scrubbers (with employment of different solvents) and designing of new scrubbers
Carbon capture with Alfa Laval's 'PureSOx' commercial sulfur scrubber	2021 (Japan)	On board pilot project (vessel at port)		Alfa Laval (Sweden)National Maritime Research Institute (NMRI) (Japan) - Unspecified shipowner (Japan)	NMRI-developed carbon capture technology with Alfa Laval's 'PureSOx' commercial sulfur scrubber (hybrid system in closed-loop mode)
Carbon capture system integrated into 'TECO 2030 Future Funnel' commercial multipollutant remover	2021-2023 (USA)	On board pilot project		TECO 2030 ASA, AVL List GmbH (Austria) - Sustainable Energy Solutions (SES) (USA) in 2020) - Chart Industries (USA)	Unconventional vapor-solid (V-S) cryogenic separation with SES Cryogenic Carbon CaptureTM (CCCTM) patented technology
CO2 Capture Module integrated into Value Maritime's 'Filtree' commercial multi-pollutant remover system	2021-ongoing (NL)	patented commercial product on operational vessel		Value Maritime (NL), Bureau Veritas, Visser Shipping (NL) - X-Press Feeders (Singapore) (international)	Amine or ammonia
CC-Ocean	2020-2022 (Japan)	Modeling/On board pilot project		Mitsubishi Shipbuilding Co., Ltd, Kawasaki Kisen Kaisha, Ltd (K-Line) & Nippon Kaiji Kyokai (ClassNK)	Undisclosed scrubber/stripper system,
Compact Carbon Capture - 3C' Technology	2020 - ongoing (commercial expected in 2023) (Norway)(International)	Modeling (results n/a yet)/On board pilot project expected in the future/Commercial product expected in the future		Compact Carbon Capture AS (owner of technology) (Norway) & Baker Hughes Fjell Technology Group AS, Equinor ASA, CMR Prototech AS, SINTEF Tel-Tek	Amine or ammonia scrubber/thermal stripper with high-gravity rotating packed beds, with CO2 liquefaction & on board storage of liquid CO2 in tankstechnology; refers to carbon capture only
iDeCarbon™ patented commercial product	commercial expected in 2022 (Canada)			Ionada Inc.	Membrane separation & on board storage of CO2
MemCCSea - Innovative Membrane Systems for CO2 Capture and Storage at Sea'	2019-2022 (GR)	Modeling/ Lab/Successor on board pilot project expected in the future ('MemOnBoard')		Consortium led by CERTH (GR)	Membrane separation with CO2 liquefaction & on board storage of liquid CO2 in tanks; considering option of discharging CO2 (&/or carbonates) and solvent into seawater
T-TRIG PMW A3C Technology	2020 (6 months) (UK)	Modeling/Successor on-shore & onboard pilot project expected in the future		UK Consortium led by PMW Technology Ltd (University of Chester, Houlder Ltd & Tees Valley Combined Authority)	A3C - Advanced Cryogenic Carbon Capture' process (TRL: 3/4; UK Patent No GB2553277 (2020)):
DecarbonICETM Technology	2019-ongoing (DK)	Modeling/Promoting IMO's approval of proposed in-seabed storage solution of CO2/Developing of class notation & insurance clauses		Industrial consortium: Maritime Development Center (MDC; Denmark);large shipping companies, large ship building companies and maritime equipment & services companies;	
RECAST - Reduce Emissions of Carbon from Shipping & Transport'	3-5 years (UK/AUS)	Goal: Modeling/On shore pilot project/ On board pilot project		Calix, Ltd (Australia) & Windship Technology, Ltd (UK)	Chemical absorption of CO2 by low-CO2-emissions CaO in a dry CaO carbonator (calcium looping)

C.3 Stakeholders

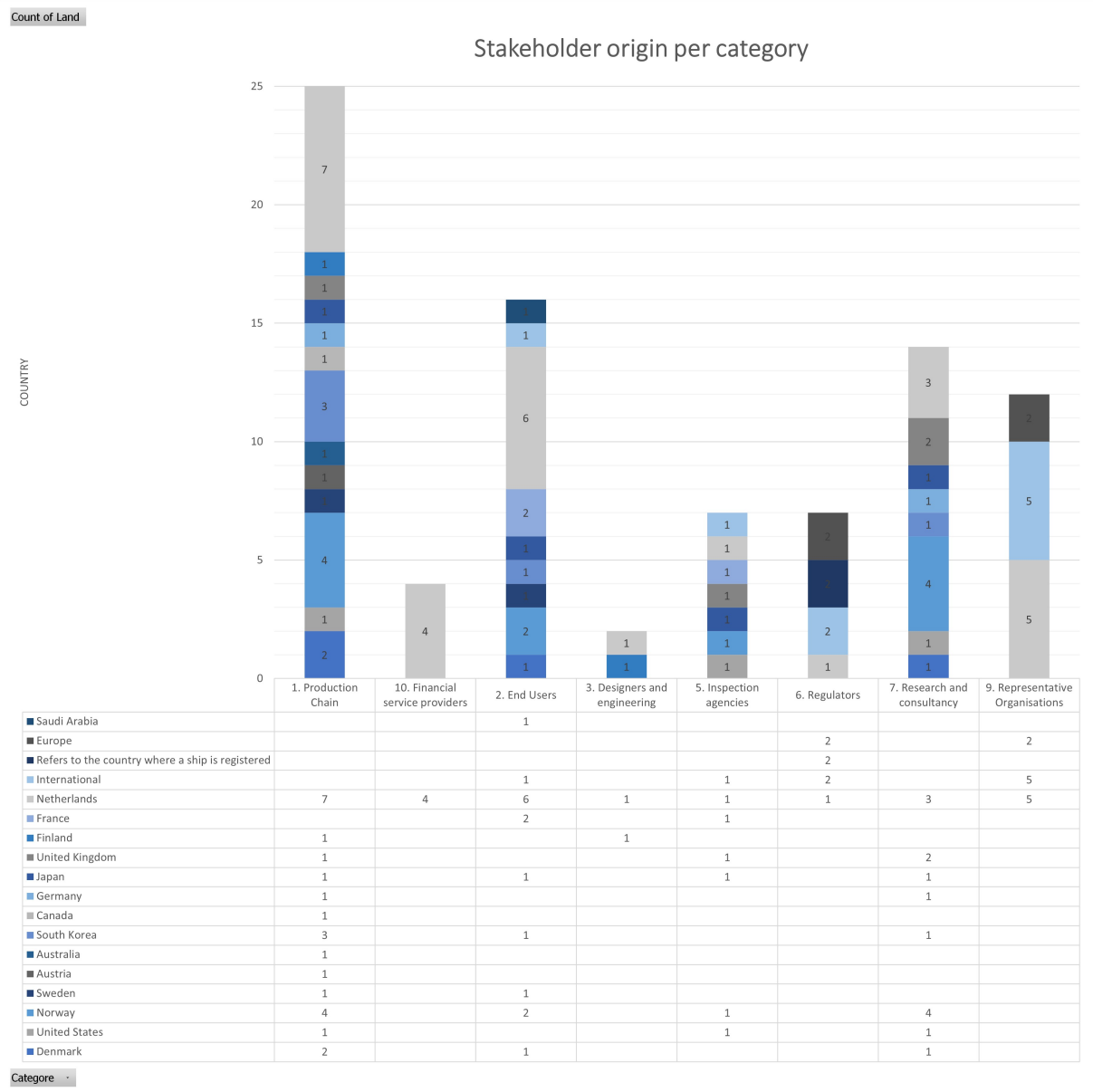


Fig. C.6. Stakeholder origins per category

Part 1			
Category	Country	Stakeholder	Source
1. Production Chain	Norway	Aker Solutions	LINCCS
1. Production Chain	Sweden	Alfa Laval	Interviews, REMARCCABLE, Pure Sox
1. Production Chain	Austria	Andritz	News publication
1. Production Chain	Netherlands	Bouman Industries	Interviews, EverLoNG
1. Production Chain	Australia	Calix Limited.	CCShip
1. Production Chain	Netherlands	Carbon Collectors	Interviews, LNG Zero
1. Production Chain	United States	Carbon Ridge	News publication
1. Production Chain	Netherlands	Carbotreat (Bouman)	Interviews, LNG Zero, EverLoNG
1. Production Chain	Norway	CMR Prototech	Compact Carbon Capture - 3C
1. Production Chain	Norway	Compact Carbon Capture AS	Compact Carbon Capture - 3C
1. Production Chain	South Korea	Daewoo Shipbuilding and Marine Engineering (DSME)	DSME JDP
1. Production Chain	Netherlands	Damen	Interviews
1. Production Chain	Denmark	EcoSpray	Interviews
1. Production Chain	South Korea	Hi Air Korea	DSME JDP
1. Production Chain	Canada	Ionada	News publication
1. Production Chain	Germany	MAN	EverLoNG
1. Production Chain	Japan	Mitsubishi Heavy Industries	CC-ocean
1. Production Chain	South Korea	Panasia	News publication
1. Production Chain	Denmark	Pureteq	News publication
1. Production Chain	Netherlands	ROG shipyard	Interviews
1. Production Chain	United Kindom	Seabound	News publication
1. Production Chain	Netherlands	Value Maritime	Interviews, Filtree
1. Production Chain	Netherlands	VDL AEC	Interviews, LNG Zero, EverLoNG
1. Production Chain	Finland	Wärtsilä	Interviews, CCShip, LINCCS
1. Production Chain	Norway	Yara	Interviews
2. End Users	Netherlands	Anthony Veder	Interviews, LNG Zero, EverLoNG
2. End Users	France	CMA CGM	Interviews
2. End Users	International (headquartere	GasLog	DSME JDP
2. End Users	Netherlands	Heerema	Interviews, LNG Zero, EverLoNG, DERISCO2
2. End Users	South Korea	HMM	Interviews
2. End Users	Netherlands	Samskip	Interviews
2. End Users	Netherlands	JR Shipping	Interviews
2. End Users	Japan	Kawasaki Kisen (K-Line)	CC-ocean
2. End Users	Norway	Klaveness	CCShip
2. End Users	Denmark	Maersk	Interviews
2. End Users	Sweden	Stena	Interviews, REMARCCABLE
2. End Users	France	Total Energies	EverLoNG
2. End Users	Netherlands	Visser shipping	Filtree
3. Designers and engineering	Netherlands	Conoship	Interviews, LNG Zero, EverLoNG
3. Designers and engineering	Finland	Deltamarin	REMARCCABLE
2. End Users	Netherlands (Royal Dutch S	Shell	Interviews, LNG Zero
5. Inspection agencies	United States	ABS	Interviews, REMARCCABLE, DSME JDP
5. Inspection agencies	France	Bureau Veritas	Interviews, EverLoNG, Filtree
5. Inspection agencies	Japan	ClassNK	CC-ocean
5. Inspection agencies	Norway/Germany	DNV GL	EverLoNG
5. Inspection agencies	International (based in Swit	ISO	Interviews
5. Inspection agencies	United Kingdom	Lloyds Register	Interviews, LNG Zero, EverLoNG
5. Inspection agencies	Netherlands	NEN	Interviews
6. Regulators	European Union	Europese Commissie	Interviews
6. Regulators	European Union	Europese Parlement	Interviews
6. Regulators	Refers to the country where	Flag State	Interviews
6. Regulators	International (United Nation	IMO	Interviews
6. Regulators	Netherlands	INW	Interviews
6. Regulators	International (part of IMO)	Marine Environmental Protection Committee (MEPC)	Interviews
6. Regulators	Refers to the country where	Port State	Interviews
7. Research and consultancy	Germany	Forschungszentrum Jülich GmbH (FZJ)	EverLoNG
7. Research and consultancy	United Kingdom	Global Centre for Maritime Decarbonisation (GCMD)	Interviews,REMARCCABLE
7. Research and consultancy	Denmark	Maersk McKinney Moller institute	Interviews
7. Research and consultancy	Japan	National Maritime Research Institute Japan (NMRI)	Pure SOx
7. Research and consultancy	United States	NexantECA	EverLoNG
7. Research and consultancy	Norway	Norwegian CCS Research Centre (NCCS)	CCShip
7. Research and consultancy	Norway	NTNU	CCShip
7. Research and consultancy	Scotland, United Kingdom	Scottish Carbon Capture & Storage (SCCS)	EverLoNG
7. Research and consultancy	South Korea	Seoul National University	CCShip
7. Research and consultancy	Norway	SINTEF	CCShip, EverLoNG, Compact Carbon Capture - 3C
7. Research and consultancy	Netherlands	TNO	Interviews, LNG Zero, EverLoNG, REMARCCABLE,
7. Research and consultancy	Netherlands	TU Delft	Interviews, LNG Zero
7. Research and consultancy	Netherlands	Universiteit Twente	Interviews, LNG Zero
7. Research and consultancy	Norway	University of Oslo	CCShip
9. Representative Organisations	International (coalition of en	Clean shipping coalition	Interviews
9. Representative Organisations	European Union	European Community Shipowners' Associations (ECSA)	Interviews
9. Representative Organisations	Netherlands	FME	EverLoNG, DERISCO2
9. Representative Organisations	International	IACS	Interviews
9. Representative Organisations	International	International Chamber of Shipping (ICS)	Interviews
9. Representative Organisations	Netherlands	KVNR	Interviews
9. Representative Organisations	Netherlands	NML	Interviews
9. Representative Organisations	Netherlands	NMT	Interviews
9. Representative Organisations	Europe (Shipbuilding and M	Sea Europe	Interviews
9. Representative Organisations	International	SGMF	Interviews
9. Representative Organisations	Netherlands	Stichting de Noordzee	Interviews
9. Representative Organisations	International (non-profit org	Transport & Environment	Interviews
10. Financial service providers	Netherlands	EBN	Interviews
2. End Users	Norway	Equinor ASA	EverLoNG
2. End Users	Saudi Arabia	Aramco	Interviews, REMARCCABLE
10. Financial service providers	Netherlands	NIBC	Interviews
10. Financial service providers	Netherlands (Port and Mari	PortXL	LNG Zero
10. Financial service providers	Netherlands (Credit Insurar	Atradius	Interviews

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