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GREENING OF THE MARITIME INDUSTRY

DELIVERING PRODUCT AND SERVICE ECO-INNOVATIONS

BY
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DISSERTATION SUBMITTED 2015

AALBORG UNIVERSITY
DENMARK

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Delivering product and service eco-innovations

by

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Dissertation submitted

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CV

Roberto Rivas Hermann (León, Nicaragua, 1982) graduated as an Environmental Quality Engineer at the University of Central America, Managua, in 2006. After a six-month professional experience in maritime pollution control at the environmental consulting firm EPC S/A, Roberto started a career in academia. From 2007 until 2009 he worked at the Nitlapan Institute (University of Central America) as a researcher for an international project on local water resource governance funded by the Danish Research Council for Development Research, Ministry of Foreign Affairs. In 2009 he obtained an Erasmus-Mundus scholarship to pursue the Joint European Master in Environmental Studies at the Technical University Hamburg and Aalborg University. His MSc thesis inquired on eco-entrepreneurship with a focus in the maritime industry of Frederikshavn. In October 2011, Roberto started this Ph.D. project in collaboration with the Maritime Centre for Operations and Development (MARCOD).

SUMMARY

The maritime cluster in Region Northern Jutland faces the challenge of improving collaboration and competencies among suppliers in order to obtain the economic and societal benefits of accessing the emerging market of maritime eco-innovations. These challenges can be partly addressed if suppliers are part of a value network, which secures a loyal customer base. A key issue for exploration is how to create value in the development and commercialization of eco-innovations, while at the same time improving collaboration and competences among local suppliers. However, the literature on this subject is dispersed and fails to tackle the links between eco-innovation and value creation. Therefore, the purpose of this thesis is to explain the relationship between the processes of eco-innovation and value creation with a focus on the Danish maritime industry.

The thesis addresses the main research question: *How can maritime suppliers deliver product and service eco-innovations to the maritime industry?* The thesis analyses four areas of interactions among suppliers and end-users through a multiple-case study design. The following paragraphs illustrate the scope of each of the research articles:

The first article, "Drivers for Eco-innovation in the Shipping Industry: A Case Study of the North European Emissions Control Area" focuses on how regulations influences eco-innovation by interacting with other drivers (e.g. market, technology and business internal aspects) in the maritime industry.

The second article, "Partnerships for Environmental Technology Development in the Shipping Industry: Two Danish Case Studies", focuses on how partnerships create arenas for the co-creation of eco-innovations between maritime suppliers and other actors. The article presents two case studies on Danish partnerships for developing cleaner technologies for the maritime industry; The Partnership for Cleaner Shipping and Green Ship of the Future. The analysis focuses on two issues. The first case study, looks at how two (initially separate partnerships) interact, in addition, to the outcomes of this interaction in terms of eco-innovations and business relations. The second issue looks at what characterizes public-private partnerships for cleaner technology development in terms of the initiative of partners, participation, the scope of the projects and the division of roles.

The third article "Innovation in Product and Services in the Shipping Retrofit Industry: A Case Study of Ballast Water Treatment Systems" focuses on how business models support the development and implementation of eco-innovations through value propositions. The case study analyses the business models in the development, installation and operation of ballast water treatment systems from a perspec-

tive of Danish maritime service suppliers. Based on this analysis, the article focuses on the aspect of joint value creation by analysing how suppliers can propose innovative product and service offerings to the maritime industry, taking as example port-based ballast water treatment systems.

The fourth article, "The Function of Intermediaries in Collaborative Innovation Processes: Retrofitting a Danish Small Island Ferry with Green Technology" focuses on how intermediaries initiate and stimulate the development and implementation of eco-innovations through facilitation and project management. The case is a study of the green retrofit on the Læsø ferry, which focuses on the roles of innovation intermediaries along the innovation process for collaborative demonstration projects.

The overall finding is that Danish maritime suppliers can improve the deliveries of their environmental products and services to the maritime industry if they are able to create value nets between local suppliers and maritime actors. This can be seen as a process which starts by setting up eco-innovations projects and partnerships. These partnerships and activities create eco-innovations by combining knowledge business, technologies and regulations, .Demonstration projects, play an important role in competence building. They are characterized as "temporal structures" which focus on end-customer value and purposeful cooperation between suppliers to co-produce value propositions. A closer look at a demonstration project where a vessel was retrofitted with environmental technology shows that innovation intermediaries support the interactions between supply firms that previously had not been active suppliers in collaboration with other firms in the cluster. Furthermore, innovation intermediaries also facilitate the development of service packages for the green retrofit of vessels, which demands close communication and competence building in a narrower network of suppliers. The process of developing new markets and technologies requires a business model which provides a joint narrative and a vision to present a value-proposition integrating the actors in the supply network –as seen in the ballast water treatment systems case study. The process of transforming the relations of the suppliers into value networks also strengthens the competences and collaboration among actors in the cluster through: i) cluster initiatives as mechanism to initiate and develop environmental technologies ii) active participation of end-users and key suppliers in the cluster initiatives and iii) through the support and steering provided by innovation intermediary organizations.

The first contribution of this thesis is to propose a conceptual framework to analyse and understand current research on value creation in supply networks through eco-innovation. The framework resulted from an interpretative process of reviewing literature and getting insights from the actors involved in the Danish maritime supply networks. The use of the conceptual framework in the four case studies indicates that value creation is a way to motivate key stakeholders in the clusters to collaborate and increase their competences for the provision of environmental products and services. A second contribution of this research is providing a better understanding of the greening of the maritime industry from the perspective of value creation through the development of maritime eco-innovations. In particular, cluster initiatives allow shipowners and their suppliers to collaborate and develop new competences while co-creating environmental technologies. The process of co-creation works in the direction of greening the industry because these initiatives could become "niches" of experimentation and learning with new technologies before commercialization.

DANSK RESUME

Det globale marked indenfor maritime eco-innovation har vakt interesse hos en række leverandører, specielt den del af den maritime klynge i Region Nordjylland, der omfatter reparation af skibe, vedligeholdelse og levering af specielt udstyr. Den maritime klynge i regionen er mødt af udfordringer i forhold til at forbedre kompetencer og øge samarbejdet mellem leverandørerne for at opnå økonomiske og sociale fordele på dette marked for maritime eco-innovationer.

Disse udfordringer kan imødekommes, hvis leverandørerne bliver en del af et værdinetværk, der kan sikre en loyal kundebase. Et fokuspunkt er, at kombinere skabelse af værdi i udvikling og kommercialisering af eco-innovationer med udvikling af samarbejde og kompetencer mellem de lokale leverandører samtidig styrkes. En relativt begrænset mængde litteratur behandler dette emne, især hvad angår forholdet mellem eco-innovation og værdiskabelsesnetværk. Denne afhandlings formål er derfor at undersøge og forklare sammenhængen mellem processerne i eco-innovation og værdiskabelse i netværk med udgangspunkt i den maritime industri i Danmark.

Afhandlingen præsenterer en konceptuel ramme for analyse af : *Hvordan kan maritime leverandører levere **produkt- og service eco-innovationer** til den maritime industri?* Den konceptuelle ramme er resultatet af en iterativ proces mellem det teoretiske og empiriske arbejde i form af litteraturgennemgang, case studier og de fortløbende interviews og interaktion med aktørerne i de danske netværk af leverandører til den maritime industri via MARCOD.

Afhandlingen er baseret på et multiple-casestudiedesign bestående af fire case studier, der fokuserer på fire centrale interaktionsfelter mellem leverandører og slutbrugere indenfor maritime eco-innovationer: motivation, partnerskaber, de innovative mægleres rolle og forretningsmodeller. Analyserne af de fire interaktionsfelter er både en forudsætning for og et resultat af den konceptuelle ramme.

Den første artikel ” Drivers for Eco-innovation in the Shipping Industry: A case study of North European Emissions Control Area” fokusere på hvordan regulering influere på eco-innovation i et komplekst samspil med andre drivkræfter så som Technologi, marked og Industri/organisations interne aspekter.

Den anden artikel ” Partnerships for Environmental Technology Development in the Shipping Industry: Two Danish Case Studies” fokusere på hvordan Partnerskaber skaber arenaer for sam-skabelse af eco-innovation mellem maritime leverandører og andre martime aktører. Studiet præsenterer tom case studier af danske partnerskaber for udvikling af renere teknologi i den maritime industri: ”Partnerskabet for renere

skibe" og "Fremtidens grønne skib". Analysen fokusere to tematikker: Den første tematik der undersøges er hvordan to selvstændige og autonome partnerskaber interagerer og spiller sammen, samt hvordan denne interaktion mellem partnerskaber bidrager til at forbedre mulighederne for at skabe eco-innovationer og forretningsrelationer. Den anden tematik, der undersøges er vedrører dynamikken i offentlige-private partnerskaber med henblik på bedre at forstå hvordan de initieres, deltagelse, projekt scope samt aktør roller.

Den tredje artikel "Innovation in Product and Services in the Shipping Retrofit Industry: A Case Study of Ballast Water Treatment Systems" fokusere på hvordan at business modeller bidrager til udvikling og implementering af eco-innovationer gennem udvikling af "value propostioner". Case studiet undersøger og diskutere forskellige business modeller for udvikling, installation og operation af ballastvand behandling ud fra et service leverandør perspektiv. Artiklen fokusere på denne baggrund særligt på aspekter knyttet til udvikling af "joint value creation" ved at undersøge hvordan leverandører kan udvikle forskellige innovative produkt /service ydelser til den martime sektor.

Den fjerde artikel "The Function of Intermediaries in Collaborative Innovation Processes: Retrofitting A Danish Small Island Ferry With Green Technology" fokusere den rolle som medierende aktører i form af individer og organisationer spiller for udvikling og implementering af eco-innovation gennem facilitering og project management. Casen er et case studie af processen med at etablere og udvikle grøn retrofit til Læsø færgen i Nordjylland. Artiklen fokuserer på betydningen af medierende aktører for at etablere og tilvejebringe eco-innovative demonstrationsprojekter, samt hvordan at indhold og omfang bestemmes af en kompleks interaktion og samspil mellem forskellige teknologier, viden og aktører interesser.

Afhandlingens overordnede resultat er, at danske leverandører kan levere miljøløsninger og -ydelser til den maritime industri, hvis de er i stand til at udvikle og indgå i værdiskabende netværk baseret på de eksisterende styrker i de lokale klyngedannelser. Denne udviklingsproces begynder med dannelse af partnerskaber om at udvikle specifikke miljøløsninger på et givet problem. Disse partnerskaber er et resultat af aktiviteter, der tilstræber at opbygge viden om nye teknologier og reguleringer. Tilsvarende kan demonstrationsprojekter karakteriseres som "temporære strukturer", der fokuserer på at skabe værdi for slutbrugeren og på et formålsrettet samarbejde med leverandører for at medproducere værdi.

En nærmere analyse af et demonstrationsprojekt, hvor et fartøj bliver eftermonteret med miljøteknologi, viser at innovationsmæglere/-formidlere understøtter interaktionen med de leverandører, der hidtil ikke havde været aktive i samarbejdet med andre firmaer i klyngen. Derudover støtter de innovative partnerskaber udvikling af servicepakker til miljørigtig retrofit af fartøjer, hvilket kræver tæt kommunikation og kompetenceudvikling i et snævert netværk af leverandører.

Processen med at udvikle nye markeder og teknologier kræver en forretningsmodel, som skaber en fælles fortælling og vision til at præsentere et værdigrundlag, som integrerer de involverede i et værdinetværk – som det fremgik i case studiet om rensning af ballastvand. Den gradvise transformering af leverandørernes relationer ind i et værdinetværk styrker kompetencer og samarbejde mellem deltagere i klyngen gennem: i) klyngeinitiativer som mekanismer til at igangsætte og udvikle miljøteknologier ii) slutbrugernes og nøgleleverandørers aktive deltagelse i klyngeaktiviteterne iii) støtte og styring ydet af innovationsformidlende organisationer.

Afhandlingen bidrager først og fremmest til den nuværende forskning i eco-innovation ved at analysere og forstå værdidannelse i leverandørnetværk gennem eco-innovation baseret på en konceptuel model. Brugen af den konceptuelle ramme i de fire case studier indikerer at værdidannelse er en måde til at motivere nøgleaktører i klynger til at samarbejde og øge deres kompetencer i forhold til at levere miljøløsninger og ydelser.

Afhandlingen bidrager således til en bedre forståelse af hvordan maritime leverandører kan levere produkt og service innovation til et fremvoksende marked for eco-innovation gennem udvikling af netværk og samarbejde ud fra et værdiskabende perspektiv Værdinetværk er således centralt for udvikling af klyngeinitiativer, der fremmer samarbejdet mellem rederier og deres leverandører om at udvikle nye miljøteknologier og kompetencer.

PREFACE

Founded in 2011, through public and private association, the Maritime Centre for Operations and Development (MARCOD) became established as an information centre to increase competence and knowledge in the Danish maritime cluster. The main task of MARCOD is to support maritime firms in creating synergies that lead to economic growth through the development of new products and markets. Since its inception, MARCOD has made the development of clean technology one of its main priorities, leading to the need to motivate maritime suppliers to enter this niche market. With the purpose of understanding how to improve the process of creating competencies in the maritime cluster for eco-innovation, MARCOD and Aalborg University began this Ph.D. project in October 2011.

In this Ph.D. thesis, the results of this joint research project between MARCOD and the Department of Development and Planning at Aalborg University are presented and reflected. The subject of research is how maritime equipment and service suppliers can co-create environmental technology (products and services) through value propositions which increase the competitiveness of the Danish maritime cluster. The theoretical and methodological reflections are presented together with four peer-reviewed articles, their synthesis and their contribution to both theory and practice.

My experience in the maritime industry began in 2005 through a six-month employment opportunity as an environmental engineer for a Nicaraguan firm (Environmental Protection and Control S.A.). Due to the MARPOL[1] convention, Nicaraguan harbours must ensure the capacity to contain oil or chemical leakages from vessels. As a result, the firm specialized in emergency response to these oil spills. My time with (insert firm name), made me aware of the complexities behind this specific environmental protection practice. Five years later, this professional experience inspired me to do a semester in Panama as part of my MSc in Environmental Studies at Aalborg University. There I inquired how City of Knowledge, located in the vicinity of the Panama Canal could develop eco-innovations that served the Canal's authority. When analysing the empirical data through the theoretical lenses of "Triple Helix", and writing the report, I found a new and intriguing subject of research: inter-organizational collaboration for developing eco-innovations in the shipping industry and associated services.

[1] International Convention for the Prevention of Pollution from Ships

As a nation, Denmark's maritime industry still generates thousands of direct and indirect jobs, therefore, maritime service firms along with equipment manufacturers have to continue to adapt to a rapidly changing and fiercely competitive international market. For example, the value chain in the industry has evolved to include operation models where shipyards now outsource their own workforce, competencies and the installation of equipment to different suppliers, instead of controlling all aspects of production (Hameri and Paatela 2005; Hammervoll, Halse, and Engelseth 2014). Given these changing dynamics, the Danish maritime industry focuses on developing and installing energy and environmental efficient maritime equipment to cut operational costs in new and old vessels. Furthermore, the Danish authorities and Shipowners Association promote a green discourse and strict enforcement of the MARPOL convention by all countries in addition to compliance with the existing rules regarding the control of air pollution (i.e. SO_x, NO_x) and support for further regulations on i.e. black carbon, or the cleaning of ballast water. The promotion of this discourse on stricter environmental regulations and enforcement represents an opportunity to build a market niche for Danish equipment manufacturers of environmental technology (including technology to control emissions, monitoring equipment, energy efficient pumps, etc.). Both Danish public authorities and private actors have made the development and diffusion of cleaner technologies for the maritime industry a priority, along with goals such as increasing competencies, improving the critical mass of available labour and keeping the maritime industry competitive. These priorities are reflected in a number of cluster initiatives in the Danish Maritime industry, to name a few: Transport Innovation Network, Blue Denmark, Partnership for Cleaner Shipping, Green Ship of the Future, Maritime Centre for Operations and Development (MARCOD).

I became acquainted with this dynamism of the Danish maritime cluster and the high priority of environmental technology when writing my M.Sc. Thesis in Environmental Management and Sustainability Studies during the spring of 2011. At the time, I had the opportunity to participate in the project Maritime Innovation in Kattegat and Skagerrak (MARKIS), which included academic and public agency partners from three regions in Denmark, Sweden, and Norway. During the project, a key concern was creating collaboration between ship owners, public actors, and equipment manufacturers in order to innovate cleaner technologies for the maritime industry. The focus of my research was on ecopreneurs,-maritime service firms which began to offer new products and services with the purpose to improve the environmental performance of vessels, in addition to their usual business activities. While the organization's goal was to understand why these firms eco-innovated, my research failed short in understanding the external collaborations between these ecopreneurs with other organizations. Such as through which mechanisms these firms and individuals increased their absorptive capacity to new competencies and knowledge. Surprisingly, this interest was not only mine, but also that of an incipient organization: MARCOD.

Coordinating inter-firm collaboration, and creating cleaner technology projects is a challenging task. At the same time, it has practical implications for organizations such as MARCOD but also firms that take part in the maritime cluster. In this thesis, I reflect on these issues through my research questions and the science position through which I approach the question: I consider knowledge as being co-constructed by stakeholders on the ground, and my role as a researcher is to collect their different perspectives, in order to support a joint reflection between them as actors and the academia.

ACKNOWLEDGEMENTS

After three sailing years, this clipper finally arrives to safe harbour. It benefited of good winds (people and organizations) which pushed it through the three-year journey and without their assistance this Ph.D. thesis would not be a reality. The first main wind was the Maritime Centre for Operations and Development (MARCOD), which hosted me during the last three years and was the gate to the maritime Northern Jutland. The staff from MARCOD was an invaluable source of ideas, knowledge and contacts for the creation of the various case studies. I also thank those past and present people in MARCOD with whom I had the opportunity to share time, ideas and push this thesis project forward: Jeanne-Christine Lunde Christensen, Erik Møller, Allan Hejslet, Niels Christensen, Tanja Jorgensen, Dusko Nikic, Søren Thue, Steen Hjulskov, and Anette Hermann Sørensen. The other two key winds in this journey were my supervisor, Professor Arne Remmen and my co-supervisor, Associate Professor Søren Kerndrup. They are part of Sustainability, Innovation and Policy (SIP), a research group made up of creative and intellectual exigent scientists with whom I engaged in two Interreg maritime projects during the last four years, in special, Carla K. Smink, Henrik Riisgaard, Mette Mosgaard and Stig Hirsbak. In SIP I also had the opportunity to spend most of my time with great people, who did not directly collaborated in my projects but were a great source of ideas during our common meetings, Martin Lehmann, David, Kristen, Anja, Rikke and Kristina. I thank two more people in SIP for their valuable background support regarding University formalities and proofreading of articles: Annelle Riberholt, Mette Reiche Sørensen and Dorte Norgaard Madsen.

I acknowledge the support of other people not related to MARCOD nor Aalborg University. I had the opportunity to actively collaborate with other motivated researchers who shared their time to co-author a journal article with me. Their insights were valuable to increase the scientific quality of the original manuscript: Jonathan Köhler from the Fraunhofer Institute for Systems and Innovation Research (ISI) in Karlsruhe, who also hosted me in April 2013; and Arno Scheepens from TU Delft.

However, this Ph.D. Thesis clipper had a main engine which propelled it faster while crossing turbulent waters. I would like to give special thanks to my family: my wife Catherine, who together with my children Marianne (1) and Ruben (3) gave me that extra needed propulsion when I needed it the most. Last but not least, I thank all my relatives who accompanied me through this voyage, in particular, Kristy Aldridge for helping with the language correction of the final Thesis.

CONTENTS

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ABBREVIATIONS

EMS	Environmental management systems
HSG	Hantsholm Service Group
IMO	International Maritime Organization
LNG	Liquefied natural gas
MARCOD	Maritime Centre for Operations and Development
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine diesel oil
MEPC	Marine Environmental Protection Committee
MGO	Marine gas oil
MNF	Maritime Network Frederikshavn
OEM	Original equipment manufacturer
QDAS	Qualitative data analysis software
SCM	Supply chain management
SECA	Sulphur emissions control area
TEU	Twenty-foot equivalent units

OVERVIEW

This Ph.D. thesis was inspired by the environment of the Danish maritime industry, which aims to combine the goals of growth along with cleaner shipping and the development of environmental marine technology (Danish Government 2012). These goals are reflected in a set of "cluster" initiatives to improve the connectivity of actors, but also their proactive role within the maritime cluster in international negotiations. Including the push for environmental regulations for shipping, considered by these actors as an opportunity to develop market opportunities for green technologies (Cerup-Simonsen 2009; Danish EPA 2007). The first part of thesis' title: "Greening of the maritime industry" synthesizes the context of the research: an industry that experiments with internalization of environmental issues. This context is reflected by defining the research problem, but also by providing a frame to understand the results. The subtitle: "Delivering product and service eco-innovations", presents the subject of research within the supplier side of the industry, and how the new requirements of end-users (ship owners) motivate changes along the supply chains. Changes which encourage suppliers to develop compelling environmental product and service propositions in order to capture part of the growing demand of ship owners for cleaner technologies.

The maritime industry is a key economic sector in the Danish economy, and both public and private actors aim to keep this industry in steady growth. Part of this effort is to consider shipping as the centrepiece and to connect it with the associated maritime cluster —"Blue Denmark". The importance of shipping is shown in the official statistics as of the 1st November 2014 (Danish Shipowners' Association 2014), the Danish registered fleet accounted for 647 ships representing 15,9 million deadweight tonnes (DWT) and 13,8 gross tonnes (GT). From the GT data, 71% were for the liners (i.e. Container ships), 22 % for tankers (i.e. Oil and gas) and 7% for tramp[2] shipping. All shipping firms combined earned 201 billion Danish Kroner, which counted for 19% of the total Danish foreign currency earnings in 2014. In terms of employment, shipping generated 25 000 direct jobs (Danish Shipowners' Association 2014). Given its economic contribution, shipping is a key pillar of the Danish economy.

Starting in the early 2000s, the national government promoted the policy concept of Blue Denmark in order to improve the collaboration between shipping firms –which are considered the centrepiece of the Danish maritime industry- and maritime

[2] Tramp shipping refers to vessels providing transportation services without predefined schedules

equipment suppliers, offshore companies, educational and research centres and maritime service firms (Sornn-Friese 2003). Statistics on direct and indirect jobs reflect this shipping steering role in the Blue Denmark with maritime service firms generating 36 711 jobs, equipment production 37 173, ship construction 5 880 jobs and oil and gas 9 318 jobs (Danish Shipowners' Association 2014).

Concerning the international environmental regulations, a milestone was the year 2006, when the member States of the International Maritime Organization (IMO) approved the Annex VI of the MARPOL convention, which establishes limits for the emissions of SO_x and NO_x. The Danish representation at IMO was influential on technical aspects about how emissions reductions should be achieved. Similarly, Danish ship owners took an active role before the formulation of the Annex VI requirements, but also when the new rules entered into place. The proactive role of both public and private actors was reflected in the creation of public-private partnerships with the purpose to foster innovation of environmental technologies to comply with the new rules in a cost efficient way. In addition to ship owners and public authorities, maritime equipment suppliers and service providers have an active role in these partnerships (i.e. Partnership for Cleaner Shipping, Green Ship of the Future, Partnership for Retrofit).

These national partnerships are complemented by initiatives originating in harbours and regions where for many years companies have been working together, and thus nurturing the growth of firms specialized in developing maritime equipment and service through the life cycle of a vessel. Examples are the shipping cluster in Copenhagen, the offshore cluster in Esbjerg, the marine equipment cluster in the island of Fyn and the maritime service and repair cluster in Northern Jutland (Danish Government 2012)

In the last three years, the Maritime Centre for Operations and Development, MARCOD, has worked hard to promote the concept of green retrofit among Danish maritime service firms, giving particular attention to Northern Jutland, given the region's maritime firms' traditional areas of expertise. This endeavour has employed a number of activities with different aims: First, those activities falling into the concept of enhancing "absorptive capacity" (Ndiege, Herselman, and Flowerday 2012) aiming to create new knowledge and competencies surrounding the subjects of green retrofit, cleaner technologies and new environmental regulations. Second, supporting the creation and strategic planning of networks of maritime service suppliers with the aim to increase cohesion and collaboration between these firms.

Although both missions have their own difficulties a particular challenge has been finding a way to change the mindset of firms and workers who have the competencies, in particular conventional technologies (not necessarily environmental). This Ph.D. thesis has accompanied the activities of MARCOD since the inception and has focused on how to solve this dilemma, approaching it through the research question:

How can maritime suppliers deliver product and service eco-innovations to the maritime industry?

The research question is presented after a more detailed problem definition in section 1. The concepts used in the research question are also developed with greater detail in *Part II: Theory* and briefly defined as follows. Product eco-innovations are defined as process, or end-of-pipe technologies which seek to improve the environmental performance of vessels (i.e. Scrubbers, catalyst reduction, but also engines running with liquefied natural gas, etc.) Service eco-innovations include the renovation of vessels with environmental technologies (i.e. Green retrofit), but also the conventional installation of one piece of equipment provided it improves the environmental performance of the vessel. Maritime suppliers are defined as a broad range of organization types, ranging from micro (one employee) to small and medium-sized enterprises, which provide a broad range of products and services to the maritime industry. The focus in this thesis is on maritime suppliers of equipment, but also on electrical /metalwork suppliers and shipyards. Although other suppliers exist (i.e. Food catering) these are not considered under the concept used in this thesis.

In order to understand the dynamics behind the improvement of collaboration and competence of supply networks regarding environmental technologies, I position my thesis in the eco-innovation realm within an ecological modernization perspective. Ecological modernization stands for addressing environmental problems through incremental “improvements” to the current socio-technological system (Jänicke and Jacob 2005). One of the means to achieve these “improvements” is the diffusion of environmental technologies and cleaner organizational/ institutional routines (eco-innovations), which can eventually overcome environmentally damaging ones. Eco-innovations are the result of a lengthy and complex process, where individual actors-innovators are part of a socio-technological system. Eco-innovations, as part of this system face, windows of opportunities and constraints to be diffused to a larger number of users. These constraints are for example the existing institutional settings, which are configured as to allow conventional technologies, but also asymmetric competences and knowledge in relation to the green technologies. To deal with these constraints, the promoters of eco-innovations act in different networks —i.e. Regulatory, business, academic (Hansen, Søndergård, and Meredith 2002). Collaboration and competence building cannot be understood without collaboration between eco-innovators with other actors in these networks. I analyse eco-innovations as a process creating collaborative competencies and as such focusing in three domains: establishing partnerships for the early stages of eco-innovations, generating collaborative value and analysing the role of intermediary in eco-innovation processes.

The Ph.D. thesis is based in four articles, presented in *Part IV Results and Discussion*, these articles translate the research questions into empirical findings and theoretical inferences:

- Rivas-Hermann, R. and Remmen, A. (2015) Drivers for eco-innovation in the shipping industry: A case study of the North European emissions control area. Journal of Cleaner Production (Submitted).
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- Rivas-Hermann, R. Köhler, J. and Scheepens, A. (2014) Innovation in product and services in the shipping retrofit industry: a case study of ballast water treatment systems. Journal of Cleaner Production (Accepted)
- Rivas-Hermann, R. Mosgaard, M. and Kerndrup, S. (2015) Intermediaries functions in collaborative innovation processes: retrofitting a Danish small island ferry with green technology. International Journal for Innovation and Sustainable Development (Submitted)

In addition, I prepared one report focused on the use of eco-labels for the promotion of wind-assisted propulsion in cargo ships (Appendix B). The report is a deliverable for the Interreg IVB project SAIL —Sustainable Approaches and Liaisons, in which I participated from 2013 until 2015. This report was not included as part of the results, but it complements the insights of the first article. The reference for this report when used in this thesis is:

- Rivas-Hermann, R., Smink, C. K. and Hirsbak, S. (2015) Eco-labelling for the promotion of wind-assisted propulsion in cargo ships. Aalborg, Aalborg University. http://www.nsrsail.eu

In order to contextualize the articles, the Ph.D. thesis is divided in five parts. *Part I: Introduction* answers *Why*? This part provides a background for the empirical and theoretical problem, which is then scooped into a delimitation and problem formulation, including sub-questions. These sub-questions are then related to the different scientific articles. *Part II: Conceptual Framework*, presents a conceptual framework, which aims to provide propositions as a red line to the four articles. *Part III: Theory of Science and Methods* answers *How?* In this part, I position the research as qualitative research from a constructivist scientific paradigm and explain how this position affects the methodological choices. *Part IV: Results and Analysis* begin with a chapter that briefly introduces the four scientific articles. In *Part V: Conclusion*, I summarize the main findings of the articles in relation to the overall research question. The theoretical implications of the thesis are highlighted along with suggestions for further research.

PART I

INTRODUCTION

The purpose of this section is twofold: first, to provide an empirical and theoretical background for the topic of this thesis; second, to formulate the research problem along with specific sub-questions. Part I contains two chapters: *Chapter 1 Introduction and Chapter 2 Delimitation of Research.* In Chapter 1 the research problem is positioned within the broader context of the maritime industry's maritime equipment and service supply chains. As well as the role of Western European shipyards in these supply chains. This is expanded by presenting how the Danish region of Northern Jutland seeks to create value for the sub-cluster of maritime service in this context. In *Chapter 2 Delimitation of the research,* I first scope the research problem, which is formulated as a research question and sub-questions. Second, I explain the relationship between the research sub-questions and the scientific articles

1
INTRODUCTION

In this Chapter, the background of the study is presented in three sections. Section 1.1 introduces the broad context of the problem by analysing the historical evolution of the global maritime industry while emphasizing on how the role of European harbours and shipyards has changed over time. Additionally, section 1.1 highlights the maritime industry as a customer demanding high added value products and services in countries such as Denmark while outsourcing the labour intensive shipbuilding processes to Southeast Asia. Finally, Section 1.1 sketches how international regulations and self-regulation from major shipping firms has increased the demand for environmental technologies.

Section 1.2 further explores how the Northern Jutland region in Denmark has embarked into industrial activities of high added value with the purpose to supply the maritime industry. This regional strategy is underpinned in the existence of a national and a regional maritime cluster, composed of actors along the maritime industry's supply chains (i.e. Equipment suppliers, maritime service suppliers, ship owners, insurance firms, etc.).

Section 1.3 advances the argument that the evolution of the maritime industry has favoured the emergence of supplier networks, which seek to create product and service offerings of higher added value for shipping firms. Ultimately, this section illustrates how the maritime service networks of Region Northern Jutland are responding to this market condition by jointly offering new services to the maritime industry.

1.1 TRANSFORMATIONS IN THE MARITIME INDUSTRY SUPPLY CHAINS

Shipping provides the service of waterborne transportation of freight and passengers. In the case of freight, it complements other modes of transportation such as air, truck, rail and pipelines. In the case of passenger services, it complements the modes of air, road and rail modes (Rodrigue, Comtois, and Slack 2013). International shipping has been associated with global trade and different authors highlight the role of shipping in facilitating the globalization of supply chains for several industries, i.e. Dicken (2011) and Fremont (2005).

As the capacity and the technical diversification of ships allow for growth in trade while becoming more complex, the maritime industry faces a twofold transformation. The first aspect of this transformation implies changes in the industry's construction, operation and ship's end of life supply chains. All of which have had implications in the business models of European shipyards and the maritime service suppliers as explained in section 1.1.1.

The second aspect of the transformation deals with the challenge of cleaner operations, and the industry's struggles in dealing with growing demand and higher operational costs (i.e. Fuel costs show a constant increase over the years). This aspect of the transformation within the industry also brings new opportunities for maritime service suppliers and European shipyards (See section 1.1.2).

1.1.1 EVOLUTION OF EUROPEAN SHIPYARDS' ROLES IN MARITIME SUPPLY CHAINS

The growth in shipment tonnage (see Table 1) could not be possible without technological developments in ports and ships which require similar adaptations on one and the other (Appendix A, Table 26).

Table 1 Development of international seaborne trade in 1970-2012 (millions of tons loaded). *Source*: UNCTAD (2013)

Year	*Oil and gas*	*Main bulks*[a]	*Other dry cargo*	*Total (all cargoes)*
1970	1 440	448	717	2 605
1980	1 871	608	1 225	3 704
1990	1 755	988	1 265	4 008
2000	2 163	1 295	2 526	5 984
2005	2 422	1 709	2 978	7 109
2006	2 698	1 814	3 188	7 700
2007	2 747	1 953	3 334	8 034
2008	2 742	2 065	3 422	8 229
2009	2 642	2 085	3 131	7 858
2010	2 772	2 335	3 302	8 409
2011	2 794	2 486	3 505	8 784
2012	2 836	2 665	3 664	9 165

(a) Iron ore, grain, coal, bauxite/alumina and phosphate rock. Data from 2006 onwards are based on various issues of the Dry Bulk Trade Outlook.

The port's importance is often reflected in the total of tonnage or TEUs handled. These statistics reflect the dynamics of globalization. Table 2 illustrates how in the

1970s the harbours with higher container throughput were located in North America or Western Europe. In 2012 the top 10 harbours in container throughput shifted to harbours located in South-East Asia (including seven Chinese harbours). Table 2 also illustrates how over the last 40 years, the economies of scale have increased the demand for larger harbours to accommodate larger vessels.

Table 2 Global top 10 container ports 1970 -2012. *Sources*: Jephson and Morgen (2014) and UNCTAD (2013)

1970			***2012(a)***		
Port	***Country***	***Total TEU***	***Port***	***Country***	***Total TEU***
Oakland	USA	336 364	Shanghai	China	32 500 000
Rotterdam	Netherlands	242 328	Singapore	Singapore	31 600 000
Seattle	USA	223 740	Hong Kong	China	23 100 000
Antwerp	Belgium	215 256	Shenzhen	China	22 940 000
Belfast	UK	210 000	Busan	Korea	17 030 000
Bremerhaven	Germany	194 812	Ningbo	China	14 973 400
Los Angeles	USA	165 000	Guangzhou	China	14 520 000
Melbourne	Australia	158 127	Qingdao	China	14 500 000
Tilbury	UK	155 082	Dubai	UAE	13 280 000
Larne	UK	147 309	Tianjin	China	12 300 000

(a) Preliminary data according to UNCTAD (2013)

The period between World War II and the early 1970s oil crisis marked the uptake of a Japanese dominated, shipbuilding market in Asian shipyards instead of Western European yards. The main reason was that shipbuilding was a low to medium skilled, labour intensive industry with a priority in cost efficiency (Poulsen and Sornn-Friese 2011). Japanese shipyards engaged in the construction of simple large capacity tankers, bulk and general cargo vessels, while European shipyards found a niche in more specialized vessels with higher added value vessels -i.e. Ferries, leisure, military, offshore service, etc. (Poulsen and Sornn-Friese 2011). After the 1970s, the decline in new ship construction commands to European shipyards continued on behalf of Japanese, Chinese and South Korean shipyards

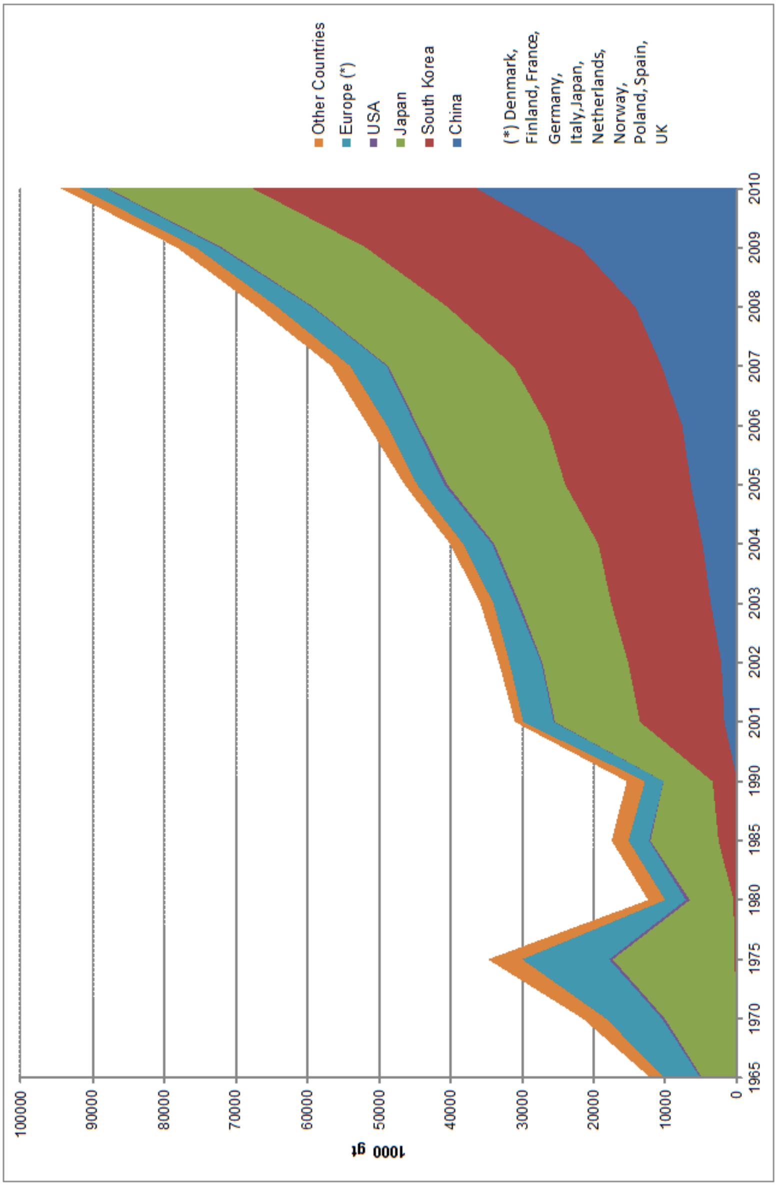

Figure 1 World merchant ships completed by major shipbuilding countries. *Source*: ISL (ISL 2011, 269–271)

By the end of the 2000s, the European shipbuilding industry directly employed around 150,000 people specializing in the construction of high tech ships –i.e. Cruise ships, military vessels, etc., but also in the repair of ships (EMF and CESA 2007). In Denmark shipbuilding declined as a major industrial activity in the 2000s due to major shipping liners such as Maersk, DFDS and Lauritzen whom internalized shipbuilding, owned national shipyards and commanded internal ships. In the long term this strategy proved unviable (Poulsen 2013). Sweden, whose shipyards were second in the number of ships constructed in the 1970s, survived until the end of the 1980s by constructing specialized large capacity tankers (Sjögren, Lennerfors, and Poulsen 2012). In the case of off-shore service vessels (OSV), Engelseth and Zhang (2012) consider the case of Norwegian shipyards, which are still relevant as facilities for assembling and fitting components, while claiming that the competence of the local workforce shortens the construction time of these kinds of vessels in comparison to Chinese and Brazilian OSV shipyards.

According to a study of DG Enterprise and Industry (2014), the European shipbuilding and ship repair industry is made up of ca. 300 shipyards and 90% of the order book is for export markets. The same study highlights the European equipment manufacturing industry (propulsion, cargo handling, automation, integrated systems) being formed by ca. 7500 companies and with 70% of production for export markets. In other words, the ships are built in Eastern Asia, but are still equipped with high-end European technologies. In total the European Shipyards and maritime equipment industry generate a yearly turnover of 72 billion Euros (DG Enterprise and Industry 2014). European maritime equipment and service suppliers to shipyards need to innovate services and products of higher value from the perspective of shipyards and end-users (ship owners). European marine equipment suppliers and service providers can integrate the supply chains of the maritime industry in different phases of ships' life: research and design, construction, operation and end-of-life (Figure 2).

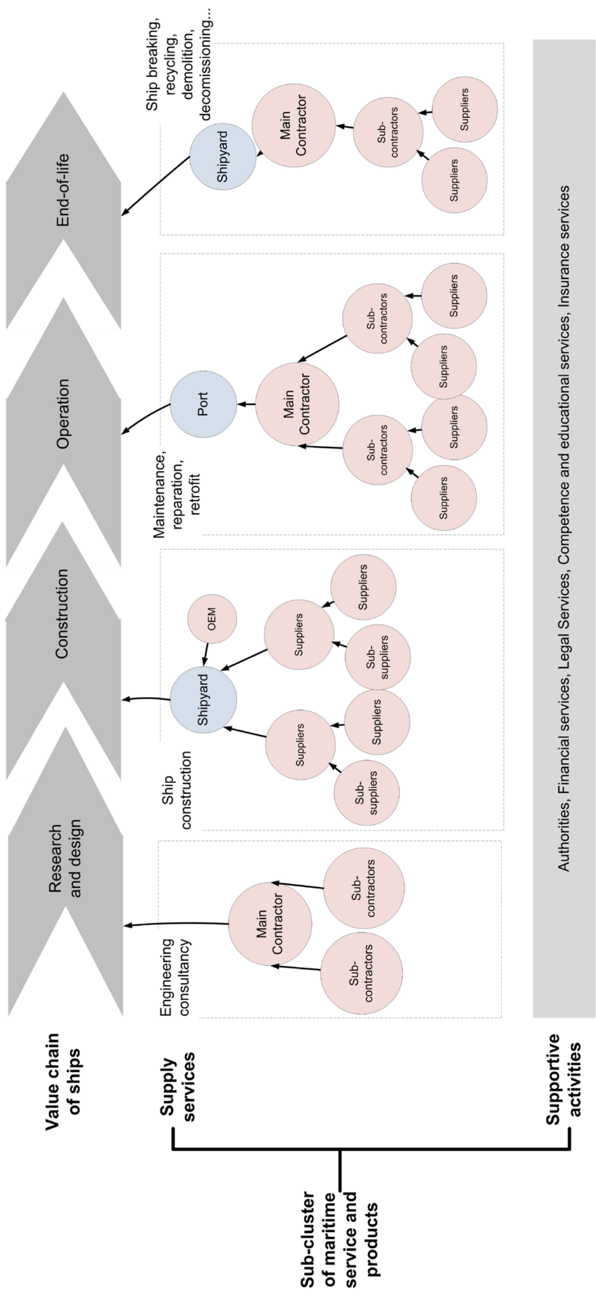

Figure 2 Supply chains of the maritime industry with focus on value networks for ship construction, maintenance, repair and retrofit and shipbreaking.

During the construction phase, shipyards hire the necessary labour to build the hull structure of the ship, to install equipment as the engines, to do piping and ventilation metalwork and commission the lighting and navigation systems, etc. All these services represent added-value as they require a skilled workforce with knowledge on the different technologies and settings of installation, and these services are provided by external sub-suppliers or OEMs (Hameri and Paatela 2005). This illustrates that European equipment manufacturers are still important suppliers in the shipbuilding phase. A report by the European Association of Marine Equipment manufacturers –SEA highlighted two scenarios for the market share of European shipbuilding suppliers (BALance 2014). The first scenario accounts for large equipment manufacturers, whom are global companies dependent on the market development on a global scale and serve the whole shipbuilding market (incl. East Asian shipyards). In the future, these companies will face more competition from Asian marine equipment suppliers, and thus have to follow two strategies: the first is ensuring global networks of service and the second is to create alliances with Asian suppliers (i.e. License agreements, joint ventures and production sites), with the purpose of avoiding losses in the Asian markets. The second scenario accounts for maritime service SMEs, which can have international operations, but because of their size are restricted to regional, national or across European borders. These SMEs engage in subcontracting (manufacturing and assembly) within two broad categories of firms: the first group is former shipyards with a variety of competencies (joinery, accommodation specialists, pipe factories, thin metal shops). The second group is composed of companies specializing in the assembly of specific ship systems, who are often subsidiaries of larger systems or component suppliers. Companies belonging to the second scenario need to associate with shipyards in order to improve processes and reduce costs. Additionally, they could broaden their geographical area of service or engage in alternative supply chains — i.e. other industries (BALance 2014).

During the operation, ships are subjected to routine maintenance or emergency repairs in harbours or while the ship is sailing. In addition, the operations requirements towards e.g. energy efficiency and the environment become a key driver for retrofitting ships with environmental technologies (section 1.1.2 is focused on this issue). The global market for ship repair and maintenance was estimated at 18,5 billion USD, with 50% covering labour costs and the other 50% the spare parts and subcontracts with suppliers.

In the event that the service is provided in a harbour, the ship owner or ship management contacts a main contractor. This main contractor employs its own staff to service the vessel or has a network of sub-contractors for specialized and various other tasks. Harbour maintenance implies higher costs for the ship owner as the vessel is set to be out of operation, with the perspective of being moved to a harbour located in a location different from its operational area. Given these costs, harbour repairs are combined with scheduled maintenance –as stipulated in the

IMO license. A second type of repair and maintenance service is carried out in open waters. In these situations, the ship owner or manager contacts the main contractor, which sends its own staff –or subcontractors- to the ship's location (Figure 2).

According to the SEA report, the main challenge for European suppliers delivering repair, maintenance and conversion services is twofold. First, although part of the market is captive to Western European shipyards due to the market's preference of high-quality services (i.e. Liners and cruise ships); maritime service SMEs without a global reach face having their share of the market absorbed by shipyards located in Far-East, Middle-East or Eastern Europe (i.e. Ukraine) given the lower costs. A way to address this challenge is to create closer networks between suppliers and shipyards for complex ship conversion. The second threat is the financing of non-routine maintenance, for example, engine type conversions or environmental technology retrofits. In this case ship owners often find themselves needing to borrow money in the finance system, and it is hard to justify a conversion investment in an old ship (BALance 2014).

Shipbreaking or the recovering of steel and other high-value materials has its own international market. Ship owners can sell the old ship to a shipbreaking company which pays according to the ship's capacity. Around 90% of ships are dismantled in Bangladesh, India, Pakistan, China and Turkey as companies in these countries pay the best price (Rossi 2011; Litehauz 2013). In Bangladesh and India ships are dismantled through the "beaching" method —ships lie on the beach—, the drawbacks of this method are the health hazards to the workers and environmental impacts as the dismantling usually takes place directly on shore without any protection to the sea or surrounding areas (Demaria 2010). Fewer ships are dismantled in Europe, as the activity is done in special areas located in harbours, in a process which is regulated by environmental regulations applicable at the municipality, but since December 2013 the EU Ship Recycling Regulation has entered into force. This regulation could be a game changer for ships sailing under any EU flag as the regulation requires ship owners to decommission the vessels in authorized facilities (in the EU or out of the EU), these facilities shall ensure the protection of workers' health, but also the surrounding areas from potential hazards (as leakages, explosions, etc.). In 2009, the IMO approved the Hong Kong Convention for the Safe and Environmentally Sound Recycling of Ships, which is still not yet entered into force. This convention enters into force 24 months after ratification by 15 states, representing 40% of the world merchant shipping by gross tonnage –as of February 2015, only three states representing 1,98 % of the gross tonnage of the world's merchant fleet had ratified the convention (IMO 2015).

1.1.2 ENVIRONMENTAL TECHNOLOGIES IN THE MARITIME INDUSTRY

International regulations for the maritime industry are drafted and approved within the IMO, which is part of the United Nations System. These regulations are international, because shipping is a global industry with a myriad of different stakeholders based in different countries (i.e. Ship owners, flag-ship states, port-state authorities, etc.), ships sail between different countries and harbours, but also in international waters, hence being under different jurisdictions. The IMO hosts different committees, among them the Marine Environment Protection Committee (MEPC), where governments jointly define globally applied regulations on navigation safety, but also on the marine environment and seafarers' working conditions (Mensah 2007). Concerning environmental protection, Comtois and Slack (2007a) highlight that IMO has approved more than 40 conventions and 800 rules have been adopted by IMO since it was founded in 1958. In Appendix A (Table 25), an updated list is presented (as of February 2015) with IMO conventions in key areas of environmental protection. The list shows that different environmental aspects have been tackled by international conventions since the beginning of the 1970s. Environmental regulations, enforced or planned, are a reality and a key driver for the adoption of cleaner technologies in the industry (Krozer, Mass, and Kothuis 2003). Despite this, the maritime industry considers these regulations as a financial challenge, thus leading to their delayed implementation over the years – this will be addressed by this thesis in greater detail.

The second key driving force for a more sustainable transportation is the maritime industry's self-regulation. The main drivers of self-regulation in the maritime industry can be grouped into six categories: organizational, customer, society, the natural environment, innovation/technology push and corporate governance. The application of self-regulation strategies provides shipping firms with revenue-related outcomes and with cost-related outcomes –i.e. Growth opportunities, competitive positioning, brand equity, cost of labour, operational efficiency, cost of capital and risk management (Pawlik, Gaffron, and Drewes 2012). A great number of ports and shipping firms are acquainted with the environmental impacts of their activities, but not all the firms have embraced self-regulation strategies with a focus on environmental protection. The existing literature provides an overview of to what extent self-regulation strategies are translated into actual environmental programs in ports and shipping firms. For example, in a worldwide survey of CSR practices in the maritime industry, Comtois and Slack (2007b) found that only 85 out of 800 ports and 41 out of 120 shipping firms around the world had an Environmental Management System (EMS) to address their environmental impacts. According to their conclusions, environmental strategies are concentrated in major ports in North America, Europe, Asia and Australia while the larger shipping firms have formalized EMS. Besides EMS, another environmental strategy by ports and shipping firms is participation in eco-labelling schemes, which seek to promote the operation of cleaner ships[3] (Appendix B). The purpose of these schemes is to provide incentives to ships, which fulfil certain criteria, in particular, environmental friendly design and operation. The incentives are diverse: from differentiated fees in Sweden for the right to use a label that can be used for marketing purposes (Pike et al. 2011).

The combination of environmental regulatory pressures and self-regulation will have an impact on the demand of environmental technologies for ships. Environmental technology comprises process-integrated (e.g. Clean Technology) and end-of-pipe technology (Rennings 2000). Clean technology is defined by the United Nations as: “The installation or a part of an installation that has been adapted in order to generate less or no pollution. Clean as opposed to end-of-pipe technology, the environmental equipment is integrated into the production process” (UN 1997). End of pipe technologies, on the other hand has the aim of “isolating or neutralizing polluting substances after they have been formed”. In the time frame 2010-2020, the type of environmental technologies is diverse both for new ships and for existing ships subjected to changes (retrofit) for installing these kinds of technologies (Table 3). Some of these technologies are process-oriented equipment aiming to reduce the emissions at the source (i.e. Low sulphur heavy fuel oil, distillate fuels, pure LNG engine, waste heat energy recovery). End-of-pipe technologies, clean the exhaust gases or the ballast water before releasing into the air or sea, i.e. SO_X scrubber, ballast water treatment systems (Hellweg et al. 2005).

Table 3 Environmental technology required by environmental regulations 2010-2020. *Source*: DNV (2012)

Technology	Construction	Operation	End of life
Low sulphur heavy fuel oil	■	■	
SO_X scrubber	■	■	
Distillate fuel	■	■	
Pure LNG engine	■		
Dual-fuel engine	■	■	
Exhaust gas recirculation	■		
Selective catalytic reduction	■		
Propulsion efficiency devices	■	■	
Waste heat recovery	■		

[3] During the preparation of this PhD thesis, the author co-authored a report entitled: “Assessing Eco-labelling schemes to promote wind-propulsion technology in cargo vessels” as part of the project SAIL (www.nsrsail.eu). This part takes inspiration in the report which is presented in Appendix B.

Technology	Construction	Operation	End of life
Shaft generators	■		
Hull shape optimisation	■		
Contra-rotating propulsion	■		
Air cushion	■		
Wind power	■		
Smaller engine/de-rating (speed reduction)	■		
System efficiency improvement	■	■	
Hybrid propulsion system	■		
Ballast Water Treatment System	■	■	
Water injection	■		
Water in fuel	■		
Low NOx tuning	■		
Lightweight constructions	■		
Ship recycling	■		■
Reduction of seawater ballast capacity	■		

1.2 ADDING VALUE TO MARITIME SUPPLY CHAINS: THE MARITIME CLUSTER IN NORTHERN JUTLAND

The case of the maritime cluster in the Northern Jutland region of Denmark is relevant for several reasons: First, the region concentrates a great diversity of actors involved in the maritime supply chain (NIRAS 2014). Second, the maritime industry in the region shifted its main activity from exclusively shipbuilding into a large number of supply activities that jointly create more added-value (Olesen 2013). Third, maritime service providers in the region have organized formal networks seeking to provide joint services, in particular with a focus on the operation phase of ships. Finally, the region hosts several education and knowledge organizations (Universities, Technical High Schools, Knowledge centres) that provide a good basis for the development of new competencies as for example in relation to service and clean technologies.

1.2.1 ACTORS AND INSTITUTIONS IN THE REGIONAL MARITIME CLUSTER

Porter (1998) defined industrial clusters as:

> Clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialized inputs such as components, machinery, and services, and providers of specialized infrastructure. Clusters also often extend downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies, or common inputs. Finally, many clusters include governmental and other institutions –such as universities, standard-settings agencies, think tanks, vocational training providers, and trade associations –that provide specialized training, education, information, research and technical support.

In March 2014, the regional authorities published the study “The Blue Northern Jutland” and defined the maritime cluster as the business activities linked to three economic areas: fishing, offshore (oil, gas and wind energy) and shipping. As these three economic areas are interlinked (i.e. They rely on ships and harbours), the cluster integrates key stakeholders as: Ports, transports and logistics companies, education and training institutions, maritime service firms, fisheries and fishing firms (Figure 3).

The cluster is also influenced by maritime equipment manufacturers, ship owners and operators and ferry lines. In particular, Danish ship owners and operators have a great influence in the cluster through i.e. the largest container shipping company (Maersk), world-leading dry bulk carriers (Norden, JL) and important tanker companies (Torm, Esvagt, Switzer, A2SEA). These shipping companies have been important in shaping the maritime cluster policies and collaboration climate with other local suppliers and public authorities (Sornn-Friese, Poulsen, and Iversen 2012).

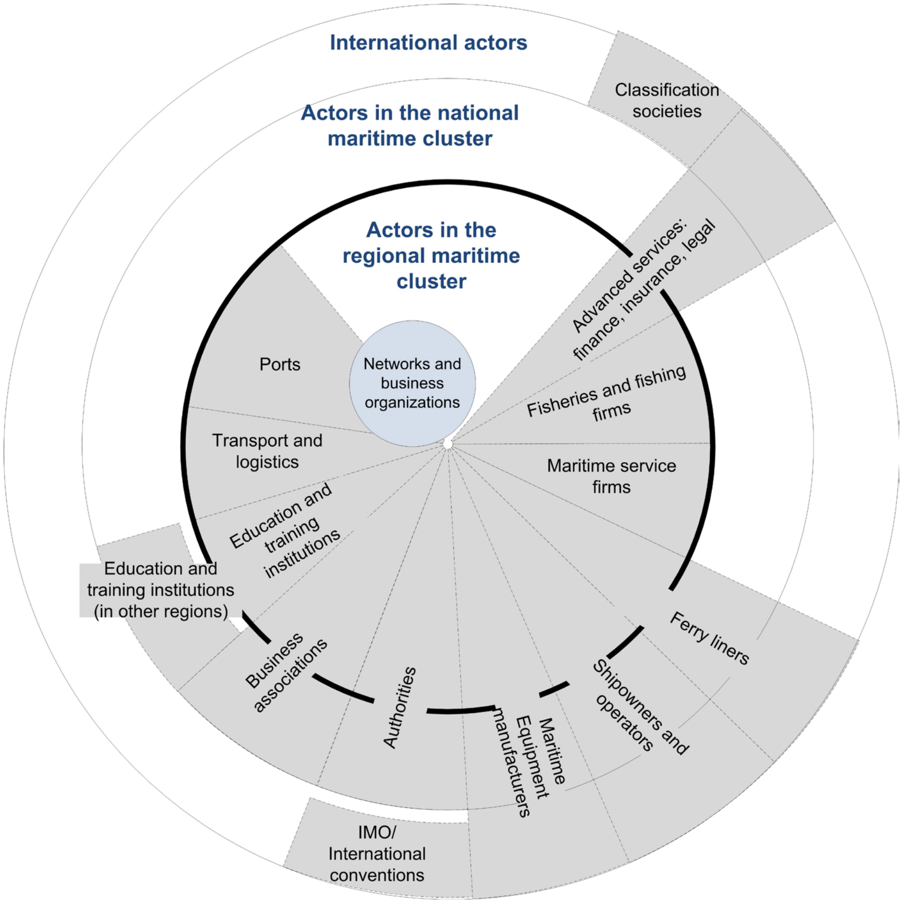

Figure 3 Maritime Cluster in Northern Jutland. Adapted from: Sornn-Friese (2003) and NIRAS (2014)

Public agencies play a role in the cluster by providing resources and setting the stage for collaboration. These functions go beyond the traditional command and control responsibilities of public agencies. The Danish Maritime Authority, *Søfartsstyrelse* is in charge of the ship registry and the preparation of statistics while also representing the government in most command and control requirements at ports –i.e. Inspections. Besides these functions, the Danish Maritime Authority is a main actor in several partnerships involving public and private stakeholders. One of them is the Partnership for Retrofit, launched in December 2013 with the goal of developing competencies in suppliers and ship owners on new environmental technologies and retrofit options to comply with new international regulations and reduce operational costs. The Danish Environmental Protection Agency, *Miljøstyrelsen* has the responsibility to enforce air quality regulations. Instead of following a strict enforcement approach, the agency builds capacity and partnerships between ship owners and equipment manufacturers. The resulting partnership (Partnership for Cleaner Shipping) has allowed ship owners to collaborate with equipment suppliers to develop technological solutions to comply with the MARPOL Annex VI regulations on SO_x and NO_x limits (this partnership is analysed with greater detail in Chapter 9).

Public agencies have a collaborative relationship with business organizations: The Danish Ship Owners Association, Danish Maritime[4] (Equipment suppliers) and Danish Harbours. These organizations are involved in partnerships with the public agencies and individual shipping firms with the purpose of promoting innovation and diffusing knowledge of environmental regulations and market conditions.

Although these stakeholders are important, the focus of this thesis is on maritime suppliers and sub-suppliers. Section 1.2.2 takes a closer look into the characteristics of this sector.

1.2.2 MARITIME EQUIPMENT AND SERVICE SUPPLIERS: A PERSPECTIVE FROM REGION NORTHERN JUTLAND

In the last 20 years, the once important shipbuilding sector in Northern Jutland has shifted its focus from new ship construction into a more complex network of maritime service and equipment supplier firms. These suppliers are integrated into the value chains of four main industry sectors: shipping, fishing, offshore oil and gas and offshore wind power (Figure 4).

The creation of complex supply networks -which originated as spin-offs from the previous large shipyards (e.g. In Aalborg and Frederikshavn) - generates more added value to the economy than the shipbuilding branch alone. Olesen (2013) presents the case of the port of Frederikshavn, where until 1999 the shipyard Danyard generated most of the jobs in the harbour. Due to a series of financial drawbacks, the shipyard went bankrupt. The skilled workforce was hired by multiple firms hosted in a new business park established in the former shipyard.

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[4] Danish Maritime was originally a shipyard organization, but now also represents some major equipment manufacturers. Another maritime equipment branch organization is Danish Marine Group under the Danish Export Association, it counts 160+ equipment suppliers as members. However, Danish Maritime is a more active organization in the different public-partnerships aiming at developing maritime eco-innovations in the country.

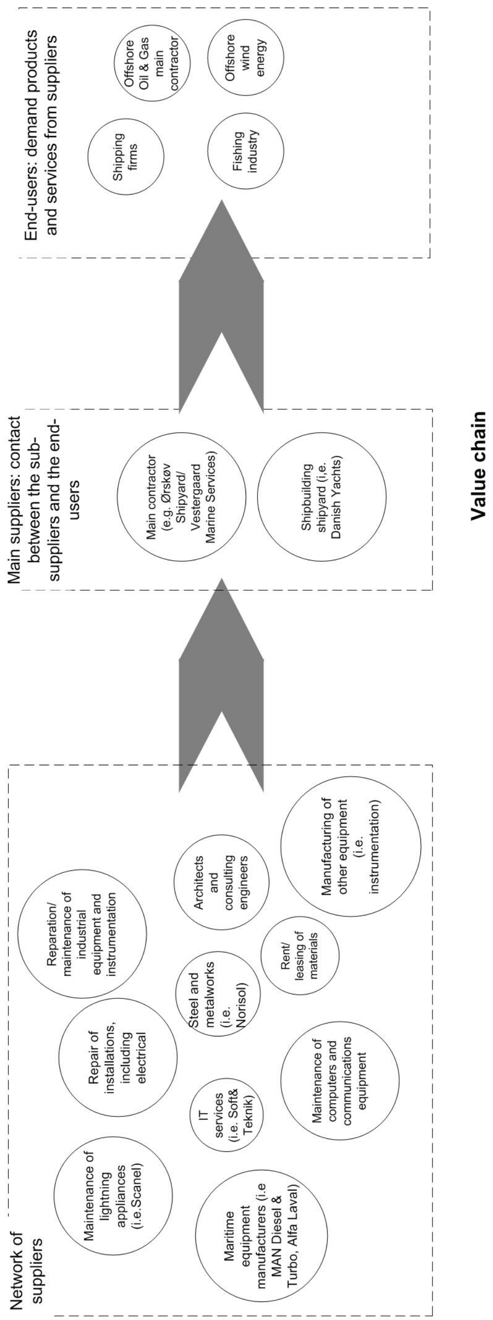

Figure 4 Maritime services and equipment suppliers in Region Northern Jutland. *Source*: NIRAS (2014)

Maritime equipment and service suppliers are important for the region's maritime cluster as a source of employment. The maritime cluster generated 19 116 jobs in 2011, out of which 8 564 corresponded to the maritime branches (e.g. Listed as end-users in Figure 4) and 10 552 to the auxiliary industries (listed as networks of suppliers and main suppliers in Figure 4) (NIRAS 2014). In Northern Jutland, the branch of maritime equipment had a net profit (total sales minus costs) of 2064 million DKK. A comparison of all Danish Regions shows that in Northern Jutland the branch of maritime equipment generates the highest revenues in the region's maritime cluster, with 46% of the total added value of all the six branches. The auxiliary industries, generated a joint net profit of 1 807 million DKK and employs 3 520 employees —excluding the navy and gross trading who have no relation to the maritime industry (NIRAS 2014).

Some of these firms have a leading role in the regional cluster. The number of personnel employed is the definitive factor in whether a given stakeholder is considered as "key". A list with the 10 companies in Northern Jutland with the highest number of employees is presented in Table 4. The figures are from a non-published database prepared by MARCOD in collaboration with Region North Jutland government employment office. Some of the identified actors in Table 4 are global firms with local offices in the Region (i.e. Alfa Laval Aalborg, MAN Diesel & Turbo, Wärtsilä), which implies a leading role in national, regional or local (harbour-level) networks. Alfa Laval Aalborg A/S, MAN Diesel & Turbo and DESMI/ DESMI Pumping are partners in national partnerships such as Green Ship of the Future (Schack 2009) and the PROTEUS project for the servitization of the industry (Hsuan et al. 2012). These firms are relevant for shipping supply chains because they belong to the sub-group of "global" suppliers (1.1.1): meaning that they have access to the tender process of new ship constructions even if it takes place in e.g. shipyards in East Asian countries. The firms are also looking into activities, which can generate added-value, instead of only delivering products. An example of this is their participation in the PROTEUS initiative in creating value by generating product service systems (Mougaard et al. 2013).

The second group is made up of firms, which are not global, but are central organizations in the region due to spillover effects of their activities –in terms of sub-contracting other companies to fulfil their assignments. In the port of Skagen, one of those firms is Karstensens Skibsværft, which specializes in the construction of ships up to approximately 135 m (including fishing boats, small ferries and navy vessels). In the harbour of Frederikshavn, three companies, Vestergaard Marine Services, Scanel International and Orskov Yard A/S attract service vessels in the harbour, but also send their service staff in missions abroad. These three firms are also a good example of service-oriented suppliers, which have adopted an internationalization strategy to avoid being locked into the changing dynamics of a regional shipbuilding/ repair sector (see section 1.1.1). Therefore, these firms can connect the regional sub-suppliers, with a broader reach as they have offices and regularly send staff for missions abroad to Brazil, Norway or Middle East.

Table 4 Northern Jutland key maritime firms. Source: MARCOD, personal communication

Firm	***Main activity***	***Cluster category***	***Number of employees§***
Alfa Laval Aalborg A/S	Industrial boilers, industrial instrumentation	Maritime equipment	502
MAN Diesel & Turbo	Service centre, ship engines and propellers	Maritime equipment	474
Bladt Industries A/S	Metal works	Steel and metalworks	461
DESMI/DESMI pumping	Compressors and pumps	Manufacturing of other equipment	240
Karstensens Skibsværft	Ship and boat building	Ship and boat building	233
Orskov Yard A/S	Repair and maintenance of ships and boats	Maintenance of electrical engines	216
Wärtsilä Danmark/Svanehøj	Ship service, pumps	Maritime equipment	182
Hydra Tech	Hydraulic works	Manufacturing of other equipment	169
Scanel International	Electrical installations	Repair of installations, including electrical installations	145
Vestergaard Marine Service	Engine services	Maintenance of electrical engines	108

§As for January 2015

1.3 NETWORKS OF MARITIME SERVICE SUPPLIERS IN NORTHERN JUTLAND

Section 1.2 introduced a closer look to the maritime cluster in the region of Northern Jutland (Denmark) with the purpose of illustrating the diversity of companies, included under the title of "maritime suppliers" or maritime service industry. The focus in section 1.3 is to show how these different suppliers are able to collaborate with other contractors and sub-suppliers in order to deliver a service to the ship owners, thus profiting of the maritime supply chain opportunities.

1.3.1 OVERVIEW OF EXISTING SERVICE-OFFERINGS BY THE MARITIME NETWORKS IN NORTHERN JUTLAND

In recent years, maritime suppliers in Northern Jutland have created several formal networks through a management board, paid fees and a website, etc. The main purpose of these networks is the provision of services or services associated with particular products (i.e. Installation of refrigeration equipment in fishing vessels). This service is delivered as added value compared to those delivered by single companies as companies complement their competencies. This section takes a closer look into the different regional networks, and the types of services they deliver. Most networks were initiated in harbours as reflected by their names; a few networks are integrated by firms from different harbours and municipalities. Harbour administrations in the region have taken initiatives to organize the local maritime service firms: Hirtshals Havn (Hjørring Municipality), Hanstholm (Thisted Municipality), Frederikshavn Havn A/S and Skagen Havn (Frederikshavn Municipality). The type of services and products provided by the firms established in or near the harbour shape the business focus of the harbour and the overall strategies of its administration. In order to provide better services, theses harbours have supported the creation maritime firm networks. Across all cases, a main incentive was to attract external customers, by making the harbour an active location for ship owners and maritime equipment and service suppliers. In total, six networks have focused diversifying markets of the maritime and off-shore industry.

The port of Hirtshals supported the creation of two maritime service networks to secure incomes for the firms located in the harbour, and also financial sustainability to the port. The first network is Hirtshals Service Group (HSG) with 47 paying members who participate yearly in the conferences DanFish in Aalborg and NorFishing in Trondheim. HSG has a market related to the following services: the repair of fishing vessels in and out of harbour, the repair in and out of harbour of other types of vessels (i.e. Offshore supply vessels), fish processing industry and in offshore –oil and gas (HSG, personal communication). Different firms within the network Hirtshals Service Group can provide joint services for fishing vessels. These joint services are illustrated in the value chain of the fisheries and fish processing industry (Figure 5). The left part of the figure is the firms that repair and provide maintenance to trawlers fishing vessels in the harbour or abroad. The right part in the figure is other firms within the network that can jointly supply the fish processing industry with services of maintenance and repair of vessels or equipment (i.e. Refrigeration, fish processing equipment).

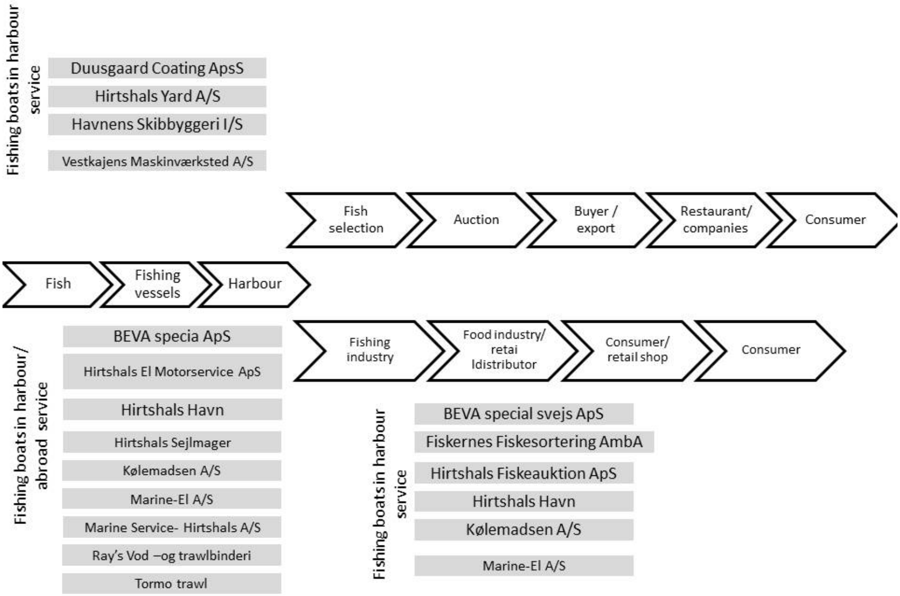

Figure 5 Maritime service and repair of trawler vessels in the supply chain for the fishing industry. *Source*: MARCOD (Personal Communication)

Repair4Norway is a second network with base in the harbour of Hirtshals, created independently of HSG, but now in the process of merging with them. Repair4Norway members promote their services among Norwegian offshore and shipping companies. Among these services are electrical installations, coat-painting of metal installations, metal works, ship repair, installation of equipment, among others. The network provides a joint platform to create business partnerships with their Norwegian counterparts, promote Hirtshals companies through joint stands in conferences, and give joint presentations to Norwegian firms among others (MARCOD, personal communication).

The multipurpose port of Hanstholm is located in the Municipality of Thisted. Until 2010 Smyril lines connected Hanstholm to other Scandinavian ports, since then the main activities are related to the discharge of fish and fish processing. The port has undergone a development plan, which aims to expand the number of basins, but also the harbour area. The plans of expansion also seek to diversify the services currently offered in the harbour: freight transport (75% increase in the period until 2025) and offer new services of optimization and maintenance to oil, gas and wind offshore platforms in the North Sea (Mogensen and Tornblad 2012). In the context of the Hanstholm port expansion, the Thy Business Council, the Municipality, the port management and a consortium have plans to start a maritime service network. The network will be a continuation of the initiative service project Hanstholm. This earlier project lapsed but provided local companies clearer ideas about the business potential if firms collaborated and offered joint services. The project also supported the creation of North Sea yard. The goal of the new network is to establish ad-hoc groups to initiate joint projects in the following areas: fisheries, maritime service to fishing trawler ships, offshore platforms decommissioning, logistics and freight transport, and competency development with the support of external organizations (MARCOD, personal communication). The concept idea of the project Trawlerboost is summarized in Figure 6, and the value proposition is to optimize trawler fishing vessels to achieve 30% optimization of the fuel consumption and to increase the vessel's lifetime. The project involves the participation of multiple firms in the network, and each one will provide complementary services as described in the left part of the figure.

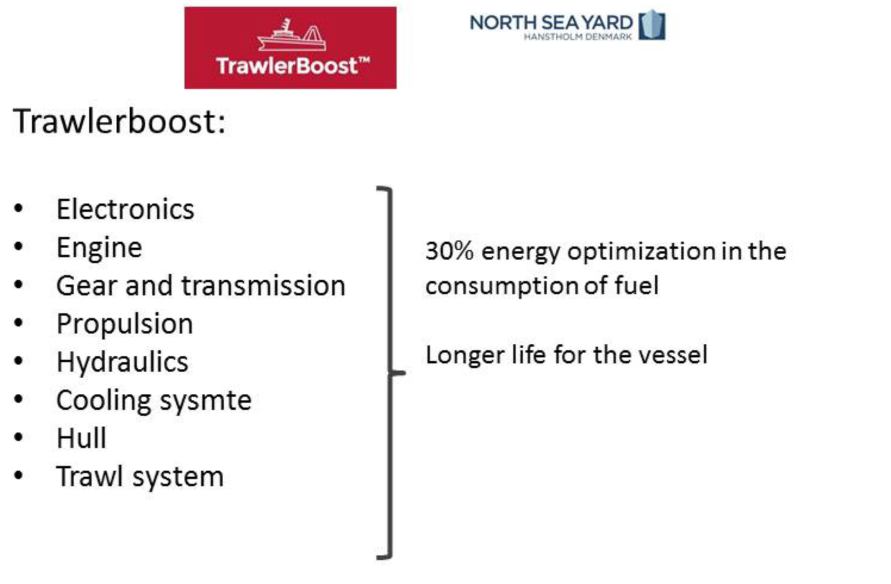

Figure 6 Trawlerboost: Example of joint offer of services in the maritime network of Hanstholm. *Source*: MARCOD (Personal Communication)

The Municipality of Frederikshavn has two harbours considered key for the maritime cluster in Northern Jutland: Frederikshavn and Skagen. The port of Frederikshavn has three main activities: the Stena Lines ferry terminal, the naval station and maintenance and repair services. The main activities in the port of Skagen are fish-meal and fish processing in several plants located in the harbour area and maritime services, including a yard for the construction of recreational and offshore service ships. An extension of the port began in 2005, and will when completed include a new extended basin, water depth of 11 meters and a larger port entrance.

The port of Frederikshavn initiated and coordinated for some years the Maritime Network Frederikshavn (MNF), which then became an independent organization now administered by MARCOD. MNF promotes a one-stop, full-service concept, through its 38 member firms located in or around the port of Frederikshavn. The network seeks to create joint value by proposing the following services:

- Ship maintenance and repair, in-yard and abroad
- Offshore oil and gas in yard and abroad
- Offshore wind energy in yard and abroad
- Ship decommissioning

Figure 7 outlines an example of a joint service offered by the network done by providing ship repairs abroad and combining the competencies of different firms within the network. The figure illustrates the flow process, when a ship owner or operator needs a ship to be repaired or serviced abroad, the operator/ owner contacts the main contractor firm (located in the harbour) and these main contractors send staff abroad. In case they lack the competencies of a particular type of service, these contractors subcontract other firms within the network. The left part of the figure provides the names of some key firms involved in this joint service and the right part the four main contractor firms within the network.

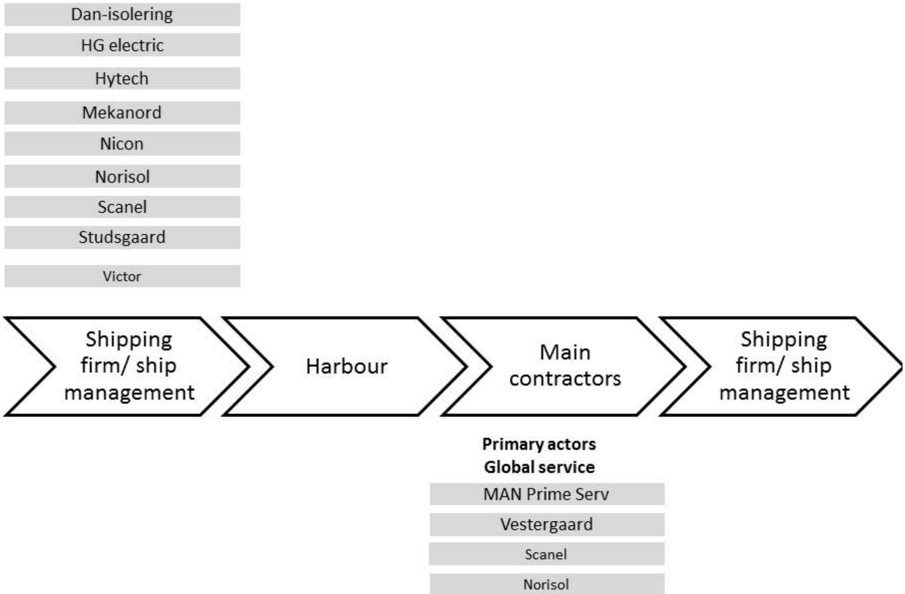

Figure 7 Ship service and repair abroad. An example of joint service offering by the Maritime Network Frederikshavn

Service Team Skagen is a network of 38 maritime firms located in and around the port of Skagen. The consortium also promotes the "one-stop" service concept in the areas of: ships repair and service, shipping and logistics, bunker, fishing industry and port service, maritime educations and financial advice (Skagen 2015).

Offshore Base Scandinavia is a regional network of 32 firms from the ports of Frederikshavn and Hirtshals. The network's main purpose is to offer services of repair and maintenance with focus on the 177 offshore oil rigs located in the North Sea, 92 of which have dimensions that fit with the harbours of Frederikshavn and Hirtshals. The network provides a joint platform to companies that can either become subcontractors of the main contractor Orskov Offshore (member of the network), or directly contracted with the 23 nearby rig-responsible companies operating in the North Sea. The network consultants actively contact drilling contractors, main contractors in order to promote the services of the network's member (MARCOD, personal communication).

1.3.2 OFFERING PRODUCT AND SERVICE ECO-INNOVATION THROUGH MARITIME SUPPLIERS NETWORKS

The maritime networks described in section 2.3.1 acknowledge that the potential market of environmental technologies brings opportunities during the construction of new ships but also during their operation. The evolving demands of the maritime industry included new products and services related to environmental protection. These markets focus on the maintenance of fishing ships (or ships in general) in harbours or abroad, but also on retrofitting vessels with environmental technologies (Maritime Network Frederikshavn).

Proposing new products and services for the market niche of environmental technology overlaps with the general purpose of innovation but primarily with eco-innovation. Innovation is the breaking of the ”routine” through the introduction of novelty into the socioeconomic system, by making “new combinations” of existing ideas, skills and resources and by overcoming the social inertia -role of entrepreneurs (Jan Fagerberg 2006). Within this broad definition of innovation, eco-innovation is a sub-concept, focused on innovations which result in improving the environmental performance of the industry that adopts them. The following definition of eco-innovation is applied (a closer analysis of eco-innovation is presented in section 8.2.1):

> Eco-innovation is an innovation that improve environmental performance, in line with the idea that the reduction in environmental impacts (whether intentional or not) is the main distinguishing feature of eco-innovation. From the social point of view, it does not matter very much if the initial motivation for the uptake of the eco-innovation is purely an environmental one (Carrillo-Hermosilla, del Río, and Könnölä 2010)

The product service offerings for the maritime networks in Northern Jutland is summarized in Table 5.

The main challenge of translating interest in new types of service and product offerings either through individual offers or as network products, is that not all the maritime service firms within the networks have all the key competencies[5] necessary. For example, in terms of environmental protection procedures in the decommissioning of vessels, ISO certification process, retrofit of old vessels with eco-efficient equipment or environmental technologies, energy optimization, project management and lightweight and alternative materials). At the same time, some actors in the cluster have already developed competencies in these fields. Frontrunner maritime equipment firms in the region have found a market niche in environmental technologies (in particular those depicted as “global” or regional leaders in section 1.2.2), to cite a few examples: ballast water treatment systems, exhaust gas cleaning

[5] “Competence” is defined as demonstrated personal/ organizational attributes and demonstrated ability to apply knowledge and skills according to the ISO norm 14025:2006

systems, monitoring instrumentation for energy use, monitoring equipment for gas emissions, composite materials for ship construction, etc.

Table 5 Markets of the maritime networks in Northern Jutland. The table presents in grey background the service offerings with potential for eco-innovation. *Source*: Own elaboration based on MARCOD (personal communication, 2015)

Market	Hirtshals Service Group	Repair4Norway	Hanstholm harbour Maritime Network	Maritime Network Frederikshavn	Service Team Skagen Harbour	Offshore Base Scandinavia
Logistics	X		X	X		
Maintenance/ reparation of Fishing vessels abroad	X		X	X	X	
Maintenance/ reparation of Fishing vessels in harbour	X		X	X	X	
Maintenance/ reparation other types of ships abroad	X	X		X	X	
Maintenance/ reparation other types of ships in harbour		X		X	X	
Offshore wind supply	X			X	X	
Offshore wind supply vessels (construction/ maintenance)					X	
Fishing industry	X		X			
Maintenance/ reparation oil and gas offshore rigs in harbour	X	X		X		X
Maintenance/ reparation oil and gas offshore rigs abroad	X			X	X	X
Decomissioning oil/gas rigs, ships in harbour	X			X		X
Education and competence development				X		
Ship retrofit				X		
Parterships with equipement suppliers for maintenance/ installation				X		

Similarly, some service firms have also attracted customers for the installations of ballast water treatment systems at the region's shipyards, or have for some years been part of the market of retrofit of offshore oil and gas platforms and large ferry ships with efficient lighting systems. To address the lack of some competencies, maritime service firms can profit from business relations with their networks of suppliers, main contractors, ship owners or other actors. To be competitive, these networks of suppliers offering new, eco-innovation products and services need to respond to the changing demands of the end-users (ship owners).

2
DELIMITATION OF THE RESEARCH

The broader context of the problem analysis was presented in Chapter 1 by positioning the research within the area of supply chains in the maritime industry (Figure 8). The chapter argued that because the developments in the industry over the last 50 years, European shipyards are driven to deliver products of higher added value by recombining the competencies of suppliers. The market potential is situated in the construction and operation phases. During ship construction, European suppliers can deliver specialized equipment and shipyards can build special and high technology ships. In the operation phase, European maritime service firms and shipyards have opportunities in the market of repair, maintenance and conversion of ships. In the recycling phase, there are some perspectives of business for maritime service providers given the new regulatory regimes in the EU for the recycling of ships. In this context, regulation and self-regulation brings even higher opportunities for European Shipyards due to the requirement of environmental technology for cleaner operations. This technology consists of several types of equipment, which are to be installed in new ships, or on already operating vessels through retrofitting. This point was further developed by presenting the networks of maritime service suppliers in Region Northern Jutland, where actors have joined together to offer a combination of products and services with the purpose for creating higher value offerings. The contextual conditions of the market share of ships retrofitted with environmental technology had an influence on the types of offerings provided by these networks. Furthermore, the argument was linked with the concept of eco-innovation, which is about offering new products and services with less environmental impacts.

Figure 8 Context of the problem definition as introduced in Chapter 1

2.1 RESEARCH AIM, OBJECTIVES AND RESEARCH QUESTIONS

In this thesis, I investigated how Danish maritime service suppliers can co-create new offerings of maritime eco-innovations such as products and services. The research has been carried out in a context where the maritime suppliers in Region Northern Jutland have set formal networks of firms that complement each other's competencies and knowledge.

The thesis contributes information on what compels end-users to participate along suppliers in the co-creation of product/ service eco-innovation, how to stage and facilitate the value creation, innovation processes which involve supplier networks and end-users and what kind of value propositions can be relevant to engage networks of suppliers in delivering product/service eco-innovation to the market. In brief, how a suppliers can create value through the development and commercialization of product and service eco-innovations. The research provides this knowledge by proposing a conceptual framework which combines insights from the literature on supply chain management (e.g. Supply networks, supply chains, value, value co-creation, value propositions and value network) and the emerging literature on eco-innovation (networks of eco-innovation, intermediaries and business models).

The research aims to contribute to the existing cluster initiatives in Denmark, and in other frontrunner countries seeking to develop eco-innovations for the maritime industry through the following academic objectives:

- To explain why end-users (ship owners) engage along with suppliers in the development of maritime eco-innovative products and services.
- To provide insights into the role of suppliers in collaborative partnerships seeking to develop eco-innovations along with end-users and public actors.
- To contribute theoretically to the studies of eco-innovation by proposing and testing conceptual frameworks, which draw insights from supply chain management, innovation processes, intermediaries and business models for eco-innovation.
- To guide further research in the emerging field of cluster management, with a particular focus on value networks and environmental products and services.

These academic objectives will be achieved by answering the main research question:

How can maritime suppliers deliver product and service eco-innovations to the maritime industry?

This main question will be analysed through four specific questions:

1. *What are the drivers for developing environmental technologies in the maritime industry?*
2. *How can maritime service and product suppliers create value and partnerships to fulfil the demands for environmental technology from markets and new regulations?*
3. *How can collaborative eco-innovation processes be organized at the project level for environmental technology in the maritime industry?*
4. *How to improve competence and collaboration among cluster stakeholders for the provision of environmental product and services to the maritime industry?*

The first sub-question explores the drivers for the development of environmental technologies in the maritime industry, these factors are key to understanding how the technologies are co-shaped and entangled in the technological and regulatory regime of the industry. The second sub-question addresses the aspects of business models and partnerships related to joint value creation- one of the pillars of inter-firm collaboration for delivering added-value products and services. The third sub-question zooms into collaboration processes between firms by analysing how to create value through eco-innovation processes. The fourth sub-question looks into the "competency improvement" part of the main research question by analysing cluster, steering roles and the dynamics of knowledge circulation in value networks as a way to initiate joint cluster initiatives –i.e. Environmental products and services.

2.2 RELATION BETWEEN ARTICLES FOCUS AND SUB-QUESTIONS

The four articles included in this thesis have the purpose of addressing the academic objectives by answering the sub-questions. This section explains how the four articles relate to the sub-questions, and which theoretical aspects they cover, as summarized in Table 6.

Table 6 Relation between articles, sub-questions and focus of the articles

Article	*Thesis Sub-questions addressed*	*Focus*
Rivas-Hermann and Remmen (2015)	1	The analysis of the case is about how regulation influences eco-innovation by interacting with other drivers (e.g. market, technology and business internal aspects) in the maritime industry.
Rivas-Hermann, Smink and Kerndrup (2014)	2,3	Two case studies of Danish partnerships for developing cleaner technologies for the maritime industry are presented: The Partnership for Cleaner Shipping and Green Ship of the Future. The analysis is around two issues, the first looks at how two initially separated partnerships interact, and what are the outcomes of this interaction in terms of eco-innovations and business relations. The second issue looks at what characterizes public-private partnerships for cleaner technology development in terms of the initiative of partners, participation, the scope of the projects and division of roles.
Rivas-Hermann, Köhler and Scheepes (2014)	2,4	The business models are analysed around the development, installation and operation of Ballast Water Treatment systems from a perspective of Danish maritime service suppliers. Based on this analysis, the article focuses on the aspect of joint value creation by analysing how suppliers can propose innovative product/ service offerings to the maritime industry taking as example port-based ballast water treatment systems.
Rivas-Hermann, Mosgaard and Kerndrup (2015)	3,4	A case study of the green retrofit of the ferry Læsø is presented, and the focus is on the roles of innovation intermediaries along the innovation process for collaborative demonstration projects.

A brief presentation of each article is given below.

- Rivas-Hermann, R. and Remmen, A. (2015) Drivers for eco-innovation in the shipping industry: A case study of the North European emissions control area. Journal of Cleaner Production (Submitted).

This is a single case study of the implementation of a Sulphur Emission Control Area (SECA) in Northern European seas (e.g. An area covering all the English Chanel, North and Baltic Seas). The article's theme of inquiry delves into the drivers of eco-innovation, while focusing how the sulphur limits regulation interacts with the drivers of market pull, technology push and business self-regulation. The article addresses sub-question 1 by expanding the understanding of why maritime service suppliers have a growing market of environmental technologies. Through a concrete case, the article demonstrates which kind of technology, maritime service suppliers need to acquire new competencies in order to adapt to the dynamics of the market, and the emerging EU and IMO regulations that promote the adoption of certain types of environmental technologies. In addition, the interactions are analysed between business self-regulation approaches to the development of new technologies and the effects of the market in the demand of marine cleaner technologies.

- Rivas-Hermann, R. Smink, C.K. and Kerndrup, S. (2014) Partnerships for environmental technology development in the shipping industry: two Danish case studies. International Journal for Innovation and Sustainable Development (Submitted)

In this article, the authors present case studies which address "How" maritime service firms can enter the emerging market of environmental technologies by joining public-private partnerships for environmental technology development. The article presents two case studies of Danish public-private partnerships that co-created new business relations and maritime environmental technology. The article sheds light on two issues regarding the partnerships in sub-questions 2 and 3. First, the article analyses what characterizes public-private partnerships for eco-innovation in the maritime industry in terms of initiatives, participation, the scope of the project(s) and division of roles between the actors. As well as to how independent public-private partnerships interact and what the results of these interactions are. The second issue analyses the "organizing collaborative eco-innovation processes" (sub-question 3) by illustrating how partnerships can set the stage for different actor interaction and the generation of new joint projects.

- Rivas-Hermann, R. Köhler, J. and Scheepens, A. (2014) Innovation in product and services in the shipping retrofit industry: a case study of ballast water treatment systems. Journal of Cleaner Production (In press)

In the third article, the authors present a case study of business models related to the development, the installation and operation of ballast water treatment systems (BWTS) by Danish equipment and maritime suppliers. BWTS was chosen as one critical example of environmental technologies because the value networks of maritime service/ product suppliers have the potential to create added value offerings to the maritime industry. For this reason, the case of BWTS is useful to answer sub-questions 2 and 4. Sub-question 2 is addressed under the scope of value creation, The article presents how the business models in the three phases of BWTS integrate different suppliers and the added value that these suppliers provide in the manufacturing, installation and operation of BWTS. The concept of Product Service Systems (PSS) is introduced in the analysis of the business models to understand how maritime suppliers can provide added value in the phase of operation/maintenance of BWTS. The case highlights the importance of rethinking the concept of BWTS, which should be seen less as a product and more as a system of services that could be built around BWTS. The last part of the article presents a theoretical model of what would be a PSS concept that achieves competitive value for customers of BWTS, whilst minimizing environmental impacts. Sub-question 4 is also addressed in the article by presenting the aspects of business models and value exchange between firms in the cluster of BWTS (as one example of provision of environmental product and services to the maritime industry).

- Rivas-Hermann, R. Mosgaard, M. and Kerndrup, S. (2015) Intermediaries functions in collaborative innovation processes: retrofitting a Danish small island ferry with green technology. International Journal for Innovation and Sustainable Development (Submitted)

In the fourth article, the authors present a case study of the environmental and energy efficiency retrofit of one small island ferry in Denmark (Margrethe Læsø). This project was the initiative of some actors in the Northern Jutland region and was selected because it illustrates how firms involved in maritime service networks could collaborate in developing new product/ service offerings to the maritime industry (in this case, the green retrofitting of vessels). For this reason, the article addresses sub-questions 3 and 4. The results shed light on two issues. First, on the roles played by innovation intermediaries in the initiation and development of eco-innovation demonstration projects. Intermediaries can play simultaneous functions, some of them become key to initiate and keep collaboration alive in a network of companies over time. The second issue is on the network dynamics along the innovation process, which sheds light on sub-question 4: sub-cluster creation

PART II
CONCEPTUAL FRAMEWORK

Part II introduces the conceptual framework which explains how supply networks evolve into a value network through the eco-innovation of products in the maritime industry. In the conceptual framework, I propose a relationship between the concepts of supply chains (SC) and innovation. This relationship is proposed in order to understand how suppliers can develop new types of relationships and business models to improve collaboration and competences with regards to maritime environmental technology. The literature on SC is used to explain how actors relate in order to create value, and how innovation provides an understanding of the mechanisms to develop new types of environmental products and services.

Part II has two Chapters. Chapter 3 focuses on the contributions of the supply chain management literature in order to understand concepts such as supply, supply networks, value, value creation and shared-value. The focus of Chapter 4 is the concept of eco-innovation along the research streams, which provide inputs to the conceptual framework.

3
INSIGHTS FROM SUPPLY CHAIN MANAGEMENT

The purpose of Chapter 3 is to introduce the various concepts that allow the understanding of the relationship between the literature on supply chain management (SCM) and eco-innovation. On the one hand: supply, supply chains and supply networks (in section 3.1). On the other hand: the difference between value co-creation and shared-value creation (section 3.2).

The broad term maritime supply chain used in *Chapter 1: Introduction,* refers to two different specific concepts within the supply strategy literature explained in this section: supply chains (SC) and supply networks (SN). These two terms are used to explain how the suppliers collaborate to deliver products and services to shipowners and operators. In addition, the concept of value networks (VN) is introduced as a new approach within the SCM literature that bridges between the concepts of SC and SN with that of innovation. Finally, an emerging perspective is that of shared-value creation (CSV) which also accounts for the social benefits generated by a given activity.

3.1 SUPPLY CHAINS AND SUPPLY NETWORKS

Harland, Lamming and Cousins (1999) define supply as:

> A holistic approach to managing operations within collaborative inter-organisation networks, allowing the formulation and implementation of rational strategies for creating, stimulating, capturing and satisfying end customer demand through innovation of product, services, supply network structures and infrastructures, in a global, dynamic environment.

This definition of “supply” implies that actors collaborate in networks or other form of relationships, with a clear objective to fulfil the demands of an end-user. The definition also includes innovation as the mechanism to constantly renew the offerings to end consumers. Harland (1996) proposes four levels to analyse supply which fulfil the above objective:

- Intra-firm supply chains concerned with the flow of materials and information.
- Bi-party (dyadic) relations between one supplier and the end-user.
- A supply chain (SC) which involves, among others, a supplier, sub-suppliers, customer.

- An inter-organizational supply network (SN) of connected business, which purpose is the supply of product and services to end customers.

The first level is the "classical" focus of the SCM literature, which deals with the flow of materials from suppliers through end-users from a company perspective. This perspective of supply takes into consideration management's approach to optimizing organizational activities, functions and processes to plan and control inventories, but also, to deliver an efficient product or service to end-users (Basnet 2013; Jones and Riley 1987). The second level of analysis is about of dyads of buyer–supplier dyads or supplier-supplier (Wilhelm 2011). This line of research inquiries about processes as contract manufacturing, distribution, new product development or logistics relationships (Klein and Rai 2009), and optimizing transaction costs between the dyads (Saeed, Malhotra, and Grover 2005).

The first two levels are part of the original SCM literature which focuses on minimization of transaction costs between buyer and suppliers. The main interest in the SCM literature has evolved into the analysis of relationships between stakeholders. Therefore, the initial interest on transaction costs is replaced by issues as value delivery and alliances through vertical and horizontal relations, which are represented by SC and SN levels (Giunipero et al. 2008). In this thesis, as a consequence of the problem definition (Chapter 3), the focus of the conceptual framework is on relationship building among actors in supply chains rather than optimizing transaction costs. Therefore, its focus is on the second and third categories, SC and SN, respectively.

In relation to the third level, in the early 1970s, the concept of the supply chain (SC) had a narrow meaning and was used to explain the physical movement of goods, implying the total flow of materials from suppliers to end-users. In the 2010s, this original concept of SC was modified, and SC is now used to explain collaboration and relationships between firms to fulfil the end-user needs of products and services (Braziotis et al. 2013). The SC is characterized by linear configurations, stable structures, low complexity, predictable and stable operations. Members in the SC rely on collaboration and coordination among members to enhance the competitiveness (Braziotis et al. 2013). This definition of SC is relevant to the conceptual framework because maritime service firms can be part of multiple SC, for example, one company specialized in steel and metal works, can be part of the SC of lighting systems in off-shore platforms, but can also be part of the SC for providing the service of ship repair in harbours (as described in greater detail in the problem definition, section 1.3.1). In both cases, there are stable structures, predictable operations (i.e. The metalwork can be sub-contracted), and there is coordination between the main contractor and the different sub-contracting firms.

The fourth level, inter-organizational supply networks (SN) are one of the supply strategies stressed by Harland (1996). The concept of SC reveals many similarities with that of supply network (SN). In Braziotis et al. (2013) some overlaps and key differences between SC and SN are revealed. The concept of SN incorporates the aspect of business relationships:

> The SN focus is on the web of relationships. In terms of configuration, it was seen as an enhanced or wider view of one or more SCs, incorporating indirect relationships and subsidiary or satellite organisations in addition to core members. Some members of a SN are active, but others may be inactive. For example, an organization may have a connection to another company via a previous supplier with whom it is not currently working. The SN is perceived as a dynamic, trust-based and extended; hence, complex and non-linear… Essentially, a SN is a web of SCs and associated satellite companies, with enhanced complexity of inter-firm relationships where power aspects and relationship management among members emerge as key difficulties in managing the network (Braziotis et al. 2013, 648).

This aspect of relationships was partly inspired by the works of the IMP (Industrial Marketing and Purchasing) group in the early 1980s. The main contribution of the initial work of the IMP group was that business exchange between organizations was not a simple commercial transaction, but instead revealed complex relations between the seller and buyer organizations and the exchanged-product and service resulted from this bilateral relation (IMP Group 2015). From the IMP group research, a business network was defined as the result of the agglomerated bi-partite relationships between the actors in the network:

> Any relationship is because of its substance a constituent element of the wider network in which relationships are interconnected. Activity links, resource ties and actor bonds in a relationship are connected, directly or indirectly, to some others. The aggregated structure is an organized web of conscious and goal-seeking actors; it is also an organized pattern of activities as well as an organized constellation of resources (Håkansson and Snehota 1995, 40)

The concept of SN is relevant to the maritime industry because shipbuilding (and consequently later maintenance and repair) became modular. This means that entire sections –or equipment within ships, are generally supplied by a network of suppliers rather than a single supplying shipyard as it used to be in the past —an issue which is also analysed with greater detail in Chapter 9. As a result of this modular approach to shipbuilding, the SN become entangled with service sourcing and even participate in new product design (Hameri and Paatela 2005). Both aspects, service-sourcing to SN and the involvement of SN into new product design are analysed in the conceptual framework, however, the concept of value-creation is a key element to understand the link between SN and innovation and that is the focus of section 3.2.

3.2 VALUE-CREATION IN SUPPLIER NETWORKS

A major contribution to the literature of SCM has been the analysis of collaboration between actors within and beyond the structured SN in order to create value propositions. Different terms are used to differentiate this kind of network to SC and SN, which purpose is not necessarily the co-creation of value. These terms include value creating networks, market networks, value nets and value creating networks (Kothandaraman and Wilson 2001). Value-creating networks are characterized as temporal structures with an explicit strategy to focus on end-customer value and purposeful co-operation between suppliers to co-produce value-offerings, exchange service offerings, deliver added-value products and services to the end-customer, and co-create value (Lusch, Vargo, and Tanniru 2010; Harland, Lamming, and Cousins 1999).

Value networks are relevant in the context of this conceptual framework because SN can evolve into value-creating networks, when they have a purposeful strategy to develop new products and services with higher value for the end-user. In the process to co-create these added-value products and services, the end-user is also involved (value co-creation). The theory of innovation can contribute to the understanding of the mechanisms by which the actors in the SN (along with end-users) can develop higher value-propositions. Section I present the concepts of value and value propositions which are linked to the theory of innovation, when used in the context of value (co-) creation.

3.2.1 WHAT IS “VALUE” AND “SHARED-VALUE”?

In supply networks, the understanding of value (which is also the dominant approach in the SCM literature) is the relationship between market offering to price. The resulting ratio will have significance according to the end-user’s perception (Kothandaraman and Wilson 2001). Lindgreen and Wynstra (2005) expand this approach by suggesting satisfaction as an additional aspect in the customer/ end-user perception of value. Satisfaction is the possibility to obtain customized products and high-quality service, social fraternization and special treatment (e.g. customization) from the suppliers, but also building trust and relations with the supplier. For suppliers, value is associated with the wealth generated for the shareholders. Therein, when suppliers collaborate in e.g. a supply chain, the aim to create value should consider both the supplier and end-user’s goals, and if the end-user/ consumer is satisfied with the product and service. When this is reached, the supplier will then also generate wealth for its shareholders (Bititci et al. 2004).

Here is where the concept of value proposition comes into play. The value proposition is defined as the promise of what suppliers can deliver to the customer. The value proposition is in direct relation to the internal competencies of the supplier, as these competencies will shape what types of value propositions and offerings the supplier is capable of delivering to fulfil the end-user demands (Bititci et al. 2004). Since value propositions connect end-users with suppliers through collaborative, non-coercive means (Lusch, Vargo, and Tanniru 2010), a customer has the freedom to choose the higher value propositions fulfilling its needs. This issue is dealt with further details on the conceptual framework in Chapter 10.

Porter and Kramer (2011) propose the idea of shared-value which seeks to fulfil the aims of the business (suppliers/users) but also the needs of society. The concept results from a criticism of the traditional concept of value discussed above. According to the criticism, the supply chains fail to address non-fulfilled societal needs that otherwise can affect the long-term competitiveness of the supply chain, i.e. lack of competences in the producing workforce or infrastructure (Porter and Kramer 2011). Shared value is defined as:

> The concept of shared value can be defined as policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates (Porter and Kramer 2011).

Shared value from this perspective does not imply a redistributive purpose, such as paying a supplier a higher price for a same type of product. Instead, it implies a focus on improving the supplier’s production conditions which will then have an impact on the final product as it will have a higher quality and thus much better price (Porter and Kramer 2011). Value from this perspective differs from the concept of value, commonly used in supply chain management (Table 7).

Table 7 Key differences between two current approaches to value in the business literature

Value definition (Lindgreen and Wynstra 2005)	Shared-value definition (Porter and Kramer 2011)
• Fulfilment of expectations to the end-user • Benefits to the end-user • Fulfilment of benefits to shareholders	• Fulfilment of societal needs • Enhancing competiveness of a company (e.g. supplier)

In this thesis I consider that both concepts are complementary, as one of them focuses on the relations between supplier/ end-user, and the second expands this scope to fulfilling the needs of the society. Another issue where both concepts differ is on how value is created.

3.2.2 VALUE CO-CREATION AND SHARED VALUE CREATION

In networks of suppliers, value creation is when supplying firms develop capabilities beyond the firm, in order to improve the value proposition embedded in the supplier's service and product. Single-supplying firms look into collaborative relationships with other suppliers (Vargo and Lusch 2004; Vargo and Lusch 2007). The process of co-creating value is influenced by the quality of competences of the partners and the type of relationship between the partners. The combined competences of the firms in the network will create superior value propositions. Meanwhile, the type of relationship between the partners will influence how well the firms communicate and ultimately a better relationship will lead to higher value propositions (Kothandaraman and Wilson 2001). The customer/ end-user also induces the type of competences required in the value network, as the needs of the end-user will shape the competence requirements from the firms in the network (Kothandaraman and Wilson 2001). The process of value creation between suppliers, but also with the insights from end-users lead to closer buyer-supplier relationships as suppliers are seen as partners and are then involved in collaborative problem solutions and the development of new products (Harland, Lamming, and Cousins 1999). Value co-creation focuses on this process when end-users/ consumers jointly create value along with suppliers, but also it involves the end-user jointly defining the problem and solving it (Prahalad and Ramaswamy 2004).

Shared-value can be created in three strategies: by reconceiving products and markets, by redefining productivity in the value chain and by enabling local cluster development (Porter and Kramer 2011). The first strategy is reconceiving products and markets. The purpose is to develop new products that fulfil the needs in underserved markets. The firm shall identify society's needs, benefits or even harm that could result from a given product. This could be for example products that protect the environment (eco-innovations).

The second strategy is redefining productivity in the value chain. The purpose of this strategy is to examine which changes can be made along the value chain in relation to four aspects:

- Energy and logistics
- Resource use
- Procurements
- Employee productivity

These changes, prioritize for example local suppliers over overseas suppliers with the purpose of reducing the energy and climate footprint.

The third strategy is enabling local cluster development. Firms can improve their productivity when improving framework conditions surrounding the cluster, these can be attracting capable suppliers, developing procurement benefits, but also joining public-private partnerships to improve infrastructure or market frame conditions (Porter and Kramer 2011).

These three strategies of shared-value creation are relevant for suppliers in the maritime industry. However, in the conceptual framework I deal with the first and third categories, as these have a closer link with the aim of innovation, which is about introducing novelty into socioeconomic systems through new products, processes, supply chains, markets, organizations or making new combinations of existing ideas, skills and resources (Jan Fagerberg 2006). As introduced in section 1.1.2 in relation to the maritime industry, suppliers of i.e. maritime engines will create societal value if they develop engines which emit less NO_X emissions. In this way, coastal agglomerations will benefit of cleaner engines on ships by having less polluted air and by reducing public health expenses. Meanwhile, the low NO_X emission engine supplier might create value for its own shareholders and the shipowner (end-user) will also create value by delivering goods in a cleaner way. In the case of the local cluster, it could also benefit from this situation because main suppliers, end-users and possibly public authorities will likely invest in developing competences for these new technologies (as is the case in Denmark, see sections 1.2 and 1.3). In the next section I further develop these types of value propositions, which integrate the first and third category of CSV and become the basis of the conceptual framework.

4
CO-CREATION OF VALUE THROUGH ECO-INNOVATION

Chapter 4 presents the conceptual framework used to explain the mechanisms and processes by which suppliers and end-users can co-create value propositions for maritime eco-innovation, but also how these value propositions could eventually lead to shared-value. The concept of eco-innovation is introduced in section 4.1 while section 4.2 summarises the four current streams of research within eco-innovation. In Section 4.3, these streams of research are integrated into the conceptual framework along with the concepts of value creation in supply networks.

4.1 DEFINING ECO-INNOVATION

The term eco-innovation is part of a family of related innovation concepts, such as "eco-", "green", "sustainable", and "environmental innovation". A review by Schiederig, Tietze, and Hertstatt (2012) concludes that the four concepts do not differ substantially with the exception of "sustainable innovation" which incorporates a social dimension to innovation, in addition to the ecological and economic dimension of the remaining three concepts. While the terms "sustainable" and "environmental innovations" were predominant in the scientific literature in the 1990s, "green" and "eco-innovation" have just been increasingly used in the last 10 years (Schiederig, Tietze, and Herstatt 2012).

Since the late 1990s, different definitions of eco-innovation have been proposed. One of the first definitions of eco-innovation was a contribution by Fussler and James (Cited by Garrido Azevedo et al. 2014, 4) which states that eco-innovation is the creation of "new products and processes which provide customer and business value but significantly decrease environmental impact". Later, Carrillo-Hermosilla, del Río, and Könnölä (2010, Box 1) compiled 16 different definitions of eco-innovations characterized by the following points, also shared in other reviews of the concept of eco-innovation as i.e. Pansera (2012):

- Eco-innovation is considered as one particular type of innovation, which is beneficial to the environment: "any form of innovation" (European Commission 2007), "innovation processes towards sustainable development" (Rennings 2000), and "innovations that benefit the environment and lead to sustainability" (Oltra and Saint Jean 2009). While acknowledging eco-innovation as a special type of innovation focused on sustainability, this meaning of sustainability remains broad. Several goals are linked to eco-innovation. One of these goals is to use natural resources in a more proficient way: "The efficient use of resources", "minimization of the use of natural resources per unit of output" "reduction of energy use". A second goal is cleaning up already existing environmental problems (VINNOVA 2001). A third goal relates to a broadly defined reduction of environmental impacts: "specified sustainability targets"(Rennings 2000), "reduction of environmental impact, intended or not" (OECD 2009).

- Different authors focus on different targets, when concerned with the targets of eco-innovation. These targets include, novel products (goods and services), processes, procedures, business methods and management. Machiba (2010) proposes a concept with targets in three categories: processes and products, organizations, and marketing methods and institutions. From this perspective, eco-innovation comprises novel targets within the organization, but also beyond the organization's boundaries (OECD 2009).
- Eco-innovation is considered both about developing but also assimilating (adopting) the targets specified in the previous point.

What are the implications of the above characteristics of eco-innovation for the actors in maritime supply chains described in section 1.3?

This section introduces a typology of eco-innovation, which is useful to set the context of the conceptual framework presented in section 4.3. The typology and the definition of eco-innovation in the maritime industry are further addressed in the article included in Chapter 8. Machiba (2010) proposes a typology of eco-innovation, which acknowledges its different targets and mechanisms. Targets could include processes, products, institutions, organizations, marketing methods and institutions. The mechanisms could be modifications, re-designs, alternatives and creation. "Modification" and "redesign" relate to incremental innovations in existing technologies, whereas "alternatives" and "creation", are tending to radical changes in existing technologies and seek systemic solutions. Incremental innovation refers to slight continuous changes or improvements in the existing technological systems (Carrillo-Hermosilla, del Río, and Könnölä 2010). Radical innovations are a discontinuous change of technology, which seek to replace already existing technology (Hellström 2007).

In the maritime industry, processes and products of eco-innovations include end-of pipe technology. This technology is characterized by slight modifications or add-ons at the end of the production process to reduce the release of emissions into the environment. Yet, end of pipe innovation often yields to incomplete environmental solutions as they move the environmental impacts from one medium to another, e.g. from wastewater to sludge, etc. (Remmen and Thrane 2007a). Some examples of end-of pipe technology include exhaust gas cleaning systems or ballast water treatment systems, all which are discussed in the case studies presented in Chapters 8 and 10.

Cleaner production is about preventive changes in the production process in order to reduce pollution at the source. This includes reducing the consumption of raw materials, water and energy and thus reducing waste (Thrane and Remmen 2007). In the maritime industry, cleaner production relates to the use of cleaner fuels as LNG, which requires retrofitting vessels to reduce the fuel consumption and energy use, as presented in the article in Chapter 11. Another trend is retrofitting old vessels with efficient propulsion equipment (i.e. Engines, propellers, etc.), but also technology on board (i.e. Lighting) in order to improve the ship's energy use and reduce costs (Jafarzadeh and Utne 2014; DNV 2012).

Other categories of eco-innovation are not the focus of the conceptual framework. These include eco-efficiency, life cycle thinking and industrial ecology. Eco-efficiency is about seeking the re-design of products and processes, but also involves changes at the organizational level. An example in the maritime industry is the use of low speed steaming, which reduces the consumption of fuels and climate change potential (Krozer, Mass, and Kothuis 2003). Other examples of eco-efficiency are the construction of new ships according to the Energy Efficiency Design Index, which is a relation between the CO_2 emissions of the ship and the amount of goods transported (IMO 2009). Life cycle thinking deals with the management of a product's life cycle from cradle to grave. It encompasses the accounting of material flows used in the production process and in the products, the prediction of further uses (i.e. re-use, recycling and disposition), the analysis on whether this product can be replaced or rethought with others that can produce reduced environmental impacts (Remmen and Thrane 2007b). In the maritime industry an example of life cycle thinking is the Danish shipping firm Maersk, which introduced the Cradle to Cradle passport for its new fleet of Triple-E class ships (Ellen MacArthur Foundation 2015). Industrial ecology seeks a symbiosis between industries that are located in a similar geographical area, by sharing inputs and outputs from one production process to the other and thus gaining closed loop production strategies (Lifset and Graedel 2002). As presented with greater details in section 1.1.2, in the maritime industry ship decommissioning becomes an emerging opportunity for collaboration between firms at harbours as it could integrate the re-use of materials from old ships into production loops of other industries (Litehauz 2013).

In the conceptual framework proposed in section 4.3, the focus is on the mechanisms of modification and the redesign of existing technologies. This emphasis results from the initial problem analysis discussed in Chapter 2, and the typologies of eco-innovation in the maritime industry presented above. The conceptual framework also is focused on three targets: process and products, business models and partnerships. The latter two targets are not included in the typologies of eco-innovation proposed by Machiba (2010), however, in the context of the maritime industry, they convey a better representation of targets of eco-innovation as compared to organizations, marketing and institutions (see the theoretical framing in chapters 9 and 10). Figure 9 highlights the mechanisms and the targets of eco-innovation, which addresses the conceptual framework of this thesis.

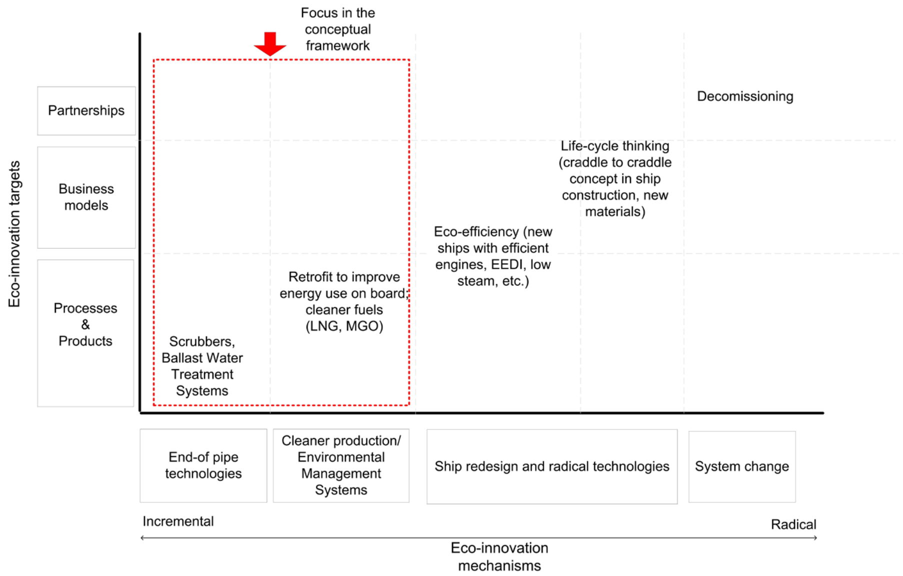

Figure 9 Eco-innovation in supply networks: understanding how to co-create value though eco-innovation in the maritime industry. Adapted from Machiba (2010)

4.2 DEVELOPING ECO-INNOVATIONS: THREE STREAMS OF RESEARCH

The research on eco-innovations as products (goods and services) is multidisciplinary, for that reason the thesis identifies three streams of research which are followed to understand the dynamics of developing, adopting and diffusing eco-innovations. One stream is about understanding the drivers of eco-innovation (adoption and development) in different industry sectors. The second stream of research, relates to eco-innovation as an open innovation process (Chesbrough 2003), characterized by the premise that companies require collaboration with others in order to complement competences and develop eco-innovations. One aspect is the analysis of formalized partnerships for eco-innovation and the other aspect is the role of innovation intermediaries in the eco-innovation processes. The third emerging research stream sheds light on business models as a mechanism for creating value through eco-innovations, this approach addresses how suppliers can co-create value by looking into the associated services that can be provided to a product along its life cycle.

4.2.1 ECO-INNOVATION DRIVERS

In the first stream, the development and adoption of eco-innovations are investigated through the combination of four drivers: regulatory push and pull, market pull, technology push and business internal aspects (Rennings 2000; Rubik 2005; Cleff and Rennings 1999). Chapter 8 presents a complementary presentation of these drivers.

The term regulatory push encompasses different forms of policy instruments as market-based instruments (taxes and tradable permits), standards, negotiated agreements and information-based instruments –i.e. eco-labels (Ekins 2010). Cleff and Rennings (1999) consider that market incentives such as taxes and tradable permits, have the best potential to unleash eco-innovation, as they provide permanent incentives for reducing the pollution associated with a product and a process. Conversely, standards or negotiated agreements are less efficient in promoting eco-innovation because there are fewer incentives that push actors to go further than the standards. Regulations along the supply chain and in other countries also have an impact on product eco-innovation. Horbach (2012) cites the example of the Japanese suppliers to the automotive industry, which had to comply with US requirements on catalytic converters for all cars.

Market pull comprises factors as customer demand for greener products or production processes, firm's image which can be linked to environmental protection, improving competition by reducing costs (i.e. a product eco-innovation could entail less use of materials and energy along the production process) and creating new markets (Cleff and Rennings 1999). Market pull has an influence on suppliers. In the first place, suppliers are often involved in complex supply networks. The demand side can trigger suppliers to develop greener products as a result of indirect product regulation or indirect concern for the environment by other actors in the supply network such as distributors, dealers, or end users (Noci and Verganti 1999). In some countries, public authorities can be considered part of a "market push" when initiating green procurement programs (Horbach, Rammer, and Rennings 2012).

The driver technology push has two main effects: first, to reduce manufacturing costs in the production processes, and second to be able to commercialize a greener product (Rennings 2000). Technology push becomes a driver for eco-innovation through incremental improvements in the product's quality and in the production process by reducing material and energy costs throughout the production process (Rennings 2000). The adoption of efficient technologies brings challenges to the firm, as increased investments, however, they result in improved eco-efficiency (i.e. Energy and material) (Triguero, Moreno-Mondéjar, and Davia 2013)

The internal business aspect is another driver for eco-innovation, which comprises concepts of what the company is, its size and its structuring characteristics (Rubik 2005). These characteristics will have an impact on the technological and managerial competencies that allow for the adoption and development of certain eco-efficient technologies or product eco-innovations (Triguero, Moreno-Mondéjar, and Davia 2013). The company's mission and size define a firm's strategic orientation regarding environmental issues, and thus indirectly its potential for eco-innovation. The strategic orientation defines the technological choices, while these choices are constrained by the business competencies. Competencies are considered knowledge, skills, values and organizational routines (Hansen, Søndergård, and Meredith 2002). Limited management capacity and skills can become a barrier for product eco-innovation (Walker et al. 2008). This has consequences on the firm's environmental knowledge, such as how to environmentally improve their products (Parker, Redmond, and Simpson 2009). Resource shortage (financial, human and time) prevents the investment of R&D efforts on green products or processes and encourages the development and use of conventional products and processes (Luken and Navratil 2004). SMEs particularly sensitive to abrupt market changes when they are integrated as suppliers in value-chains (Walker et al. 2008). SMEs are also influenced by the management strategies vis-à-vis eco-innovation and presented previously. For example, a company with re-active strategy will carry only minor investments to identify the full impacts of their products and will prioritize incremental improvements (Noci and Verganti 1999).

4.2.2 PARTNERSHIPS AND INNOVATION INTERMEDIARIES IN ECO-INNOVATION

The second stream of research addresses the mechanisms of collaboration between actors in supply networks in order to develop or adopt eco-innovations. Research of this type, analyses the creation of new eco-innovative products (goods and services) in networks of firms which collaborate in order to complement competences. This research approach has received input from the innovation management literature by understanding the development of innovations as an open process. The traditional approach (closed –boundary organization) to innovations was a firm-centred perspective, meaning that firms had all the resources to carry out innovation processes from invention to implementation. However, this approach has drawbacks, for example, it requires complex organizations and a high degree of coordination between the different departments within the organization (Pavitt 2006). Nonetheless, an emerging open innovation paradigm takes into account that external research and development (R&D), can bring value to the firm. This creates an incentive for firm to enter into exchanging transactions of intellectual property, knowledge and competences with actors external to the firm (Chesbrough 2003). Such open innovation has spurred collaborative innovation activities, in the way of networks (often mediated by innovation intermediaries) which are particularly useful for smaller firms as SMEs (Hansen and Klewitz 2012b; Klewitz and Hansen 2014).

A focus of the literature within this research stream, is on how individual firms benefit from participating in one or several networks. Hansen, Søndergård and Meredith (2002) claim that firms are part of regulatory, business, and knowledge networks. The involvement in these three networks provides firms with inputs to develop eco-innovations because each network brings partial understanding of an issue. Meredith (2000) highlights that firms (especially SMEs) can participate in different networks to tackle some of the barriers to product eco-innovation because SMEs do not have the resource capacity of larger firms. The benefits of participating in networks are highlighted in terms of access to external knowledge, peer-learning and exchange (Hansen and Klewitz 2012b). The literature also analyses the functioning (structure, drivers, roles and outputs) of formal networks such as partnerships, which stimulate actors to develop eco-innovations. Partnerships are understood as a "voluntary collaboration between two or more organizations with a jointly defined agenda focused on a discrete, attainable and potentially measurable goal" (von Malmborg 2003). This is the case of greening networks, public-private partnerships on collaborative projects, learning systems or governance networks with the purpose to drive industries towards sustainability (Lehmann 2006). Being part of partnerships brings several benefits to suppliers or other type of private actors. These benefits include access to NGOs' specialized knowledge, access to networks, improve credibility and legitimacy, the strengthening of the firm's brand and positive reputation, all which aid in attracting potential customers (Kolk, van Tulder, and Kostwinder 2008). Public actors join partnerships for eco-innovation for several reasons, including the possibility to create capacity in the private sector of environmental issues (e.g. Regulations), strengthen cooperation and providing core funding for projects (Meadowcroft 1999; von Malmborg 2003). The article in Chapter 9 presents a more detailed account of these types of public-private partnerships for eco-innovation.

A second focus within the stream of research on eco-innovation in networks, deals with agent-assisted processes (Hansen and Klewitz 2012b). These processes are steered by "intermediaries", a term used in the innovation literature to refer to third parties, brokers or agencies that support the innovation process (Howells 2006). Innovation intermediaries are usually presented as "actors performing a variety of tasks in the innovation process" (Howells, 2006). The variety of tasks depends on the theoretical lenses under which intermediaries are analysed. Intermediaries' activities can vary from the provision of information about possible collaborators, bridging between the parties as mediator or facilitator or through fund raising etc.(Howells 2006). From the literature on innovation management, there is an understanding of intermediaries as organizations or individuals with a broad palette of skills and knowledge of different industries. In this way, the intermediaries become involved in early stages of the innovation process (i.e. Front end, invention), by recombining knowledge from different industries (Gassmann, Daiber, and Enkel 2011; Hargadon 2002). Such process of recombination has been extensively analysed by Hargadon (2002) through the knowledge brokering model of innovation.

This model implies that intermediaries (organizations or individuals) gain access to the resources from multiple institutional and organizational domains, which are unknown to other domains. Later they share these resources and knowledge in new contexts (industries, sectors, etc.). Chapter 11 provides further details in relation to the role of innovation intermediaries in eco-innovation demonstration projects involving a network of suppliers.

4.2.3 BUSINESS MODELS FOR ECO-INNOVATIONS

An emerging stream in eco-innovation research deals with the relationship between eco-innovation and business models. Research within this stream tries to uncover how eco-innovations can create value for the end-users and suppliers, through focusing on the market introduction of the eco-innovation rather than its development (Boons and Lüdeke-Freund 2013). The research on business models has increased since the late 1990s, and there is no agreement on what a business model is despite, the large amount of publications using the term. A review on the concept "business model" highlights three main areas: E-commerce, business strategy and technology & innovation management (Zott, Amit, and Massa 2011). The research on business models for eco-innovation is part of the third field, which main purpose is to "understand how technology is converted into market outcomes, but also new modes of innovations" (Zott, Amit, and Massa 2011). Although several definitions for "business model" exists regarding technology and innovation, in this conceptual framework, a business model is understood as a "narrative" or as a "tool" that facilitates the interaction and convergence of actors around a new venture (i.e. An eco-innovation which has the potential to generate value to the possible partners). According to Doganova and Eyquem-Renault (2009, 1568):

> In our view, the business model is a scale model of a new venture, which aims at demonstrating its feasibility and worth to the partners whose enrolment is needed. The scale model is built for the purpose of producing encounters, in which it is performed by its inscription in a document and its display to an audience…As a demonstration, the business model is performative, for it constructs both the object and the public of the demonstration: the new venture and its network.

An underlying element of the business model concept is that firms shall collaborate in order to reach success in the ventures represented by the business model. The business model as a tool contains the following elements: target customer market, products and services associated with the offered value, partners, resources to create, deliver channels, cost structure and revenue streams (Beltramello, Haie-Fayle, and Pilat 2013). Boons and Lüdeke-Freund (2013, 13) highlight the following key elements used as a communication device for new sustainable ventures such as eco-innovations:

- "Value proposition" is about defining the value of the product or service offered by the firm or the network. Besides the economic value, the ecological and/or social value should be accounted for in the model.
- "Supply chain" addresses the management of relations with suppliers. Concerning eco-innovations, this aspect implies that manufacturers are co-responsible along with the end-users on the environmental aspects of their activities.
- "Customer interface" is about structuring and managing the relationships with customers. The focus aspect of business models for eco-innovation should be to engage the customers in taking responsibility for their consumption.
- "Financial model" concerns the economic, ecological and social cost and the benefits of the first three aspects.

A review by Beltramello , Haie-Fayle and Pilat (2013) covered four large categories of eco-innovation business models: Product service systems and incentive models, life-cycle models, ICT solutions and systemic innovation (see Table 8). In the conceptual framework we focus in the first category of business models (Product Service systems and incentive models). The Product Service System (PSS) is a relevant business model for two reasons which show an overlap between the theory of eco-innovation and the empirical focus of this thesis, the maritime industry: (i) It has received increasing attention in the field of eco-innovation. The main argument presents PSS as a business model that could achieve decoupling between economic value and energy consumption. In the case of product-oriented services, possible sustainability gains can be expected in better maintenance or product and material recycling. In the case of use-oriented services, the main benefit is to intensify the use of certain products through leasing and renting. Result-oriented services are the best examples of need-oriented PSS and with the largest potential for sustainability gains (Ceschin 2013; Tukker and Tischner 2006) ii) In the Danish maritime industry PSS has received increasing attention from suppliers and shipowners as a business model that could create win-win outcomes for both. (Mougaard et al. 2013; Hsuan et al. 2012; Andersen et al. 2013; Andersen, McAloone, and Garcia i Mateu 2013).

Table 8 A suggested typology of business models for Eco-innovation. Source: Beltramello, Haie-Fayle and Pilat (2013)

Product Service Systems and Incentive Models	Life-Cycle Models	ICT solutions	Systemic Innovation
• Functional sales (i.e. related to one of the categories of PSS-results oriented) • Energy service companies (ESCO) • Chemical Management Services (CMS) • Integrated Pest Management (IPM) • Sharing or renting based business models (e.g. See the category "use-oriented" PSS below) • Design-build-finance-operate (DBFO)	• Industrial symbiosis • Craddle to Craddle (C2C) based business models	• ICT solutions based models • Tele-presence and videoconferencing services	• Eco-city • Urban transport system based on bio-gas • Electric car based mobility system

PSS is defined as "A mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs" (Tukker and Tischner 2006, 1552). Tukker and Tischner (2006) assert a necessity for a closer look into the different types of PSS to analyse the degree of sustainability. The main benefit of PSS to sustainability is the possibility to move away from products in order to fulfil users' needs, thus broadening the scope of possibilities to find sustainable solutions. Tukker (2004) presents an overview of eight archetypal models of PSS, which are divided in three main groups according to whether the value is generated mainly through the product or mainly through the service:

1. Product-oriented PSS which includes:
    a. "Product-related service". The product related service is about the services the customer needs in the "use" phase of the product (i.e. Maintenance contract, consumable parts, etc.). An example

in the maritime industry is the business model "Easy Admin PSS packages" which proposes that suppliers collaborate to formulate packages of components and systems. The end-user of the equipment pays a price (which can be included in the equipment purchase) to be serviced along the life-cycle of the product (Andersen et al. 2013)

   b. "Advice and consultancy". The producers offer advice to the consumer, such as counsel on how to structure a team to efficiently use the product.

2. Use-oriented PSS where the product is rented or leased to the user, in addition to after-sales services:
   a. "Product lease". The ownership of the product still belongs to the producer, but the user pays a fee to cover the use of the product and also its maintenance.
   b. "Product renting/ sharing". Similar to leasing, but the user does not have the unlimited ownership of the product as other users can have access to the same product overtime.
   c. "Product pooling". Similar to the previous two options, but with the main difference being that the product can be used simultaneously by other users.

3. Result-oriented PSS where a performance or capability is sold (functionality/functions/result):
   a. "Activity management". Some of the non-core activities of a firm are outsourced to third parties, i.e. catering and office cleaning.
   b. "Pay per service unit". The consumer no longer buys the product but the resulting output of the product. The producer ensures that the output is generated by taking care of the maintenance or supply of consumables. An example are printers and copy machines in offices which no longer pay for the printer but for printed units.
   c. "Functional result". The supplier agrees to provide a result rather than a product, both the user and the supplier agree on the terms of the desired-result. An example in the maritime industry is the proposed PSS "Performance-based contract" in which the end user (shipowner) agrees with the supplier on an expected outcome or performance. The supplier is then in charge of the operation of an equipment -for example, the threshold could be the legislation limit for microorganisms in ballast water (Andersen et al. 2013).

4.3 THE CONCEPTUAL FRAMEWORK

The conceptual framework was the result of an abductive process in which I combined the literature review with insights from the emerging empirical analysis. Through this approach, further introduced in section 6.1, I grounded the concepts presented in Chapters 3 and 4 in the context of the empirical setting (section 1.3).

The conceptual framework suggests that maritime supply networks can deliver product and service eco-innovations to the maritime industry by a three tier process of i) end-user involvement in the value-creation network, ii) value creation in collaborative networks and iii) delivering value propositions. The result of these three elements is the consolidation of a value-creating network integrated with suppliers and end-users. The value network will generate environmental products and service offerings to the maritime industry while improving the overall cluster competences and collaboration for maritime eco-innovations (Figure 10).

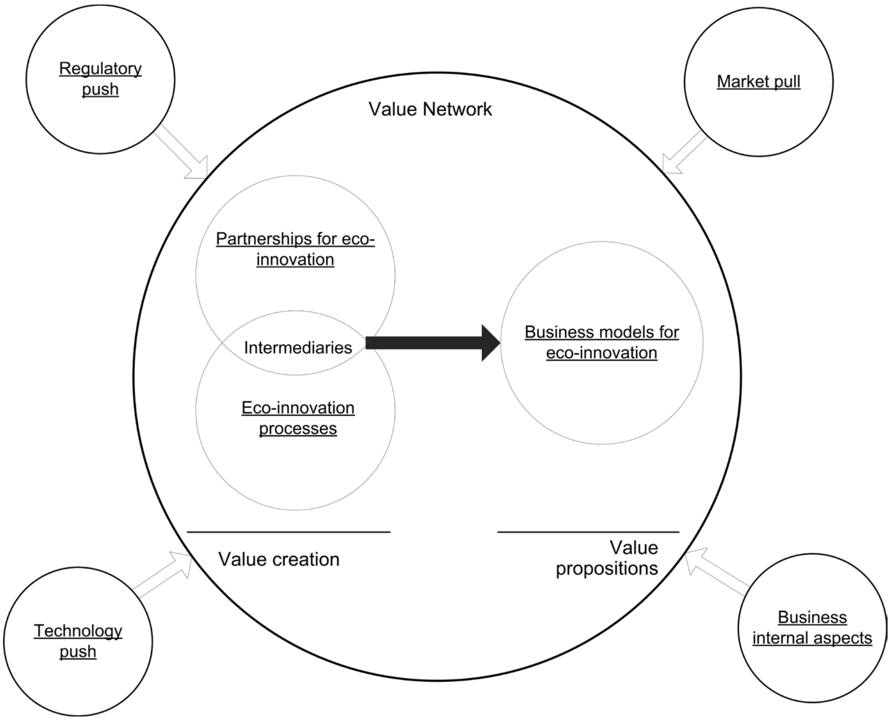

Figure 10 Conceptual Framework: explaining value creation through eco-innovation

The first part of the conceptual framework deals with end-user involvement in the value creation process. As explained in section 3.2, end-users influence the type of competences and outcomes developed within the value network (Kothandaraman and Wilson 2001; Lusch, Vargo, and Tanniru 2010). In the context of this thesis, end-users are shipping companies which either own or manage a fleet of ships, therein as explained in section 1.1, demand eco-innovations characterized by incremental modifications of existing technologies. The model proposes four drivers that motivate these end-users to become involved along with their supply networks in the development of eco-innovations, and thus co-create value: regulatory push, market pull, technology push and business internal aspects. These drivers are analysed in detail in section 4.2.1. However, from the literature review, it is not clear in which ways these drivers interact and guide the selection of particular eco-innovations. This is the focus of the conceptual framework and the empirical results of Chapter 8.

The second element in the conceptual framework is value creation. Earlier, I defined value according to two complementary perspectives (section 3.2.1): the “conventional” and the “emerging” creating shared-value (CSV) perspectives. The former has a focus on the financial benefits of an activity, by contrast, the latter emphasises the social benefits in addition to the financial ones. The problem analysis was defined from the suppliers’ interest to develop new products and services with the primary purpose to create new markets and thus generate growth in the regional maritime cluster in Northern Jutland. These goals overlap primarily with those of value understood from a conventional perspective, but it might also relate to creating shared-value if new jobs are generated in the region. However, without contrasting the conceptual frameworks empirically, it is not possible to conclude whether the suppliers and end-users have the purpose to generate social benefits from their activities. In this line of thought, similar criticism towards CSV points that social benefits can also be a side-effects of the activity without naming that activity as CSV (Crane et al. 2014). In this conceptual framework, therefore, the focus is primarily on value creation from the conventional perspective as reflected in Figure 10, but this does not discard that it can be applied to understanding CSV.

A close collaboration between end-users and suppliers can lead to co-creation, a term defined in section 3.2.2, which implies value created by co-production with suppliers, end-users or partners (Normann and Ramirez, 1993 in Vargo and Lusch 2004, 10). However, the literature fails short in explaining how value can be co-created in the practice. To address this gap, the conceptual framework proposes a relation between value co-creation and the second “stream” of research on eco-innovation presented in section 4.2.2. This stream of research addresses three mechanisms by which multi-party collaboration between suppliers and end-users is possible in order to develop new products and services. The first proposition is that partnerships with a goal of developing maritime eco-innovations can be a platform for staging this collaboration. These types of partnerships break the organizational boundaries because they bring the development of eco-innovation to an institutional level. The partnerships have a role in the environmental governance of the industry. Each stakeholder has its own drivers to be part of these partnerships. However, greater incentives arise for end-users and suppliers who can use the partnership as an opportunity to influence legislation, while public authorities can use the partnerships to steer the direction of the industry towards cleaner practices (see conceptual framework in Chapter 9).

According to the conceptual framework, it is possible to understand the development of eco-innovations by analysing the processes within the partnerships or other forms of supplier and end-user collaboration. At this point, processes can have two meanings: one referred to the functioning of the partnerships (see Chapter 9) and the other referred to innovation process which is further explained in Chapter 11. The first meaning deals with the roles of actors in the partnership, the activities and the characteristics of the actors' participation in these activities. The second meaning refers to the account of actions undertaken by actors as part of developing a new product or service over time. Both types of processes are relevant and are integrated in the conceptual framework as a circle beneath "partnerships" (Figure 10).

Innovation intermediaries represent a link between the partnerships (or any other form of multi-party collaboration) and the innovation processes. What is important in relation to intermediation is that the processes of value creation within partnerships require the continuous support of some key actors in the network which play several functions. These functions range from brokering to networking, but also increasing the absorptive capacity among cluster firms involved in the partnerships (see sections 4.2.2 and 11.2 for a more detailed account of these different functions).

The third element in the conceptual framework is how the created value as products or services, can be transformed into value propositions for further commercialization to a large group of users. Value proposition was introduced as the "promise" of what can be delivered to end-users and was in direct relation with the competences of actors (see section 3.2.1). From this perspective, value propositions are also one of the key elements included in the concept of business model, along with the supply chain, customer interface and the financial model (section 4.3). What is relevant is that the business model can be used as a tool for planning further collaboration in the commercialization of the new products and services.

The selection of case studies has the purpose to expand the analysis of the different aspects in the conceptual framework. A detailed explanation of the selection of the cases is presented in section 6.1 and the relation of the cases with the conceptual framework is expanded in Chapter 7.

PART III
THEORY OF SCIENCE AND METHODS

Part III presents the research design in two parts. Chapter 5 addresses the scientific paradigm which explains the research design, the elaboration of the conceptual framework and the choice of methods for collecting the data and reporting the results. Chapter 6 is about the research design. This chapter illustrates the relevance of using the case study inquiry strategy in the four articles, as a way to answer the research question. Additionally, Chapter 6 explores how these case studies relate to one another, in addition to explaining how qualitative methods were applied for the collection and analysis of the empirical material.

5
A CONSTRUCTIVIST PARADIGM IN QUALITATIVE RESEARCH

Creswell (2007) claims that after several decades of evolution, qualitative research has a legitimacy of its own and thus it is no longer necessary to define it in opposition to quantitative research. In line with this argument, Lincoln, Lynham, and Guba (2011) provide a definition of qualitative research:

> Qualitative research is a situated activity that locates the observer in the world. Qualitative research consists of a set of interpretive, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including fieldnotes, interviews, conversations, photographs, recordings and memos to the shelf. At this level, qualitative research involves an interpretative, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meaning people bring to them" (Lincoln, Lynham, and Guba 2011, 3)

This quote captures the essence of what I intended to investigate through my thesis, when drafting the initial research questions that guided my exploratory interviews. As the research progressed and I developed my guiding research questions, it was clear that qualitative research would be the appropriate method in unravelling how suppliers relate in order to create value or eventually shared-value. During the process of research I interacted with social actors (either authorities, service and equipment suppliers, shipowners, etc.) through methods which captured their thinking, actions and expectations regarding their daily practices and activities (i.e. Observation, interviews). These interactions took place in their "natural settings" (practitioner conferences, offices, workshops) hence allowing me as a researcher to interpret the meaning of the basic data input (their words) while in the actors' context. In summary, while doing my research, I adhered to the philosophical assumptions of qualitative research sketched in Table 9.

In qualitative research, paradigms or "worldviews" are a "basic set of beliefs guiding action" (Creswell 2007) and "nets that contain the researcher's epistemological, ontological, and methodological premises" (Denzin and Lincoln 2011). Five paradigms are the result of the historical development of qualitative research: positivism, post-positivism, critical theory, constructivism and participatory (Lincoln, Lynham, and Guba 2011). Research methods and interpretation of the results are specific to each paradigm, and this often leads to contentious issues such as: inquiry aim, nature of knowledge, goodness /quality criteria, values and voice (Lincoln, Lynham, and Guba 2011).

Table 9 Philosophical assumptions in qualitative research and implications in my research. *Adapted from Creswell (2007)***.**

Assumption	Main issue	Characteristics	Implications to my research
Ontological	How is the world and what is the meaning/ significance of social phenomena?	Multiple and subjective reality	Using quotes to unfold the actors' perception of social phenomena, i.e. what is the implication for a supplier of a new environmental regulation in the industry?
Epistemological	What is considered as acceptable knowledge in a discipline?	Social sciences require a different approach than natural sciences. The researcher attempts to lessen distance between them and those being researched	The activities of the Maritime Centre for Operations and Development (MARCOD) provided me with a close contact to maritime suppliers from Northern Jutland and Denmark, but also with authorities, shipowners, etc. In MARCOD I attended internal meetings and strategic planning seminars. All these interactions with stakeholders became inputs to my own research.
Epistemological	What is considered as acceptable knowledge in a discipline?	Social sciences require a different approach than natural sciences. The researcher attempts to lessen distance between her/he and those being researched	The activities of the Maritime Centre for Operations and Development (MARCOD) provided me with a close contact to maritime suppliers from Northern Jutland and Denmark, but also with authorities, shipowners, etc. In MARCOD I attended internal meetings and strategic plan-

Assumption	Main issue	Characteristics	Implications to my research
			ning seminars. All these interactions with stake-holders became inputs to my own research.
Axiological	Role of values	Values influence the research and the researcher acknowl-edges that bias.	In the case studies I interpret the partici-pant's quotes and make my own interpretations and values explicit. For example in the articles, I present my own posi-tion as a researcher and whether my role is active (participant observer) or passive (observer).
Rhetorical	Language of research	Informal, engaging style, i.e. the use of personal voice	In both the articles and the thesis I use a per-sonal voice to a large extent. Further, some of my case studies are presented as narratives trying to explain a sequence of events which unfold overtime.
Methodological	Process of research	Using inductive or abductive logic (see section 5.1)	I combine inductive and abductive logic in my four research articles. I work from the particular before generalizations. In other cases, as with the conceptual frame-work, I iteratively re-vise my theory accord-ing to the inputs from the case. Generalization is only possible to certain degree as the key issue is to under-stand what is particular in each specific case.

I position this thesis within the constructivist (or constructionism) paradigm. The main claim within constructivism is that social phenomena result from social interaction and are in constant change (Bryman 2012). From an epistemological position, constructivism is part of the interpretative tradition, which stipulates that the subject of study of social sciences requires different research procedures than those of natural sciences because it is necessary to grasp the subjective aspects of human and social interactions (Bryman 2012). Following the interpretative tradition, constructivism is a scientific paradigm which is epistemologically in opposition to positivism. In sections 5.1 to 5.3, I explain the positions of constructivism on selected practical issues which are in contention with other science paradigms. Furthermore, I also explain how I translate these issues in my research design.

5.1 INQUIRY AIM

In constructivism, the inquiry aim departs from acknowledging that scientific generalizations do not explain all situations encountered in social phenomena. Therefore, it becomes important to understand and reconstruct social phenomena or processes in order to inform the praxis (Lincoln, Lynham, and Guba 2011; Guba and Lincoln 2005). My own inquiry aim is to provide answers to a problem faced by the practitioners (i.e. MARCOD and maritime suppliers in Northern Jutland). As the researcher, I shared my time between the University and the field, meeting and working together with the practitioners at MARCOD in order to reconstruct a set of cases and create an understanding of social phenomena such as networks of actors innovating and developing new eco-innovations. Along the research process it became evident that pre-defined scientific generalizations in the form of deductive inference would not explain the social phenomena perceived, for this reason I relied on abductive inference as an alternative to finding links between the reconstructed social phenomena and the theory. Through the process of creating a conceptual framework by relating the empirical observations with theory, I was able to consider alternative explanations to my observations (sometimes by relying on a diverse set of theories not initially considered).

5.2 NATURE OF KNOWLEDGE

The nature of knowledge is about the researcher's assessment of the knowledge generated through inquiry. In constructivism, the created knowledge is said to be subjective and results from the interaction between the researcher and the researched subjects. Therefore, knowledge is constructed as a result of the experience gained by the subjects while interacting with other actors (Lincoln, Lynham, and Guba 2011). In my experience during the research process, I acted as a compiler of knowledge otherwise dispersed among several actors, not only individual people, but also organizations in the form of written documents. As a compiler of dispersed knowledge, I reconstructed case studies by joining pieces together. A good example, was when writing the key events that resulted in the development of the Læsø Green ferry (Chapter 11). The case study was written by joining together the experience of the people who were involved in that project, but also from minutes from meetings and other documentation. The final product was the interaction between the collective knowledge of the practitioner-actors and me as the researcher. A similar approach was followed in all the other three articles.

5.3 VALIDITY

By acknowledging that the nature of knowledge is constructed between the researched and me, the researcher, some questions naturally emerge, as for example: is the information I collected accurate? Are my results true and for whom? Did the participants agree with what I reported? How do other researchers and other epistemological communities assess my research? These types of questions relate to the goodness and quality criteria considerations that I followed in my methods and interpretation: validity, reliability and evaluation criteria. In this section, I address validity, whereas I take a closer look on reliability and the evaluation criteria in my discussion about the methods (Chapter 6).

Validity is contentious because it points to the issue of the results being sufficiently authentic to be worth the consideration (e.g. Policy action, legislation, planning) (Guba and Lincoln 2005). My approach to validity is about the authenticity of the constructivist inquiry (how rigorous is my research according to my own philosophical position). I adhere to three criteria to assess authenticity: fairness, ontological and educative authenticity and catalytic authenticity (Guba and Lincoln 2005, 207). Similarly, I also acknowledge the two types of validation suggested by Angen (2000): ethical validation and credibility.

The first authenticity criterion is fairness, which is about having a balance between all the stakeholders' views, perspectives claims, concerns and voices (Guba and Lincoln 2005). The purpose of having this balance is to avoid bias in the sense of inclusiveness, such as avoiding to marginalize the views some stakeholders. To ensure fairness, in my results I quoted interviewees and included a reference number to the interview. In this way it was possible to confirm that most of the interviewees' perspectives were presented.

The second criterion establishes that constructivism deals with human/ social inquiry and thus, ethical considerations become relevant in order to acknowledge that research is not value-free. The first element in ethical validation is that research should have a practical value and generative promise (Angen 2000). This means that the research should end by delivering new questions which open possibilities for new dialogues and perspectives, instead of delivering unchangeable conclusions. My research proposes conceptual models which complement the analysis of a case study. Both the empirical results and the conceptual models attempt to be the “true”, but instead I propose hermeneutical devices for discussion between stakeholders. For example, in the article Rivas-Hermann, Köhler and Shepeens (2014) we propose a business model for resulting oriented PSS. The idea of this model is to suggest that MARCOD could use dialogue with maritime suppliers in order to create new ways of collaboration and thus be able to deliver new products and services to the maritime industry.

A second element in ethical validation is transformation, which is also named catalytic or educative authenticity (Guba and Lincoln 2005). Constructivist/ interpretative research should increase awareness on a given issue to those researched and the other actors with whom they directly interact. After awareness has increased, it is possible to transform the actions of those researched. The underlying issue is that the researcher should not be considered as a privileged owner of knowledge, but instead the researcher should work closely with those researched (Angen 2000). The overall idea of this research project was that it should be underpinned with the activities of an organization (MARCOD) which collaborates closely with actors on the ground (e.g. Maritime service suppliers). The actions of MARCOD have an impact on the activities of these actors, and thus my research is an input for MARCOD. Indirectly it also affects the actors’ actions in cases MARCOD implements some of the insights included in the reports.

The third criterion for assessing authenticity in this research is substantive validation (Angen 2000). This implies that the researcher should be self-reflective regarding their theoretical choices, but also reflect on the implication of the constructed case(s). The reader should be able to analyse the researcher’s chain of inquiry in order to assess if the final product is worth the trust. As part of a substantive inquiry validation, the researcher should document their own personal biases, but also how their thoughts evolved along with the research process (Angen 2000). In this thesis, I applied substantive validation while reflecting on my own theoretical position and theoretical choices. Evidence of this can be found in the research design (Chapter 6), and in the discussion (Part V). In the articles, the reflections’ scope is on the relevance of the results, selection of cases and possibly generalization from the case studies.

6
METHODOLOGY

In this thesis, I seek to explain how maritime supplier networks can deliver product and service eco-innovations to the maritime industry. Explanatory research aims to: i) explain patterns related to the phenomenon in question and ii) to identify relationships shaping the phenomenon (Marshall and Rossman 2006). In my overall research approach I adapted the so called circle of constructivist inquiry (Marshall and Rossman 2006) in order to formulate the research problem, as well as to design the methodology for data collection and interpretation, and relate the empirical findings with theory (Figure 11).

The circle of constructivist inquiry starts when the researcher enters a cycle of interpretation through an anomaly which is subsequently defined as the research problem. The cycle then continues by designing a methodology to seek explanations for this particular anomaly. At this point, I considered a multiple-case study research design (CS1-CS4) for my own circle of constructivist inquiry (Yin 2014). In the line of Creswell (2007), case studies are a particular type of design in qualitative research in which the researchers explore a single bounded system (case) or multiple bounded systems (cases) over time. This exploration involves an in-depth collection of data by several methods (e.g. document review, interviews, observation). On the other hand, Stake (2005) considers case studies to be a choice on what should be studied, therein, the methods are secondary, but what is important is to concentrate on the case as a unit of study. In this thesis, both perspectives are complementary and thus, I refer to case study as a methodology which implies a process of collection, organization and analysis of data within a bounded system which leads to an interpretative report. I present the selection criteria of the four case studies (CS1-CS4), along with an explanation of the logic behind "nesting" these cases within a broader case and context (section 6.1).

A final step in the research approach (Figure 11) is relating the interpretative outcomes of the case studies to the theoretical framework before initiating a new cycle of research design and carrying out a new case study. In the actual research process, the relationship between theory and the case study took place along the interpretation and not after (as explained in greater detail in section 6.1). I relied on abductive inference in order to formulate new ideas and ways to analyse the data without drawing on preliminary theoretical premises (Meyer and Lunnay 2013). Abductive inference is based on the analytical tool of abduction, characterized by generating alternative explanations of the data that does not fit the expected theoretical propositions (Dubois and Gadde 2002).

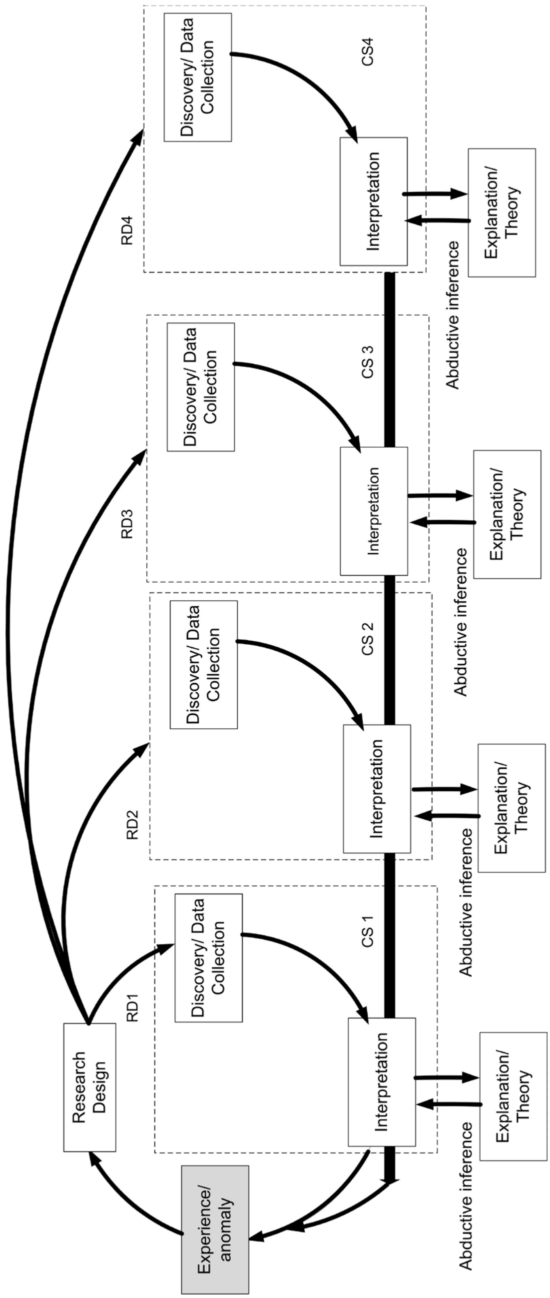

Figure 11 Research approach in the Thesis: circle of constructivist inquiry. Adapted from Marshall and Rossman (2006, fig. 2.1)

Due to its characteristic of considering the analysis of data beyond the original research premises, abductive reasoning is viewed to have more similarities to deductive inference rather than inductive inference —as in grounded theory (Patton 2002). The reason behind choosing abductive reasoning instead of carrying out deduction-driven research is because theory-driven research (deduction) may be biased to the purpose of testing out the theory, and thus less attention is paid to data not fitting the accepted theory. By relying on abduction, the researcher can address this bias by providing a complementary analysis to the original theoretical frame (Meyer and Lunnay 2013). Under this logic, as the interpretation of materials from the case studies emerged, it became clear that a pre-defined tight conceptual framework would undermine alternative ways to interpret the data and thus new interesting insights (not considered by the existing theories) would be lost.

6.1 CASE STUDY SELECTION AND USE OF THEORY

I employed case study as the methodological approach in this thesis for two reasons: i) Case study is an appropriate methodology for explanatory questions starting with "why" and "how" (Yin 2014). My research question and sub-questions belong to this category of explanatory questions for social phenomena. One exception is sub-question 1, "What are the drivers for developing environmental technologies in the maritime industry?" To answer this question I also followed a case study methodology, because the case study had an exploratory purpose which led to hypothesis and propositions for further inquiry. ii) If the questions are explanatory, a case study is appropriate when the researcher has no control of behavioural events and these events are contemporary. The events can be studied through a combination of methods such as observation, interviews, document review, etc. (Yin 2014). In the four articles included in this thesis, I focused on issues which implied contemporary events over which I had no control.

The thesis is organized as a multiple-case study design (Yin 2014). A key issue in this type of research design is the replication logic which can be of two types (a) prediction of similar results and (b) a theoretical replication based on the prediction of contrasting results due to pre-defined reasons (Yin 2014, 57). In this thesis, I rely on the second type of replication logic, because the case studies had the purpose to address four aspects of the conceptual framework (Figure 12 and Table 10). The four case studies share some context conditions. On the one side, the context was that of the supply networks within the maritime cluster of Region Northern Jutland and their relations with other actors within the Danish maritime cluster (as introduced in section 1.2). On the other side, the cases are embedded in a temporal context because the analysis undergoes contemporary situations —or the relation of past events with these situations.

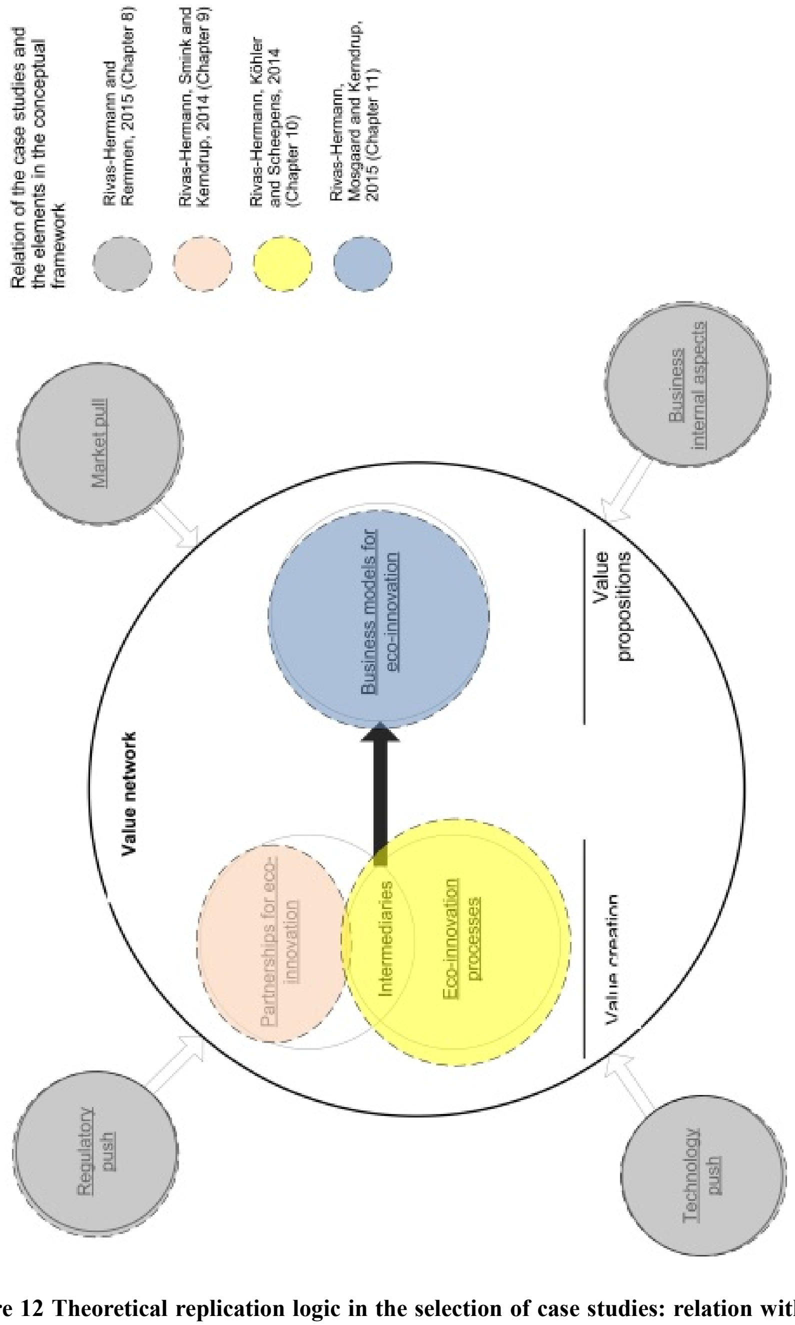

Figure 12 Theoretical replication logic in the selection of case studies: relation with the conceptual framework

Table 10 Description and type of case studies

	Article	Case boundaries	Type of case
CS1	Rivas-Hermann and Remmen (2015)	A case study on how the sulphur content in marine fuels is being regulated within the Emission Control Area of the North/ Baltic Seas	Paradigmatic (Flyvbjerg 2006). Further details about selection and type of case are presented in Chapter 8.
CS2	Rivas-Hermann, Smink and Kern-drup (2014)	Two case studies of Danish partnerships for developing cleaner technologies for the shipping industry: the Partner-ship for Cleaner Shipping and Green Ship of the Future.	Common (Yin 2014). See Chapter 9
CS3	Rivas-Hermann, Köhler and Scheepens (2014)	Business models around the development, installation and operation of Ballast Water Treatment systems from a per-spective of Danish maritime service suppliers.	Critical (Flyvbjerg 2006). See Chapter 10 for further details about selection and type of case
CS4	Rivas-Hermann, Mosgaard and Kerndrup (2015)	Case study of the green retrofit of the ferry Margrethe Læsø	Common (Yin 2014). Further details about type of case in Chapter 11.

The selection of these cases was intertwined with other activities in the research process, such as conducting a literature review, approaching the empirical world through qualitative methods, interpreting the results and writing case studies, reflecting on the implications of these cases to theory and integrating relevant theories in the conceptual framework. This going back and forth between the empirical observations and the theory allowed me to: i) expand the understanding of both theories and the empirical phenomenon ii) based on the constructivist paradigm, I also defined together with research participants —in particular MARCOD— what would be relevant case studies.

The starting point was the first sub-question which deals with eco-innovation drivers in the maritime industry. To address this research question I designed and wrote a case study on how the sulphur content in marine fuels is being regulated within the Emission Control Area of the North/ Baltic Seas (CS1). This case was selected following a "paradigmatic" logic, because the aim was an exploratory study from which some hypothesis on what drives eco-innovation in the maritime industry could be generated for further research. Paradigmatic cases fit this purpose well because they attempt "to develop a metaphor or establish a school for the domain that the case concerns" (Flyvbjerg 2006).

After elaborating this first case study, I reviewed the literature on sustainable transitions and strategic niche management (Elzen, Geels, and Green 2004; Geels 2002). My idea was to direct the inquiry process towards a broader industry analysis of transition towards sustainability. In a conference article, (Rivas-Hermann 2012), the characteristics of the maritime industry were analysed under the optic of sustainable transitions, which could be examples of eco-innovation niches that eventually will diffuse in the industry and facilitate the transition towards cleaner shipping. After further collection of empirical data and further updates to the conference article, I re-directed my analysis on how actors interacted in public-private partnerships and networks for developing eco-innovations in the maritime industry[6]. The main reason was that the previous theory of sustainable transitions focused on system change and lacked to provide a better frame to analyse the agency of actors. The case study presented in the conference paper Rivas-Hermann (2012) indicated that instead of a focus on the socio-technological characteristics of the maritime industry, it was more relevant to understand how public-private partnerships for maritime eco-innovation were organized and how they interacted. The theoretical orientation on partnerships and networks resulted in the second article (Rivas-Hermann, Smink, and Kerndrup 2014), and also an updated conceptual framework integrating the concepts of partnerships. The article included one case study with two units of analysis (CS2), which were selected as a common type of case (Yin 2014).

The third unit of analysis (CS3) was a case study about the business models for ballast water installation and the operation of ballast water treatment systems (BWTS) from Danish suppliers, which the authors selected under the logic of a critical case. The purpose of the case was to analyse one type of maritime eco-innovation where supply networks could develop new value propositions through, for example new business models. In this sense, business models around BWTS are a critical case because the international regulation that makes the use of BWTS compulsory is not yet entered into force. However, shipowners and operators are constantly looking into the market for the technologies available; suppliers have a great opportunity to develop a compelling value proposition to capture a share of this large awaiting market. The empirical analysis of the case study on BWTS business models updated the conceptual framework by integrating the theory of

[6] The conference article Rivas-Hermann (2012) was an earlier version of the CS2 and article Rivas-Hermann, Smink and Kerndrup (2014), hence it was not considered for inclusion in this thesis. However, the article as part of the conference proceedings was still accessible online by 01/05/2015

business models for creating value in networks of maritime suppliers. Another contribution was new ideas for directing the research.

At this point, one of the case studies analysed the characteristics of partnerships for developing eco-innovations while the other article analysed the business models for diffusing these eco-innovations. As a result, I decided to explore and better understand the innovation processes and the role of intermediaries in initiating and developing eco-innovations. With this purpose, in collaboration with the other co-authors, I presented a case study of the green retrofit of the ferry Læsø Margrethe (CS4). This case was also selected under the logic of a common case, because as a result of the inputs from the CS2 we identified that several partnerships and networks were initiating pilot projects for maritime environmental technology. We selected one case which was similar to the other demonstration projects, in order to redraw generalizations which could be then transposed to those cases.

The outcomes of the case studies had implications in the development of the conceptual framework, which I considered as a set of eyeglasses that allowed me to focus and sharpen the field of understanding of the research problem and its empirical domain. With a basis in abductive inference, the initial conceptual framework benefited from the inputs from these case studies provided by including new theoretical aspects which could help explain the main case study:

> "The preliminary analytical framework consists of articulated 'preconceptions'. Over time, it is developed according to what is discovered through the empirical fieldwork, as well as through analysis and interpretation. This steams from the fact that theory cannot be understood without empirical observation and vice versa" (Dubois and Gadde 2002, 555)

The conceptual framework was hence developed by constantly matching and re-matching the initial theoretical propositions with, observations of the empirical world, and with what was inferred from the case studies (Figure 11). The process also facilitated a better selection of the units of analysis (CS1-CS4) according to the criteria described above.

6.2 GENERALIZATION FROM CASE STUDIES

In this thesis, I generate new knowledge and contribute to the development of theory through constructivist inquiry (see Figure 11). To achieve this goal, I relied on a multiple-case study as both a qualitative methodology and as an example of what needs to be studied. However, I acknowledge that relying on case studies as the main methodology for contributing to theory development is not without criticisms.

The key criticism is about generalization[7]. According to Calder, Phillips and Tybout (1982), "external validity [generalization] examines whether or not an observed causal relationship should be generalized to and across different measures, persons, settings and times". The criticism of case study's inability to be generalized is often explained from a positivist paradigm. This paradigm pursuits an ideal of natural sciences and tries to incorporate it into the social sciences, for example, in the way statistical inferences are used to identify correlations between variables and thus propose a hypothesis, etc. (Flyvbjerg 2006). The logic of this criticism is that a single case study design —or to a lesser extent, multiple cases— represent a small sample, therefore it is not necessarily random. From this view, cases are not representative of a total population ,hence generalization to other units of analysis beyond the case boundaries are not possible (Yin 2014).

A number of counterarguments have been proposed in opposition to the view that it is not possible to generalize from single or multiple case. Some perspectives are critical against the value of generalization in advancing science or in creating new knowledge. From a positivist perspective, Calder, Phillips and Tybout (1982) claim that random sampling is unnecessary in theoretical research as it interferes in achieving a robust theoretical test. The reason is that random sampling increases error variance and hence reduces the validity of statistical conclusions. Hence, if random sampling is a flawed requirement to achieve external validity even from a statistics point of view, then it does not hold as a criticism to generalizing from single or multiple cases (Calder, Phillips, and Tybout 1982). A case study theorist, Flyvbjerg (2011) points that generalization is only one among other parameters to generate valid scientific knowledge. In Flyvbjerg's line of reasoning, even when you are unable to generalize the results of a case study, independently the results are still valid. The key argument behind this logic is that universal, context-independent theories (associated with the logic of generalization) cannot be applied to the study of human/social phenomena. Instead a context-dependent case delivers more valuable contributions to the understanding of social/ human phenomena (Flyvbjerg 2011).

Other counterarguments suggest that generalization is possible from case studies, but it depends on the aim of the case in relation to theory. Here three types of generalization are possible: theoretical, falsification and empirical generalization (Tsang 2013). Theoretical generalization considers that case studies are valuable in generating new theories. This is because, as a mythological tool, it allows for an in-depth understanding of the "why" and the "how" of the mechanisms within a social phenomenon instead of just a description based on variable correlation of quantita-

[7] Generalization and external validity are used interchangeably, i.e. (Yin 2014), and thus I use the first tern along this thesis.

tive approaches. In addition to presenting an in-depth understanding of a social phenomenon, case studies provide a better understanding of the context of where the empirical data is situated, in this way it is possible to understand the contingencies associated to the social mechanisms unveiled by the case study (Tsang 2013). To increase theoretical generalization, replication logic is implemented in multiple case study designs in a similar way to statistical analysis –i.e. by looking into different characteristics in any of the chosen cases (Yin 2014).

Falsification is a second type of generalization used in case studies that seek to test propositions in a theory. If the observations resulting from a case study does not corroborate to the proposition, then the proposition should be rejected or modified (Flyvbjerg 2011). The process of falsifying theoretical propositions is also a way to build knowledge and develop new theories, because evidence is collected in order to explain the mechanisms that illustrate why the proposition does not work (Calder, Phillips, and Tybout 1982). A tactic to increasing the ability to generalize a case study is through using falsification. This is the strategy of purposely selecting case studies which provide an understanding of the limits of existing theories and the development of new theories or concepts. An example of these sampling types is "extreme" and "deviant" cases (Flyvbjerg 2011)

The third type of generalization in case studies is called "empirical generalization", which is also the argument I rely to justify the generalization of my case studies[8]. According to empirical generalization, the purpose of this generalization is not to generate a universal theory applied in any context. Instead, empirical generalization is context dependent and the resulting theory shall be applied to a smaller population, preferably similar to the one of the case study (Tsang 2013). Case studies designed under this logic provide empirical patterns that could become the basis for further research and theories (Hambrick 2007). A type of case selection associated with empirical generalization is *intrinsic case studies,* defined by Stake (2005) as the case which is purposefully selected when the researcher wants a deeper understanding of a particular trait or problem within that case.

6.3 METHODS

The elaboration of each of the four case studies described in section 6.1 implied two connected processes of data collection and analysis summarized in Figure 13. The process started with an initial document review to define the areas of inquiry (e.g. which kind of data should I collect through the qualitative methods), based on this initial inquiry I elaborated a case study protocol, which related the research ques-

[8] I present a detailed explanation of how I generalize from the results in each article. This discussion is presented in the Methods or the Conclusions sections.

tion with the type of information sought. The case study protocol also guided the use of a combination of four qualitative methods: document review, interviews, observation and participant observation. Using multiple methods improved the construct validity of the case (Yin 2014). The data analysis was supported by written transcripts of the interviews and field notes, which were handled in qualitative data analysis software (QDAS) for further coding. The coded material was grouped in categories and themes to facilitate the interpretation and triangulate with the data gathered through the document review.

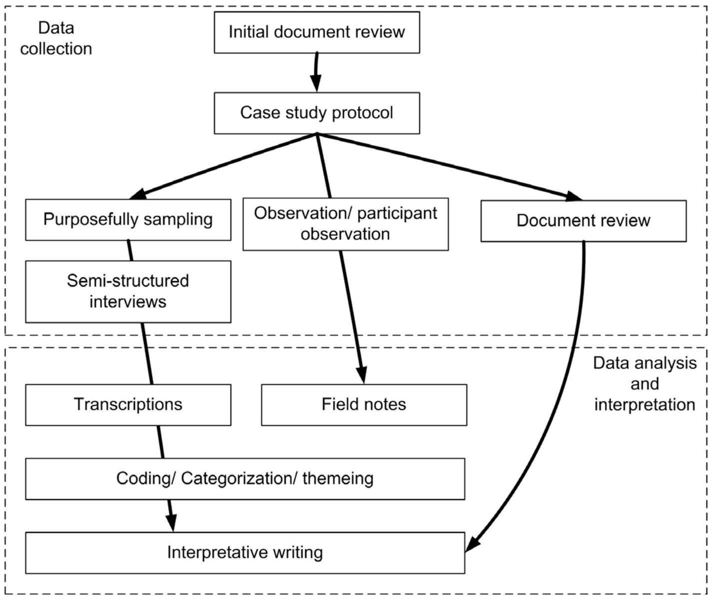

Figure 13 Methods of data collection, analysis and interpretation

6.3.1 DATA COLLECTION

I started the process of data collection through document review. This is defined by Bryman (2012, 543) as materials fulfilling the following conditions: i) they are accessible for reading, ii) they are created with purposes other than social research and iii) they are relevant as objects of inquiry. McNeill and Chapman (2005) classify documents in six categories: public or official records, personal documents, biographies, literature, historical documents and print and visual media. The document review was carried along the case study, which implied that any document of relevance was stored and became material for analysis. However, the sampling of documents varied as the case study progressed. At the outset of the data collection, the kind of documents I collected and analysed were public and official records and print/ visual media (i.e. websites, leaflets, technical reports, position papers). These kinds of general documents provided a more general overview of the different aspects related to the context of the case study and an overview of the stakeholders involved in the case study. The initial document review set the direction for the further collection of more detailed information. In later stages of the case study my sampling strategy differed from this broad and general initial strategy, and turned into the analysis of more specific types of documents. At this point, the type of document differed significantly among the different cases, for example, in CS4 I had a privileged access to private documents relevant to the case study, such as meeting minutes, email communications, project reports, grant proposals, evaluation reports. In CS1, which was an industry-broad case study, this was not possible, so I focused on a more detailed analysis of publicly available documents, like position papers, technical reports, etc.

The second step in the data collection process was the elaboration of a case study protocol (Figure 14). The case study protocol provided several benefits for the co-authors of each case study. The first benefit is that it increased the reliability of the case study, in ways such as the degree to which the data collection and analysis can be repeated and it becomes possible to obtain the same results (Yin 2014). The second benefit was that the protocol set the direction for the use of methods. As a research tool, the protocol connected the preliminary theoretical framework, the research questions, the type of empirical data sought, the methods to collect the data, and the potential interview questions. These relations were presented in a matrix (as in Figure 14), which provided a more detailed account of what type of information was supposed to have been provide for each method. The third benefit of the case study protocol was that it provided a basis for discussion among the co-authors on the structure and graphical representations of the boundaries of the case study.

The third step in the research process was the collection of data through semi-structured interviews, observation/ participant observation and document reviews. To elaborate, during the four case studies I carried out a total of 39 in-depth interviews, all but five of the interviews were in English language[9]. An important aspect is how I selected the interviewees for each case and how representative was this selection. In all the case studies, I followed the "judgmental" sampling strategy, which is also known as "purposive". This is one category of nonprobability sampling, which seeks to select a representative sample of the total population –but not in the statistical sense. Instead, representative is the result of an expert assessment of to what degree the selected interviewees will provide comprehensive information

[9] I carried the interviews in Danish together with the co-authors of the case study. In CS2 I carried one interview together with S. Kerndrup. In CS4 I carried two interviews together with M. Mosgaard and two interviews together with S. Kerndrup.

about the case study (Battaglia 2008). Along the cases I achieved this kind of representation by a previous document analysis, which allowed me to identify key stakeholders which had the potential to provide in depth information about the case study. As an instrument, I relied on semi-structured interview guides (Bryman 2012; McNeill and Chapman 2005) —see for example sections 9.8 and 10.8. The guides included a set of themes, between three and four) which were prepared beforehand through a preliminary problem assessment. A semi-structured interview guide allowed me a certain flexibility to let the interviewee provide his/her own flow of narrative, while at the same time allowing me to interrupt them and go further into details regarding one particular issue. All interviews were recorded for further transcription and analysis.

Case study protocol
Intermediaries functions in collaborative innovation processes: retrofitting a Danish small island ferry with green technology

1- Proposed analytical framework (prepared and expanded in the manuscript)

The analytical framework (in preparation) presents theoretical propositions in the following aspects:

- Innovation processes→ Three "stages" invention, development and implementation. Complexities associated with the innovation process

-Intermediation mechanisms in eco-innovation processes

2- Cases selection criteria

3- Research questions and research methods to collect empirical data

Research question	Empirical data sought	Interview questions// general for all kind of actors
Understanding the innovation processes behind the small green ferry projects	Which stage of the innovation process is the ferry project in…	Introduction—getting to know the organization ➔ What is your position within the company? ➔ Employees… ➔ Main business areas.. Could you tell us how has your company been involved in this project? ➔ What is the project about? ➔ How long have you been involved? ➔ What is the role of your company on it? ➔

4- Possible interviews

5- Time line

6- Structure of cases in article

7- Comparative case analysis and discussion in article

Figure 14 Short version of the case study protocol used for CS4. A similar protocol was used in all four articles.

In addition to document review and interviews, I relied on unstructured observation and participant observation. Unstructured observation is defined by Bryman (2012) as a method to register the behaviour of research participants with the aim to develop a narrative of that behaviour. In my cases, I used the observation method while attending in practitioners' events such as seminars, workshops and weekly meetings at MARCOD. These events allowed me to meet maritime suppliers, shipowners and operators and other relevant actors. Instead of recording behaviour, my observation focused on understanding the key issues, the position of some actors in regard to environmental technologies, barriers for the adoption of eco-innovations, position on new regulations, etc. To facilitate further analysis of my observations I relied in field notes. Another method was participant observation, which I used in one of the studies (CS3). In the practice, it differed slightly too unstructured observation, as the only change was that as an insider in MARCOD I had a closer interaction with the research participants. For example, we co-organized a one day seminar on the topic of business models around Business Models. The input from this seminar was used in the interpretation process of the case study (see section 10.3 for further details).

6.3.2 DATA ANALYSIS

The second aspect of this method is the analysis of the data collected through interviews, field notes and documents. To facilitate the analysis, I transcribed all tape recorded Danish interviews with the support of two student assistants. Each individual case study was assigned a file in the QSR-NVivo software, the QDAS facilitated by the university for this purpose. The files included the transcribed materials, field notes and certain documents pertinent to the case studies. The use of NVivo also facilitated the creation and administration of codes, which were later used to analyse the empirical materials. A code is a text string that condensates a meaning (i.e. the code "ecoinnnovation_drivers") that is later used for indexing materials, a process which is analogous to tag a piece of text with the purpose of easy retrieval later on (Bernard and Ryan 2009). The mechanical action of coding text also involved later steps of interpretation such as joining the coded materials into categories and themes in order to start a narrative. An example of this is mixing my own interpretation of the patterns with the interviewee's quotes. These steps are what I refer to as "coding" along this thesis, a standard method in qualitative research (Patton 2002; Saldaña 2009; Bernard and Ryan 2009). Although all four case studies were co-authored with other researchers, the process of creating codes, coding the empirical material and organizing the materials in categories was one of my contributions in all of the articles.

To start the coding procedure, I used a combination of exploratory methods aimed at a preliminary analysis of the empirical materials. This method is called hypothesis coding (Saldaña 2009, 123): In the empirical material I looked at the interviewees' expressions to see if they had a relation to these theoretical propositions.

Through holistic coding (Saldaña 2009, 118), I selected a text based on broad emerging topics, either mentioned by the interviewees or related to the interview questions. As an example, if one interviewee made a long presentation about their firm's drivers for participating in a given project, I coded the portion of text as "companyX_drivers". A third and final coding strategy was "Invivo" coding, which aim was to capture any striking phrases said by the interviewees.

The final step in the data analysis occurred after the exploration of the empirical material. At this point I grouped codes based on affinities as they emerged. This interpretative approach to the analysis of data is a process called "Themeing" by Saldaña (2009, 139). The process also required me to connect views from different sources which is the core of the "constructive" social construction of reality and the core of the scientific paradigm I followed in the research. As a result, I had my own bias in this process, in ways such as leaving out some quotes and including others. Themeing was a previous process for the writing of narratives of the case studies. Elliot (2005) defines narrative as one which "organize a sequence of events into a whole so that the significance of each event can be understood through its relation to that whole". The narratives understood under this logic implied mixing our own voice as authors with that of the interviewees, so it was possible to appraise the views of the different stakeholders in the construction of events and processes. During the process of writing the narratives and re-constructing the different perspectives, we relied on other visual instruments such as matrices, event-time diagrams, and illustrations which are included in the different articles (Miles, Huberman, and Saldaña 2013).

PART IV
RESULTS AND ANALYSIS

Part IV presents the results and analysis through four articles distributed in the following chapters:

In Chapter 7, the thesis provides an outline of each article and their relation to the research questions.

Chapter 8 presents the article: Rivas-Hermann, R. and Remmen, A. (2015) Drivers for eco-innovation in the shipping industry: A case study of the North European emissions control area. *Journal of Cleaner Production* (Submitted). Chapter 8 was complemented with the research report presented in Appendix B: Rivas-Hermann, R., Smink, C.K. and Hirsbak, S. (2015) *Eco-labelling for the promotion of wind-assisted propulsion in cargo ships*. Aalborg.

Chapter 9 depicts the article: Rivas-Hermann, R. Smink, C.K. and Kerndrup, S. (2014) Partnerships for environmental technology development in the shipping industry: Two Danish case studies. *International Journal for Innovation and Sustainable Development* (Submitted).

Chapter 10 is the article: Rivas-Hermann, R. Köhler, J. and Scheepens, A. (2014) Innovation in product and services in the shipping retrofit industry: A case study of ballast water treatment systems. Journal of Cleaner Production (Accepted)

Chapter 11 presents the article: Rivas-Hermann, R. Mosgaard, M. and Kerndrup, S. (2015) Intermediaries functions in collaborative innovation processes: Retrofitting a Danish small island ferry with green technology. International Journal for Innovation and Sustainable Development (Submitted).

7
INTRODUCING THE FOUR ARTICLES

The articles in chapters 8-11 provide insights into the research sub-questions and relate to the elements of the conceptual framework (Figure 12). Chapter 8 addressees the first sub-question: "*What are the drivers for developing environmental technology in the maritime industry*? In this article, the authors present a case study about how some environmental regulations (e.g. Directive 2012/33/EC and MARPOL annex VI) along with other drivers influence the short sea European shipping industry to adopt cleaner technologies. In relation to the conceptual framework, the purpose of this article is threefold: first, to define conceptual categories for eco-innovation, environmental technologies and cleaner technologies as commonly understood in the maritime industry. Second, to describe from the shipowners' perspective on why the demand of environmental technology is likely to increase in the future. Third, to provide a concrete example of which kinds of environmental products and services are likely to be part of the demand that some of the Danish suppliers can eventually fulfil.

The second research question is: "*How can maritime service and product suppliers create value and partnerships to fulfil the demands for environmental technology from markets and new regulations*? This sub-question is addressed in Chapters 9 and 10. The article "Partnerships for environmental technology development in the shipping industry: Two Danish case studies" (Chapter 9) analyses how public-private partnerships between equipment suppliers, shipowners and authorities can create conditions for the invention and development of some cleaner technologies. The article also provides a concrete example of an environmental technology developed with the support of these partnerships, the exhaust gas cleaner system. In relation to the conceptual framework, Chapter 9 addresses the circle of "Partnerships for eco-innovation". Once the environmental technologies have been developed, they can only survive if users adopt them, for that reason they need to have a competitive business model that can compete with other existing technologies. In the authors' third article "Innovation in product and services in the shipping retrofit industry: A case study of ballast water treatment systems" the focus is in the later stages of the innovation process: diffusion (Chapter 10). In relation to the conceptual framework, this case study sheds light on business models involved in the installation and maintenance of ballast water treatment systems. The article brings answers to the question of how some maritime service suppliers can find their niches in the installation and maintenance (diffusion) levels without necessarily participating in the invention and/or development processes of these products and services.

The third sub-question zooms into the processes taking place in projects which allow for the participation of several organizations in the development of maritime environmental technology. The purpose of the article in chapter 11 is twofold: First, to understand the activities and innovation pathways related to the demonstration projects for cleaner technologies in the maritime industry. Second, from the perspective of intermediary organizations, to understand how to better initiate, coordinate and support networks of suppliers in developing cleaner technologies.

The fourth question seeks to explore how the firms of a given geographical area can benefit in the best possible way from the provision of environmental technology to the maritime industry. This question is based on insights from chapters 9, 10, 11 and is dealt in Part V, Discussion.

8

DRIVERS FOR ECO-INNOVATION IN THE SHIPPING INDUSTRY: A CASE STUDY OF THE NORTH EUROPEAN EMISSIONS CONTROL AREA

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ABSTRACT

The development and adoption of eco-innovations are often explained by the influence of four drivers: technological push, market pull, regulatory push and pull, and internal business aspects. The relations between these drivers are not clearly explained by mainstream eco-innovation models; furthermore, these drivers interact differently in various industries at different times. In order to get a detailed understanding of how these drivers relate and interact in a specific context, a case study is presented. This study focuses on how different drivers influence eco-innovation, in the short sea shipping industry within the North Sea, Baltic Sea and the English Channel. In these areas, short sea shipping is subject to strict requirements on sulphur emissions by the European Union and the International Maritime Organization. The study found that a globalised industrial sector, such as shipping tends to oppose regional regulations. These regulations benefit from market conditions which slightly push the shipping companies to embrace environmental technologies when operational costs increases due to expenses such as increasing fuel prices. Meanwhile, voluntary initiatives like participating in eco-labelling schemes can motivate eco-innovations, especially, when shipowners become aware of the interest of customers in these schemes. In the maritime industry, environmental awareness has made its way to the top of the agenda. This is due to more proactive environmental policies by some shipping firms and their customers' increasing interests in the environmental footprint of transport. Based on these results, a conceptual model is proposed for the dynamic interactions between regulation, technology, business and markets, which modify the dominant focus on market pull and technological push.

Keywords

Sulphur; shipping industry; eco-innovation; environmental technologies; environmental regulation; MARPOL

8.1 INTRODUCTION

The drivers of eco-innovations have become important within the literature of ecological modernization. Earlier contributions proposed a general framework for understanding drivers as a mix of regulatory push and pull, technological push, market pull and internal business aspects (Rennings 2000; Rubik 2005). These drivers are often seen as independent and conflicting, thus the relations and interactions between them lack investigation. More recent publications seek an industry-specific understanding of drivers for the adoption of environmental technologies (Horbach, Rammer, and Rennings 2012; Kesidou and Demirel 2012).

Following the interest for an industry and context-specific understanding of the drivers of eco-innovations, air pollution from the shipping industry has been investigated in a case study. Air pollution from ships has in recent years become an important issue. In 1997 the International Maritime Organization (IMO) incorporated air pollution prevention as a further area of environmental protection by adding Annex VI to the International Convention for the Prevention of Pollutions from Ships (MARPOL) – which has been in place since 1978 (Dalsøren et al. 2009; Mensah 2007; Winebrake et al. 2009). At the request of bordering countries to put limits to SO_x emissions, the IMO created Sulphur Emission Control Areas (SECAs) in the English Channel, North Sea, the Baltic and the North American coast (IMO 2013) The European Commission issued in 1999 was one of the a directive to enforce this regulation, and it was subsequently amended in 2005 and 2012. According to the IMO and the EU regulations, compliance with SECA can be achieved by: switching to low sulphur fuel, using exhaust cleaning technology, or using LNG – liquefied natural gas (Balland et al. 2013).

The SECAs in European waters are the first in the world to be enforced, and therefore no experience is available on how the regulation interacts with other drivers for the innovation of maritime environmental technologies thus far. In this article, the authors seek to contribute to the understanding of the dynamics and interactions between the different drivers as an important mechanism for innovation and the adoption of environmental technologies. The main research question is:

How do different drivers influence the innovation of environmental technologies in the shipping industry?

Environmental issues are playing a more important role and find themselves as top items on the in the maritime industry's agenda as shipping firms develop more proactive environmental policies, and customers have begun to ask questions around the environmental footprint of transport. Investigating these dynamic changes, inspired the proposition of a conceptual model to understand the relationship between regulation, technology, business and markets, which in turn challenges the dominant focus on market pull and technology push theories of innovation that underestimate the influence of both environmental regulations as well as business policies and own initiatives.

This case study focuses on short sea shipping within the North European SECAs (North Sea, Baltic Sea and the English Channel). The empirical data was collected through document reviews, observations and in-depth interviews with the actors involved in policy making at the European level, representatives of shipowners associations, national authorities, NGOs and marine equipment manufacturers. The structure of the article is as follows: in the section "Drivers of eco-innovation" a conceptual framework is developed based on a literature review. The "Research design and methods" section explains how and why the case of sulphur limits in shipping is important for understanding the role of environmental regulation and the contextual frame. The study is part of an action research project and linked to personal and institutional practice in the adoption of environmental technologies in the shipping industry. The "Findings" section describes the dynamics and interactions between the different drivers as a mechanism for development and adoption of environmental technologies in the shipping industry. The last two sections discuss the theoretical relevance of the results and presents conclusions.

8.2 DRIVERS OF ECO-INNOVATION

A conceptual framework for analysing the drivers of development and the adoption of eco-innovations in the shipping industry needs to identify the extent in which a hybrid type of innovation such as eco-innovation is more complex to develop and adopt than a conventional one. Therefore, a typology of eco-innovations is developed before the specific drivers of environmental technology are characterized.

8.2.1 ECO-INNOVATION

Eco-innovation is a core concept in ecological modernization (Jänicke and Jacob 2005). Carrillo-Hermosilla et al. (2010) analysed different definitions of eco-innovation, while acknowledging it as an umbrella term to cover such topics as environmental innovation, cleaner technologies and others. Among all these definitions, eco-innovation is commonly associated with:

> All measures of relevant actors (firms, politicians, unions, associations, churches, private households) which; develop new ideas, behaviour, products and processes, apply or introduce them and which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets (Rennings 2000).

8.2.1.1 Environmental technologies definition and typologies

Cleaner technology and pollution prevention have been defined rather broad. In Denmark it is seen as "a continuous development process, with the prime purpose of minimizing pollution associated with the production processes and products rather than just treating the pollutants" (Georg, Røpke, and Jørgensen 1992, 548). In other words, resource use, emissions and waste should be reduced at the source inside the production and when designing new products. An important distinction between end-of-pipe solutions such as wastewater treatment plants and “clean tech”, is that clean technology is seen as a preventive process-integrated approach with focus on reduce and reuse.

Rennings (2000) differentiates between curative (e.g. soil decontamination) and preventive environmental protection. Preventive environmental protection involves process-integrated and end-of-pipe technology. Process-integrated technology is defined by Ekins (2010) as “a general term of changes in processes and production methods (i.e. making things differently) that leads to less pollution, resource and/or energy use”. Examples of process-oriented technologies are the recirculation of materials, the use of less hazardous materials, and the modification of design of equipment -process-integrated systems (Frondel, Horbach, and Rennings 2007). Process-integrated also comprises organizational innovations as Environmental Management Systems or inter-organizational initiatives as industrial symbiosis.

End of pipe is defined as “isolating or neutralizing polluting substances after they have been formed” (Ekins 2010). Examples are incineration plants for waste disposal, sound absorbers, exhaust gas cleaning systems, etc. (Frondel, Horbach, and Rennings 2007). End of pipe technology’s adoption is pushed by environmental regulations because they usually bring only environmental benefits and not economic benefits to the adopting firm (Markusson 2011).

8.2.2 ECO-INNOVATION DRIVERS IN SHIPPING

Early research contributions on eco-innovation drivers had a focus on the factors of diffusion of cleaner technologies in the industry (Kemp et al. 1992). Later, this initial focus expanded from cleaner technologies to eco-innovations, i.e. Rennings (2000) and Rubik (2005). The following conceptual framework focuses on environmental technologies (cleaner technologies and end-of-pipe) as a subset of eco-innovations in order to compare the sector specific evidence of marine environmental technology adoption in the shipping industry. The model acknowledges that endogenous and exogenous drivers influence the adoption of environmental technology.

Rennings (2000) propose that conventional innovations are driven by market demand and technological developments. These two factors are also valid for eco-innovations. In addition, regulations are a third driver for eco-innovations (Rennings 2000). Environmental policy and regulations can have an influence on how firms develop and adopt eco-innovations (Ashford and Hall 2011). Business internal aspects were later incorporated into the model. The reason is that some organizations are more receptive to develop and adopt eco-innovations depending on their internal dynamics (Rubik 2005). These different drivers are usually sketched as influencing a company's decision on whether to adopt environmental technology. Figure 15 illustrates a possible interaction of these different aspects that drive eco-innovation in the shipping industry through Rennings (2000) and Rubik's (2005) original model. The model integrates some of the representative examples of drivers within each category.

Regulations are standards for technologies, environmental performance or outcomes. Ashford and Hall (2011) make a distinction between "weak" and "strong" environmental regulation. A weak environmental regulation is that with comparable low standards. The technological response is the diffusion of end-of-pipe technology, process change, product reformulation. In contrast, a "strong" environmental regulation, will release the eco-innovation potential of affected firms. New entrants can enter into the market and propose new products, product-services or processes. International standards could eventually provide a similar effect as strong environmental regulation (Ekins 2010). However, international regulations are not without challenges. The shipping industry, for example, is a globalized industry, with assets (vessels) registered in different countries and moving in different regulatory regimes (international, national or local). There are practical challenges to enforcing IMO international environmental conventions: first, individual countries must establish national programs to enforce and monitor compliance with those conventions. Second, not all IMO member states communicate properly or establish effective mechanisms to do so (Comtois and Slack 2007a).

The premise of market pull is that demand creates incentives to develop eco-innovations (Kemp et al. 1992). Recent contributions identify evidence on how consumers or business-to-business consumers motivate firms to adopt eco-innovations (Horbach, Rammer, and Rennings 2012). Examples are green public procurement programs that set environmental standards for their suppliers. Figure 1, illustrates that voluntary initiatives are part of market drivers in internationalized industries. The cement industry started the Cement Sustainability Initiative (CSI) departing from the fact that regulatory frameworks are highly diverse at a national level. CSI seeks to reduce greenhouse gas emissions by promoting cleaner technologies among participating members (Busch, Klee, and Hoffmann 2008). Fuel prices are an industry specific market pull factor in the shipping industry, because fuel prices have consequences on the operation costs and the profit margins for the companies (Yao, Ng, and Lee 2012).

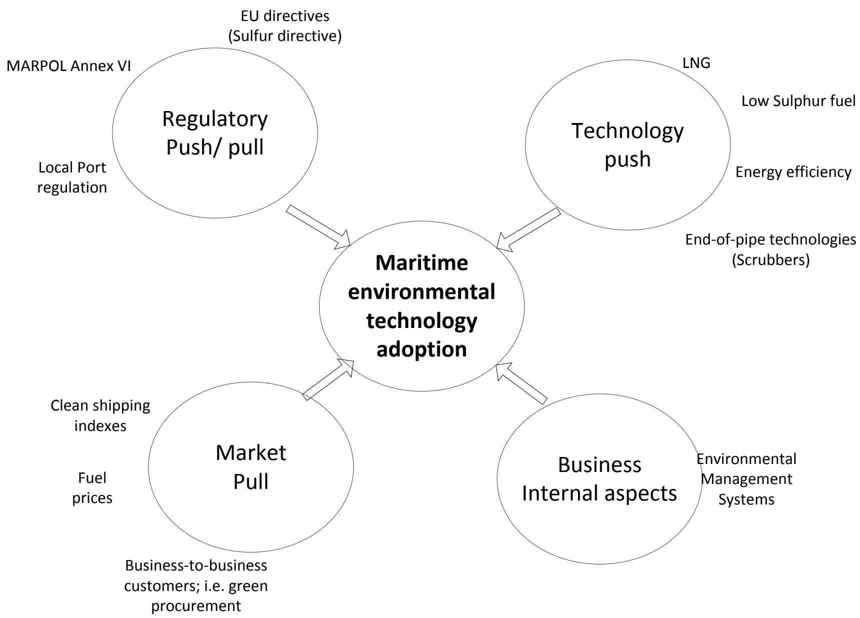

Figure 15 Eco-innovation drivers for the shipping industry: an adaptation of the classical eco-innovation drivers model. *Source*: Adapted from Rennings (2000) and Rubik (2005)

Kemp et al. (1992) claims that technological push is interlinked to market pull and both factors are complementary. Technological push refers to the supply side embedded knowledge in the form of machines, human capital and organizations. An important issue is that this knowledge differs among firms due to the capacity to invest on R&D and the company's own trajectories (Kemp et al. 1992). Marine equipment manufacturers increasingly have begun to develop engines using alternative fuels – e.g. biofuels, liquefied natural gas. These fuels will release less pollutant emissions than their heavy fuel oil counterparts (Bengtsson, Andersson, and Fridell 2011). Despite this, new technologies face selection pressures from the existing technological regime. Any marine equipment needs approval from classification societies to certify that it complies with the IMO safety-standards.

Business internal aspects are a driver for knowledge generation and for building up eco-innovative capacity (Horbach et al. 2012). The internal aspects represent how a firm is prepared to spot and integrate external knowledge and turn it into eco-innovations. Hansen and Klewitz (2012b) name this an absorptive capacity, which can be increased by some internal factors. An example is organizational innovations in the form of actor-oriented strategies. These strategies improve the inter-organizational collaboration in order to create synergies with other companies (Fjeldstad et al. 2012). Another example are Environmental Management Systems (EMS) which can overcome the lack of information linked to the introduction of cleaner technologies, because EMS include information on savings generated by these alternative technologies (Horbach, Rammer, and Rennings 2012).

8.3 RESEARCH DESIGN AND METHODS

In this section, the case study selection and delimitation as well as the qualitative methods for data collection and analysis are discussed. The case study examines the main research question: *How do different drivers influence the innovation of environmental technology in the shipping industry?* The case study analyses how the implementation of the sulphur directive (Directive 1999/32/EC) and its amendment (Directive 2012/33/EU) drives the interest for this type of technology in the short sea- shipping industry. This main research question is ordered around the following three sub-questions, which at the same time organizes the case study:

- How is sulphur content in marine fuels being regulated within the Emission Control Areas and how it influences eco-innovation in short-sea shipping?
- How does air pollution regulation influence eco-innovation through interaction with other drivers?
- What could the future directions of the combination of regulation and other drivers for eco-innovation in the shipping industry be?

The first two questions will be developed within the case study, the third question will be analysed as part of the section "conclusions and suggested research".

8.3.1 CASE SELECTION

The authors followed a qualitative single case study design (Yin 2014). The case study selection was primarily instrumental as it was guided by a research question which purpose was to provide insights on theory and redraw generalization (Stake 2005). To select the case study, the authors followed a criteria-based selection following two steps (Marshall and Rossman 2006):

- Defining the shipping industry as the industrial sector. The shipping industry comprises seaborne transportation, including: container, dry and liquid bulk, passenger (cruise and ferry) and gas (Antoine Fremont 2009).
- Within the whole shipping industry, we focused on short-sea shipping within the North European SECAs (North Sea, the Baltic Sea and the English Channel). As explained in the Introduction, this SECA is in place as a result of two European directives (which adapted MARPOL Annex VI): Directives 1999/32/EC and 2012/33/EU. The SECA in the Baltic Sea entered into force

on the 19 May 2006, whereas the North Sea and the English Channel SECAs entered into force on 22 November 2007 (T. Notteboom 2011).

Paradigmatic cases seek 'to develop a metaphor or establish a school for the domain that the case concerns' (Flyvbjerg 2006). We considered the situation of short-sea shipping in SECAs on North European waters as a paradigmatic case because is the first time that a regulation on air pollution is enforced in a regional area and not i.e. a single port or city. From this perspective, the authors considered that the case study could provide important elements for generalization in new SECAs as the North American or in possible future European SECAs (i.e. The Mediterranean).

8.3.2 DATA COLLECTION AND ANALYSIS

The authors relied on three qualitative methods to collect data for this case study: document review, interviews and observation. The document and literature review was primarily undertaken through the websites of relevant, global and European shipping stakeholders. The documents reviewed included regulations, public statements, commissioned studies and position papers[10]. A discourse analysis of this material helped identify the positions of actors vis-à-vis the regulation and the environmental technology. This first analysis was crucial in identifying which key informants were important for in-depth interviews.

Semi-structured interviews with key informants were the primary data collection method. The selection of interviewees began with their identification after the document review. However, a fair representation of different types of stakeholders involved in the amendments of the Directive 1999/32/EC was also important. A total of 14 interviews were carried between 6 April 2011 and 16 October 2012 (Table 11 in Appendix A). The interviews lasted between 30 and 60 minutes. The questions and the interview structure were different for each interviewee; however an average of 10 questions were included in each (Bernard and Ryan 2009). The purpose of having semi-structured interviews was to allow certain flexibility to the interviewee, in this way he/she could unfold information otherwise difficult to obtain with structured interview guides.

[10] Documental sources included documentation produced since 1998. The sources included European Commission's Commissioned studies, directives, green papers; IMO's conventions and Environmental committee internal communications; classification societies' safety regulation databases, commercial documentation; European and Danish branch organizations (position paper, commissioned studies); EU supported projects focusing on maritime environmental technology (INTERREG and Framework VI and VII).

Direct observation allowed the authors to get acquainted with the discourses surrounding the implementation of SO_x limits in the SECA. The main researcher is employed in the Maritime Centre for Operations and Development (MARCOD, Frederikshavn, Denmark). The Centre is in close interaction with European, Scandinavian and Danish shipping stakeholders on a regular basis. This interaction allowed the authors to take part in different activities, such as meetings, seminars, conferences and networking (Table 12 in Appendix A). After each event, the researchers created narrative memos including the most important issues at stake. These narrative memos were processed as explained below.

The authors analysed the data through an analytical induction process (Patton 2002). Analytic induction starts when the researchers create theoretical propositions, which are subsequently verified with the qualitative data (Taylor and Bogdan 1984 in Patton 2002, 3:454). The way the analytical induction was first applied was by creating theoretical inspired codes (Saldaña 2009), based in the literature review on environmental technologies and drivers for eco-innovation. Along this deductive part, the authors looked for patterns arising from the data, which generated new codes. All codes were grouped into categories and then into issues, which at the same time arose from the sub-questions. The themes, categories and codes are listed in Table 13 (Appendix B). The coding of the interview transcripts, and observation memos was carried with the support of a Computer-Assisted Qualitative Data Analysis software (Fielding 2008).

8.4 FINDINGS

As described in the "Drivers of eco-innovation" section, regulation co-exists with drivers such as technology, markets and business. To illustrate how these interacting drivers function, the main findings are presented from three different perspectives. In the first perspective, the authors analyse the EU sulphur directive's influence on the adoption of environmental technology, with a focus on the characteristics of the regulation. In the second perspective, the analysis shows how the regulation interacts with the other drivers, especially technological developments for reducing sulphur emissions and other pollutants. Finally, the third perspective analyses how the organization of business is a driver for adopting environmental technology in combination with the other drivers.

8.4.1 REGULATORY DRIVERS FOR ECO-INNOVATION IN SHIPPING

Sulphur is at the top of the present and future concerns of European shipping stakeholders – particularly due to the possibility of increased operational costs. Two main characteristics are important for understanding the dynamics and effects of air pollution regulation for the European short-sea shipping industry. The first is the tensions between the global orientation of the shipping industry (e.g. Global operations) and national and regional orientation of environmental regulation. The second is the tensions between the regulatory (environmental) demand and the business (economic) conditions in the shipping industry compared to other regulations.

8.4.1.1 Institutional side: the challenge of regional/ national regulations in a global sector

Air pollutants from ship fuels are generally regulated by international agreements with some exceptions of local ports and sub-national level regulations like in California. The current location of SECAs resulted from proposals by bordering countries in Northern Europe and in North America. For this reason, the North Sea, the Baltic and the English Channel were the first designated SECAs, followed by the North American SECA in August 2012. Seas with intense maritime traffic have not been approved as SECAs, as no agreed upon request by bordering countries have been submitted to IMO, examples of these areas include the Persian Gulf and the Mediterranean Sea. The first challenge is reaching on an agreed protocol that is fair for all 170 Member States. In particular, because the interests of flagship states contrast with those of countries lobbying for more SECAs, as well as for the spread of environmentally sound technology. In the end, this explains why SECAs can only be found in few places worldwide.

The European Commission has an observer status at the IMO. Therefore, it cannot propose the designation of new SECAs. However, the Commission sets directives to push EU Member States to enforce the IMO protocols. To accomplish this task, the European Commission prepared one directive in 1999, which was subsequently amended in 2005 (Directive 2005/33/EC) and in 2012 (Directive 2012/33/EU). The enactment of these directives allows the EU Commission to monitor the compliance of Member States. With the support of the European Maritime Safety Agency (EMSA), the Commission collects compliance reports from Member States. In this way the Commission can address situations where a Member State is not enforcing the regulations.

The EU directives are transposed into national legislation by the Member States. Port State Authorities within each country are responsible for checking compliance. Port State Authorities survey the characteristics of the fuel used by vessels calling into a port. The authorities keep registries of these characteristics and report them to the European level. The main challenge of enforcement is checking if every vessel that calls into a port is using an appropriate fuel (Interview 10).

8.4.1.2 Regulating sulphur emissions: current developments in North European waters

The North European SECAs were regulated by EU directives 1999/33/EC and 2005/33/EC. However, in 2006, the IMO revised Annex VI and the EU directives needed an update to harmonise the implementation and control of MARPOL Annex VI across the EU as well as in non-SECA ports (Interview 10). The new amended directive (2012/33/EU) also integrates alternative methods of compliance such as scrubbers and alternative fuels (e.g. LNG or methanol). Before the EU Parliament approved the Directive 2012/33/EU, the European shipowners associations were highly concerned for the directive's impact on the short sea shipping sector. The first concern was the proposal (now included in the directive) to use fuel containing 0,1% of sulphur while the ships are at berth in any EU port. The second concern was that passenger ships did not have any exceptions for complying with the stricter limits of SECAs (e.g. The use of fuel with a sulphur content of 1,5% out of the SECAs). The interviewed shipowners representative justified their position because they considered that "the EU shall avoid regional regulations because that may entail loss of competitiveness for the European shipping industry" (Interview 8).

The major implication of the sulphur directive is the rising operating costs for ship-owners. This is linked to the need to use the more expensive low sulphur fuel or to invest in environmental technology as alternative means of compliance within SECAs. The creation of new SECAs raises contrasting positions not only among various European shipping stakeholders, but also between the European shipowners associations. The European Commission concludes that from a cost-benefit analysis new SECA in the Mediterranean Sea will bring gains in health costs (Bosch et al. 2009). On-going confidential negotiations seek the possibility of a SECA in all European waters around the EU. Different characteristics were discussed such as having combinations of 12 nautical miles from the coast, or exclusive economic zones of 200 nautical miles (Interview 10). However, other interviewees claimed that the designation of additional SECAs should go through the IMO and not only be an EU decision.

8.4.2 HOW AIR POLLUTION REGULATION INFLUENCE ECO-INNOVATION THROUGH INTERACTION WITH OTHER DRIVERS

After presenting the characteristics of the sulphur regulation in the previous section, the authors explain how the current and future air pollution regulations influence eco-innovation in the European shipping industry by interacting with other drivers. The findings show how marine eco-innovation is connected to the development of market dynamics such as increasing fuel prices. The findings also show the importance of linking the ways in which regulation interacts with the continuous changes in markets and business.

8.4.2.1 Fuel price as a market driver

The sulphur regulation opens up different technological means of compliance. There are however great differences in the shipping industry depending on the type of technology used for compliance and the type of route used (short-sea or trans-continental shipping). The first technological alternative is to use distillate fuels instead of heavy fuel oil. Distillates can be marine gas oil (MGO), marine diesel oil (MDO), or intermediate fuel oils (IFO). European shipowners consider associated fuel costs as the main threat to the competitiveness of short sea shipping in SECAs. The European Shipowners Association (ECSA) commissioned an economic impact assessment of the low sulphur content fuel requirements on the short ship routes within the existing SECAs. The study concluded that the use of distillate fuel (e.g. MGO) may increase the freight rates in certain short sea shipping routes in the SE-CA. In case of higher fuel prices, short-sea shipping routes will be obligated to increase their fees, hence cargo owners will likely move their cargo by truck (Notteboom 2011).

Concerns on distillate fuel cost seem to be less important for transcontinental shipping routes. A common argument that explains this difference is the possibility to use a dual fuel system that uses heavy fuel oil (HFO) and distillate whenever a vessel enters into the SECAs. Fuel price concerns could be an important driver that explains the resource efficiency strategies undertaken by some of the largest shipping liners. An example is the Danish company AP Møller Maersk, which recently commanded 10 triple E class container vessels with a capacity of 18000 TEU[11]. Maersk claims the vessels can consume 35% less fuel per container as existing 13000 TEU vessels.

8.4.2.2 Interactions between regulation and technology push

The sulphur regulation allows for different forms of alternative (environmental), technological solutions in order to comply with the demands of low sulphur content in fuel. One of the environmental solutions is the use of scrubbers. Resolution MEPC.130 (53) sets the guidelines for scrubbers' approval, survey and certification and operation characteristics – including sulphur content in the exhaust gas (IMO 2006).

The development of scrubber technology is connected to eight manufacturers offering scrubbers to shipping companies. These scrubber manufacturers joined the Exhaust Gas Cleaning Systems Association (EGCSA). Only a few systems have been installed and tested up till now. Aalborg Industries/Alfa Laval is one of these manufacturers, with the system PureSOx ® under test. PureSOx ® is an open system that operates with seawater; the by-product (sludge) can be collected in tanks or released into the open sea. With an uptake of 2,2% HFO, PureSOx ® can reduce the

[11] TEU: Twenty-foot Equivalent Unit, a standard measure of containers in shipping

concentration of sulphur in the exhaust gas to 10 ppm SO_2 (equals to 0,06 % fuel sulphur) (Knudsen 2011).

EGCSA has succeeded in promoting the scrubber technology during the amendments to Directive 1999/32/EC at the European Parliament. The Commission's position is that scrubbers should be available along the distillate fuels to comply with the SECA requirements. Costs related to scrubber investments seem to be a major barrier for more installations before the 2015 stricter SECA limits. Financial support by EU Member States is a key issue in fostering the installation of scrubbers in the SECAs. Such Member State support must, however, be regulated and timed to avoid competition distortions among EU Member States (Interview 12).

The European Community Shipyards Association considers that around 13000 vessels will need to be retrofitted with scrubbers to meet the SECA requirements (Interview 5). The association also identifies capacity problems to fulfil the demand of retrofitting vessels with scrubber systems by 2015. The demand of scrubbers is not as high as expected despite the optimism by regulators, manufacturers and shipyards (Interview 8, 9). Shipowners' public communications and interviews highlighted the technical reasons that explain the situation. The first challenge comes from the testing the status of different scrubbers. Shipowners have partnerships with manufacturers (as in the aforementioned Alfa Laval example) and they are learning about the scrubber systems. This learning implies operational costs, possible degradation rates on a daily basis, tests in main engines, etc. Furthermore, this learning will provide closer figures on costs, which is a key decision factor for long term investments. A second challenge comes with the lack of reception facilities. This is a responsibility of ports and Member States, yet, it has been pinpointed as a major challenge for the use of scrubbers in the near future. A third major challenge is the long time frame between company level decisions and the actual certification and installation of the scrubber system. Due to the test status of many scrubber systems, shipowners refrained from investing before 2015.

In addition to scrubbers, the EU also considers alternative fuels as LNG as a compliant technology. The European Commission endorses the LNG technology in the Sustainable Waterborne Transport Toolbox (European Commission, 2011). The Trans-European Transport Network (TEN-T) Policy financially supports a project to build LNG bunkering infrastructure in the Baltic Sea SECA. The project is currently steered by the Danish Maritime Authority on a consultation basis. According to the project's baseline, LNG as a fuel is a financially viable alternative that competes with scrubbers and distillate fuels (Gullberg and Gahnström 2011).

The TEN-T project addresses the hitherto main concern with the scaling-up of LNG. The lack of bunkering infrastructure has been pointed as the main barrier in the scaling-up of this technology. Currently, LNG bunkering infrastructure only exists along the Norwegian coast. For this reason, the TEN-T project addresses this infrastructure problem. Additionally, expert interviewees have raised the point that rules for bunkering at smaller scale (what the LNG as bunker requires) are not there and need to be created and harmonised for the SECA.

In conclusion, sulphur regulation is open for different types of environmental technologies, and the development and adoption of the different types are dependent on the interaction between different drivers. The market (represented by fluctuating demand and fuel prices) is seen as a very important factor, which influences how the industry responds to the regulation and what kind of technological solutions are seen as valuable.

8.4.3 MARKET DYNAMICS AND ITS INTERRELATION WITH REGULATION AND ECO-INNOVATION IN THE SHIPPING INDUSTRY

This section focuses on how market drivers are linked to regulations. Environmental technology is seen as an investment from a market perspective, where the effects on cost or product value are important as a means to reducing risks and to complying with the upcoming changes in markets and regulations. These findings complement the results by Lai et al. (2010) and Wuisan et al. (2012) in relation to the influence of business internal drivers that promote cleaner shipping. The first section addresses common barriers to the adoption of environmental technology. The second explains the increasing importance of voluntary initiatives.

8.4.3.1 Market drivers and adoption barriers for environmental technology

The change in market conditions has been an important driver for stakeholders' increasing interest in marine environmental technology. However, stakeholders estimate in different ways the value potential of environmental technology and compliance. Some stakeholders consider environmental regulation and environmental technology as an extra cost; others consider it as a potential for creating value for their customers – a view which is closely linked to the different actors' position in the value chain. As presented in the previous sections, for authorities, marine environmental technology serves to comply with regulations. However, marine equipment manufacturers and shipowners have broader understandings of marine environmental technology. The European Marine Equipment Council (EMEC) includes in this category (EMEC 2010):

- Efficient and high-tech products.
- Existing technology to help mitigate the environmental impacts of ships.
- Technology responding to future regulation for the 'greening' of shipping.

A set of environmental technology for possible installation on board is presented in a catalogue. The purpose is to reach potential customers (ship owners) and authorities in order to make them aware of different alternatives for compliance with regulations.

The way shipowners define marine environmental technology has influenced the investments used for upgrading fleets as well as the kind of competitiveness sought after. A leading European shipowner representative was interviewed about her organization's definition of environmental technology. In her opinion, environmental technological upgrades, are a way to be ahead of possible regulations for certain environmental aspects:

> For all business an important aspect is future risks and costs. Likely, more regulations will appear. We consider that more regulations are soon to appear in such areas as greenhouse gases and transfer of invasive species. All these regulations come with costs, and therefore we are assessing future risks [associated with these regulations]. It is our strategy to look at very early stages and try to tackle from there on. Further, this implies abatement of future risks and future costs to be ahead of the game (Interview 11).

Despite positive valuations as the previous, many shipowners are not considering marine environmental technology as a potential for value creation. This lack of value potential is linked to the way business activities are usually organized in the shipping industry. During the interviews, different stakeholders pinpointed the 'conservative' character of the shipping industry. Partly contributing to this conservative character is the segmentation of business where in many cases the company buying the ship is not necessarily the same operating it. The ship buyer looks at the capital expenditure whilst the operator looks at operation expenditure. The company focused on capital expenditure commands new vessels in Asia, where they can find best prices for new builds. The technology of these vessels is not particularly innovative (usually 30 years old). Hence, retrofits or the supply of environmental technology need to be accessed elsewhere. The ship buyer will not install environmental technology without a clear incentive (Interview 9). This seems to be the case of an interviewed leading a short and transcontinental shipping liner. When chartering, the firm sets different requirements according to the route. In the case of long distances, the shipping firm requests the 'usual environmental requirements': compliance with IMO rules and port state authority regulations. In the case of short-sea chartering within the European SECA, the shipping firm sets no specific requirements besides low fuel consumption – except when the chartering is extended over time (Interview 13)

8.4.3.2 Business drivers and adoption of environmental technology through voluntary initiatives and partnerships

As described above, the ship owning and leasing characteristics of the industry could be a major barrier for eco-innovation. It can also be seen as an important potential for influencing the development and adoption of environmental technology. An example of a port-driven initiative is the Clean Shipping Project – CSP; initially funded by the Swedish region Västra Götland. CSP launched a web-based interactive index and database. Current members are large cargo owners, who can fill in 20 questions specific for different types of ships. These questions address issues such as SO_x/NO_x emissions, wastewater, bilge water, anti-fouling. A third party called the Classification Society verifies the information and the owner then registers at least 20% of their fleet. The database is then shared with carrier or trading companies. The information serves as a decision-making tool to choose the vessel with the lowest environmental impacts. The tool can also serve the shipping authorities in rewarding the best performing vessels. Forwarders and classification societies also benefit from the collected information (Interview 1).

CSP illustrates that some shipping companies invest in SO_x abatement equipment – among others- as part of their self-regulation interest. Rederi AB Transatlantic is a Swedish shipowner with SO_x compliant vessels. The company owns 30 vessels and the fleet's environmental performance information were filled in the CSP database. From a market point of view, Transatlantic AB expects to 'be a part of the increasing of green shipping, it is a win-win situation for all members and they can reach new customers globally' (Jensen Rusth 2011). The case of Transatlantic illustrates how command-and-control regulations, voluntary instruments and information release may serve similar purposes. From a shipowner's perspective, CSP is an instrument that improves the company's image and in turn attracts customers (carriers and trading companies). AB Lindex is a Swedish fashion retail company with stores in Sweden and online shopping. Their clothes are manufactured in Asia and transported to Europe. As part of their Corporate Social Responsibility, Lindex committed to reducing their environmental footprint associated with transportation. CSP helped Lindex to find a carrier with the best environmental performing vessels (Albinson 2011).

Tools like CSP may also bring in benefits to the shipowners taking part in them. Gothenburg Port proposes differentiating harbour fees based on a vessel's NO_x, SO_x and anti-fouling rating. An in-kind incentive of reduced port fees is given to the first 20 registered vessels. An interviewed expert considered differentiating fees as a relevant aspect of voluntary instrumentation (Interview 9):

> We know that Gothenburg uses the clean shipping index, Rotterdam does the same. If leading ports are rewarding cleaner ships and therefore indirectly penalising more pollutant ships, you are going to see a huge effect. And there

> is also talk in some ports to give preferential time slots to clean ships. Now I think this will convince every owner in the end. If you (…) have to wait for the crane, because you are polluting, you are going to try to do something about it, because time is money. So you can trigger the system a bit, through intelligent measures. Of course, it is our job at EU to make sure that if [Port A] does something progressive, then [Port B], which is just [some hundred kilometres distance], is not undermining it and then opening up to polluting ships at preferential fees in order to get the business. That has to be seen, but, of course, there is not a distraction in the market. But I think at the end common sense will prevail. You always have some rogue elements, ships that rarely trade with you or can only come occasionally.

The positive experience from CSP has motivated interest in replicating voluntary initiatives of this type. The Danish EcoCouncil also proposes a voluntary labelling scheme to be used in Danish harbours (Press-Kristensen and Ege 2011). However, despite the positive environmental effects of CSI and other voluntary initiatives, shipowners associations are cautious about having different kinds of indexes in each port. A Scandinavian National Association's fleet will have some advantages if they participate in this label scheme: for example, having innovative technology on board. Yet this association, pinpoints challenges when using label schemes: particularly, the risk that several evaluation indexes co-exist in different ports (Interview 4).

8.5 DISCUSSION

The authors analysed how different drivers influence the innovation of marine environmental technology. With this purpose, the authors carried a case study with a focus on the short sea shipping industry within the North European SECAs. The case study focused around two main issues:

- Is regulating sulphur content in marine fuels within the Emission Control Areas having an influence on eco-innovation?
- Does air pollution regulation influence eco-innovation through interaction with other drivers?

The case study used Rennings (2000) and Rubik's (2005) model as the theoretical point of departure. This section discusses the case study by summarizing the main findings and upgrading the conceptual framework. The revised model stresses the interaction and complementarity among the different drivers. The new proposed model was adapted to the short sea shipping and possible variations or adaptations that could take place in other industries and sectors (Figure 16).

Although not as important as regulations, market pull is expected to increasingly motivate the adoption of marine environmental technology as result of the voluntary initiatives of carriers – e.g. participation in clean shipping indexes.

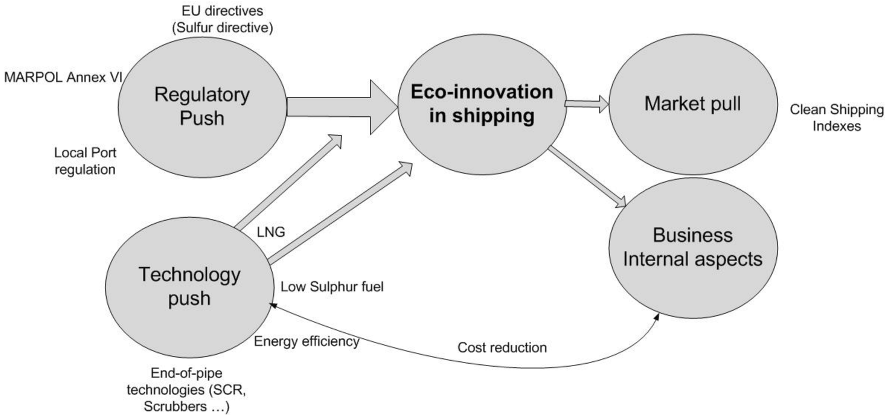

Figure 16 Drivers of environmental technology adoption in the maritime industry- a revised framework.

8.5.1 THE DYNAMICS OF AIR POLLUTION REGULATIONS FOR THE EUROPEAN SHIPPING INDUSTRY

The first major finding was that air pollution from ships is regulated globally through IMO, continentally through EU regulations and locally through port and state standards. In EU waters, one regulation is the subject of concern by shipowners: the limits to the sulphur content in marine fuels. As the case presented, different technological alternatives are available and encouraged in the EU to comply with the sulphur standards (low sulphur fuel, LNG, or scrubbers). This first finding suggests that the sulphur directive and MARPOL Annex VI may stimulate the diffusion of end-of-pipe technology while process change technology needs more time to be implemented. One of the discussed process-change technology is the use of "cleaner" fuels as LNG and low sulphur fuels as MGO. In the case of LNG, the major barriers are a lack of bunkering infrastructure and the increase in space needed on board of the ship to install the LNG tanks (Bengtsson, Andersson, and Fridell 2011). In the case of MGO or similar low sulphur fuels, the major constraints are the high bunker costs predicted for the next years (Notteboom and Vernimmen 2009).

At a first glance, this situation appears to conform to what the literature reports on the side of benefits of "strong" environmental standards: the possibility to motivate eco-innovation (Ashford and Hall 2011). However, it is not clear to what extent this "strong" environmental regulation will encourage eco-innovation. Shipowners are concerned with the high costs of cleaner technology associated with low sulphur emissions. Such attitude implies a resistance to innovating technologies, which could bring the emissions to lower levels than those required by the regulation as proposed by Ekins (2010). Meanwhile, other drivers in addition to regulation and technology push could come into play in motivating eco-innovations which could provide additional environmental benefits beyond the legal requirements -and their associated costs. These drivers are analysed next.

8.5.2 THE RELATIONSHIP BETWEEN THE MARKET AND SELF-REGULATION IN SCALING-UP THE ADOPTION OF ENVIRONMENTAL TECHNOLOGY IN THE SHIPPING INDUSTRY

The case study also presented the relationship between market pull and self-regulation as drivers for eco-innovation. One of the findings was that the current market situation of the shipping business provides challenges to environmental technologies. In particular, shipowners will not have enough motivation to install environmental technologies, if this is not required by law. An exception was participating in voluntary programs designed to share information with business-to-business customers on the environmental performance of vessels (i.e. Clean Shipping Index). The expectation with this type of voluntary initiative is that business to business customers create incentives for the installation of environmental technology (Horbach, Rammer, and Rennings 2012). Kesidou and Derimel (2012) claim that voluntary participation in these programs does not necessarily mean investments on environmental technology. In this case we could not assess whether voluntary programs have implied investments or not. The case study unfortunately could not assess an individual firm in terms of their business internal aspects. In the theoretical framework we claimed that knowledge generation is linked to this driver of eco-innovation. We have provided examples of business' activities, which could increase eco-innovation capacity. One of the examples was interorganizational work (Fjeldstad et al. 2012) and the others were EMS (Horbach, Rammer, and Rennings 2012). Voluntary programs as the ones presented in this case, could serve to address one of the challenges of adopting environmental technology: knowledge and information problems (Kemp et al. 1992). Therefore, one proxy to assess internal business aspects is to look into the participation levels in these kinds of programs. The relations between market pull drivers and business internal aspects are sketched in Figure 16. In the meantime, internal business cost reduction also influences the need to look for technologies which can reduce operating costs.

8.6 CONCLUSIONS

The purpose of the case study was to understand, how sulphur content regulations on marine fuels interact with other drivers for the adoption of environmental technologies. First, a literature review was presented based on definitions of eco-innovation and two categories of environmental technology: end-of-pipe and clean tech. At the same time this review provided a conceptual framework about drivers influencing eco-innovation in the shipping industry. The case study then analysed how these drivers interact in the short-sea shipping industry within the North European SECAs.

The first part of the case study was concerned with how a regulation on air pollution could influence eco-innovation. The analysis showed that environmental regulations influenced the development of eco-innovations, mainly motivated by the increasing costs of the use of conventional technologies like low sulphur fuels. One implication of this involves policy-makers for national or European authorities, who promote marine eco-innovation through public-private partnerships or through public subsidies. In order to ensure compliance with the EU directive on sulphur content in fuels, it is not enough as for now to propose a short list of possible compliance technologies. Instead, a target-based regulation will be able to facilitate shipping firms in finding cost-effective solutions based on their own situation. An inspiration could be the current international ballast water convention, in which many different types of technologies are available for shipowners, and many different kinds of technological combinations are possible. Many supplier companies are interested in creating their own innovations and have begun the procedures to get approvals in order to be able to sell them to the market.

The second issue in this case study was centred on the interaction between market pull, internal business aspects and regulation as drivers for eco-innovations. Inspired by the general eco-innovation model, a specific model for the maritime industry is presented. In the context specific model, market pull and business internal aspects are closely overlapping, while business internal aspects relate to the technological push by cost-reduction. In the case study, market pull and internal business aspects were exemplified with voluntary programs. In these kinds of initiatives, market pull interacts with business internal aspects by allowing stakeholders to share knowledge and information about environmental technologies.

Finally, this case study focused on short-sea shipping and in on-going environmental regulations which press the industry to tackle several environmental problems. Other environmental aspects are currently in the process of being regulated and there is a possibility of the creation of stepping stones for possible new eco-innovations. This includes climate change, energy efficiency in ships, black carbon and ballast water, among others. The third question focused on what could be future directions in the combination of regulation with other drivers for eco-innovation in the shipping industry. The case showed that market pull will continue to interact closely whenever shipowners consider environmental regulations as expenses rather than investments. The case also showed that since technological push interacts closely to regulatory push, lobbying by environmental technology suppliers will continue to be strong in order to have certain technologies included in future regulations (e.g. scrubbers in the case of recent amendments to the sulphur directive).

8.7 APPENDIX A INFORMATION SOURCES

Table 11 In-depth interviews

#	Date	Organisation	Type	Duration of the interview (minutes)	Location
1	06-04-11	Clean Shipping index	NGO	40	Gothenburg
2	07-12-2011	Danish Environmental Protection Agency - Environmental technology	Government Agency	43	Copenhagen
3	23-01-2012	Danish Environmental Protection Agency-Eco-innovation project shipping	Government Agency	51	Copenhagen
4	23-01-2012	Danish Shipowners Association	Shipowners' Association	62	Copenhagen
5	30-01-2012	Community of European Shipyards association	Branch Association	20	Telephone
6	10-02-2012	Danish Maritime Authority	Government Agency	27	Copenhagen
7	10-02-2012	Danish Eco-council	Environmental NGO	55	Copenhagen
8	02-03-2012	European Shipowners Association	Shipowners' association	47	Brussels
9	29-02-2012	DG-MARE European Commission	Regulators	51	Brussels

10	29-02-2012	DG-ENVI European Commission	Regulators	45	Brussels
11	01-03-2012	Danish Shipowners Association	National shipowners association	43	Brussels
12	01-03-2012	EU Parliament	Envi-Commission	40	Brussels
13	22-03-2012		Shipping and logistic incumbent firm	23	Telephone
14	16-10-2012		Marine equipment manufacturer	41	Aalborg

Table 12 Observation: sources of data

Event	**Date**	**Role**
Seminar 'Business opportunities by clean shipping index'	February 2011	Participant
Seminar 'Instruments for the environmental impact of shipping', Gothenburg	April 2011	Participant
Stora Marindagen 2011 [*Swedish Maritime Day*], Gothenburg	April 2011	Participant
MARKIS (Maritime Innovation in Kattegat and Skagerrak – Interreg IVB project) Yearly Conference	November / December 2011	Presenter
MARKIS Competence Arena meetings	January, February and March 2012	Presenter
MARCOD director board meeting, Aalborg, Denmark	November 2011, March 2012	Presenter, participant

MARCOD/MARKIS Maritime Conference on Business Opportunities in the wake of the new maritime environmental regulations for shipping, Frederikshavn, Denmark	April 2012	Presenter
Danish Association of Naval Engineers- Environmental aspects and the maritime industry, Copenhagen	October 2012	Participant
Green ferries and composite materials, Middlefart, Denmark	January 2013	Participant

8.8 APPENDIX B. DATA ANALYSIS

Table 13 Emerging categories and themes used to built-up the article

Themes	Categories	Relevant codes
Regulations	Institutions role in shipping air pollution enforcement	IMO, commission_role, port
	Sulphur directive	SOx, expansion_SOx, amendments
	Emerging trends in air pollution regulation	Future regulations, NECA, NOx regulations
Innovation	Contextual influences on innovation	Fuel prices, technical explanations
	Technical solutions to comply	Scrubbers, LNG
Regulation+ innovation+ market dynamics	Voluntary programmes	Market based, technology driven
	Why innovation may be hindered?	Compliance, postponing, challenges cleantech

9
PARTNERSHIPS FOR ENVIRONMENTAL TECHNOLOGY DEVELOPMENT IN THE SHIPPING INDUSTRY: TWO DANISH CASE STUDIES

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ABSTRACT

The shipping industry is confronted with stricter environmental regulations and societal pressure concerning its environmental performance. However, a command and control approach has not succeeded in facilitating the development of cleaner industries. With this goal, key public and private actors increasingly rely on partnerships and in Europe several partnerships have been created for the development of environmental technologies in the shipping industry. While the literature on partnerships with a focus on sustainability has contributed to a better conceptualization of the subject, a gap exists on the interactions of: firstly, institutions and actors in partnerships; and secondly, two or more initially independent partnerships. This paper aims to improve the understanding of how partnerships contribute to developing cleaner technologies in the Danish shipping industry by shedding light on the processes and the outcomes of two separated partnerships (Partnership for Cleaner Shipping and Green Ship of the Future) and the interactions of the two partnerships. In terms of processes, the partnerships are influenced by the participation, scope and division of roles among partners. In relation to outcomes, the first salient issue is that both partnerships have developed organizational forms which proved to overcome the tensions in traditional partnerships, between open and information-based networking on the one side and closed and development-oriented collaboration on the other side.

Keywords

Eco-innovation; partnerships; shipping; air pollution control; scrubbers; end-of-pipe; maritime industry; environmental technology; cleaner technologies; Denmark.

9.1 INTRODUCTION

Over the past 40 years, the nature of environmental concerns and their effect on policy-making have changed significantly (Rayner 2006). In the 1970s, environmental problems were regarded as the unfortunate side effects of economic growth. Governments created environmental protection agencies and ministries that were given responsibility for setting pollution limits and, in some cases, cleaning up after limits were exceeded (Colby 1991). In other words, environmental regulations focused on repairing and setting limits to harmful activity; end-of-pipe technologies, clean up strategies or business-as-usual plus a treatment plant were regarded as appropriate in this respect (Smink 2002). The regulatory approaches to dealing with environmental impacts of the international shipping industry originate from a "classical" paradigm addressing pollution by setting emission limits and suggesting the use of end-of-pipe technologies (e.g., scrubbers) and monitoring equipment.

From the mid-1980s, the dichotomy between economy and environment was challenged by concepts like sustainable development. Sustainable development has come to dominate the environment-development debate. As a key feature of the policy paradigm of sustainable development, the terms of debate have changed from traditional environmentalism, with its primary focus on environmental protection, to the notion of sustainability which requires much more complex processes of trading off social, economic, and environmental priorities (Carter 2001). In other words, a strategy for sustainable development requires new forms of societal efforts; this will not be realistic within the traditional public environmental regulations as known in the 1970s and 1980s (Jänicke and Jörgens 1998). During the 1980s and 1990s in land-based industries, public environmental regulations were increasingly supplemented with self-regulation and market-based regulation. In the shipping industry, however, until the late 1990s, only some major shipping firms were frontrunners in adopting environmental management systems (EMS) or embracing Corporate Social Responsibility strategies. These initiatives were motivated by major shipping accidents; i.e., Exxon Valdez, Prestige, Erika, and to a minor extent by the discourse on sustainable transport promoted by the United Nations (Comtois and Slack 2007a; Pawlik, Gaffron, and Drewes 2012).

The increasing number of international regulations on shipping has forced shipping companies to look for technological and organizational means of addressing environmental impacts on air quality, seawater or climate. Across the European Union, shipping stakeholders join different types of partnerships for the purpose of developing maritime environmental technology. At the European level, partnerships have been funded by the European Commission as listed in the database SKEMA (SKEMA 2015). At the national level, similar partnerships for maritime environmental technology have been established involving national partners (i.e., Low Carbon Shipping in the UK, Effship in Sweden, Partnership for Cleaner Shipping and Green Ship of the Future in Denmark). Despite this number of initiatives, few analyses and evaluations can be found in the literature regarding the processes and outcomes of partnerships as mechanisms for developing environmental technology in the shipping industry.

Partnerships is a new way to address environmental problems as cooperative environmental management regimes (Meadowcroft 1999). This shift towards collaborative approaches can be seen as shift to a new dominant paradigm (von Malmborg 2003). In the Earth Summit in Johannesburg in 2002, one of the conclusions was that partnerships should be a key mechanism for greening (Kolk, van Tulder, and Kostwinder 2008). However, the conceptualization of partnership can take multiple forms and have multiple associated meanings (McQuaid 2010). In this article, the focus is on partnerships as *"collaborative arrangements in which actors from two or more spheres of society (state, market and civil society) are involved in a non-hierarchical process, and through which these actors strive for a sustainability goal"* (van Huijstee, Francken, and Leroy 2007, 77). Partnerships with a focus on sustainability can be studied in two perspectives: The institutional level concerns the partnership as a governance mechanism; the key issue here is the role that the partnership plays in a governance regime. The second level considers partnerships from an actor perspective; here the focus is on the partnership itself, rather than the partnership and its functions within the overall environmental governance regime (van Huijstee, Francken, and Leroy 2007). Research on partnerships from an actor perspective seeks to improve the processes in the partnerships. Under this logic, partnerships are analysed in terms of advantages and disadvantages of partnering and with the aim to identify decisive success factors (van Huijstee, Francken, and Leroy 2007).

In this article, we analyse the processes and the outcomes of two partnerships in the Danish shipping industry: Partnership for Cleaner Shipping and Green Ship of the Future. It is investigated how the agendas of public and private actors are aligned for the purpose of collaborating in the development of environmental technologies. The analysis focuses on these two partnerships once they are established, which allows researching on the processes and outcomes of partnerships. Since some actors participate in both partnerships, we will also investigate how these two partnerships interact.

This article is divided into six sections. The second section presents the analytical framework. The third section describes the methodological approach to acquiring information. The cases are presented in the fourth section, and in section five, we present the discussion. The last section is the conclusion and suggestions for further research.

9.2 CONCEPTUAL FRAMEWORK

The literature on partnerships is quite diverse. Various authors have used many different classifications of partnerships (see for example Linder (1999), Nelson and Zadek (2000), van Ham and Koppenjan (2001), Bäckstrand (2006), Lehmann (2006) and Glasbergen (2007) and McQuaid (2010)). McQuaid (2010), for example, refers to Snape and Stewart (1996) who distinguish between three ideal-typical forms of partnerships: facilitating partnerships, co-ordinating partnerships, and partnerships of implementation. According to Hutchinson and Campbell (1998, 9) in McQuaid (2010), there is a consensus about a number of defining features: partnerships bring together a coalition of interests drawn from more than one sector to generate agreement; partnerships have common aims and a strategy to achieve these; partnerships share risks, resources and skills, and partnerships achieve mutual benefits and synergies. Partnerships can also be seen as networks for the greening of industry. These networks seek to bridge relations between public and private actors. The resulting relations can have several outputs as concrete projects, new forms of environmental governance, or an enhanced capacity of the actors to deal with environmental issues (Lehmann 2006). Linked with this approach to partnerships, Offermans and Glasbergen (2015) suggest that certain types of partnerships contribute to sustainability by producing knowledge. Furthermore, partnerships have been studies by a large diversity of disciplines. Van Huijstee et al. (van Huijstee, Francken, and Leroy 2007, 76) observe two major perspectives in the partnership literature: the institutional perspective and the actor perspective (see also Table 14). In the introduction of this article, we have used the institutional perspective to describe in short the context in which partnerships have arisen, the role of partnerships in society, and the institutional implications of the partnership trend. However, in this article we do not question whether or not a partnership as such is a good instrument for implementing eco-innovations in the shipping industry. Instead, we look at partnerships as instruments for the advancement of actor-specific goals, which is the focus of the actor perspective (see also van Huijstee et al. (2007)).

Table 14 Perspectives in the partnership literature (Based on Van Huijstee et al (2007))

Institutional perspective	Actor perspective
• Role of partnerships in (global) environmental governance regimes • The context in which partnerships arise: driving forces behind the partnership trend • The (potential) role of partnerships • Institutional implications of the partnership trend	• Partnerships as strategic devices • Advantages of intersectoral partnering • Risks of intersectoral partnering • Factors for successful intersectoral partnering

In our point of view, the institutional perspective and the actor perspective are not two separate viewpoints, but two overlapping perspectives. For example, in order to understand the processes and the outcomes of partnerships, which according to Huijstee et al. (2007) is at the core of the actor perspective, we consider it important to analyse how partnerships contribute to facilitating solutions and to which extent partnerships promote learning in networks. Based on a literature study, Huijstee et al. (2007) refers to these latter two aspects as belonging to the institutional perspective.

Koppenjan (2005), on the other hand, makes a distinction between the formation process of partnerships and the partnerships once established. In this article, we consider the formation process as being important, but we focus on partnerships once functioning. With this in mind, we have adapted three characteristics of partnerships from van Ham and Koppenjan (2001) to understand how partnerships for eco-innovation can be organized: 1) Participation, 2) Scope of the activities, and 3) The division of roles between actors. These three elements have overlaps with the key success factors in partnerships as described by McQuaid (2000; 2010); hence, the resulting framework has inputs from the three sources.

Participation is about which actors participate and under which conditions (Van Ham and Koppenjan 2001). We include two aspects to explain participation. The first aspect deals with trust between organizations and individuals in the partnerships. Participant organizations must count with an appropriate mix of skills and roles in order to maintain the participation over time (McQuaid 2010). The second aspect concerns the capacity for cooperation and mutualism. In order to achieve the planned targets, the actors in the partnership must have a strong network of communication and work at the local level. In practice, the strong network gives the organizations flexibility and authority to share resources and make decisions (McQuaid 2010).

The second aspect of importance to the analysis of functioning partnerships for eco-innovation is the *scope of the activities*. Partnerships for the greening of industry through eco-innovations are organized around two types of activities: collaborative projects and learning systems. Projects are limited in time, with a small number of partners. Learning systems require more commitment from the partners and the focus is on longer time frames (Lehmann 2006).

Once the partners have defined the scope of activities, they need to define their own *roles.* This does not mean that the partners must be allotted a small set of actions, but they need to clarify in which ways each partner is involved in the partnership and how they handle this involvement. Van Ham and Koppenjan (2001) propose a series of guiding roles for public and private partners. According to these, public partners are responsible for coordinating with politicians, safeguarding public interests, knowing the market orientation, providing funding, and giving guidelines on the social impact of the project. Private partners, on the other hand, are in charge of project management, involving private parties, taking care of project specifications, and sharing otherwise confidential information which is relevant for developing new products.

9.3 METHODS

This study has been carried out as part of the Interreg IV B project SAIL (Sustainable Approaches and Innovative Liaisons), which runs between 2012 and 2015 with 17 partners from the Netherlands, Germany, Belgium, France, the UK and Denmark. One of the goals of the project is to promote the creation of public-private partnerships which serve as platforms for the experimental adoption of hybrid sailing prototypes, i.e., wind propulsion (SAIL 2014). The purpose of this article is to provide insights into how a public-private partnership can be organized to facilitate processes that contribute to the desired outcome, i.e., the adoption of hybrid sailing technologies in the shipping industry. The logic of relying on the case study as an inquiry strategy is the possibility to translate the insights from one context into another under the given criteria (Flyvbjerg 2011). In this section, the authors explain the logic of the case selection and present how the empirical data was gathered and analysed.

9.3.1 SELECTION OF THE PARTNERSHIPS

In recent years, the Danish actors in the maritime industry have formed several partnerships for branch innovation. However, not all of these partnerships have a focus on environmental technology development and adoption. A criterion for selecting the partnerships for this analysis was that the partnerships should have an explicit goal of developing environmental technology. The two cases presented in this article are the two most representative Danish public-private partnerships formed with this purpose. Our strategy has been to describe and capture key issues to discover any common pattern between them. The lessons learned from our cases are assumed to be informative about the experiences of similar cases elsewhere.

9.3.2 DATA COLLECTION AND ANALYSIS

The empirical evidence was collected by triangulating four qualitative methods: literature review, documentation analysis, interviews, and observation. The literature review provided the concepts as presented in section 9.2. As a first step, we analysed documentation related to both partnerships; generally the documents were publically available on the websites of both partnerships. After the interviews, we complemented this review with documentation provided by the interviewees, such as project descriptions, minutes of meetings, yearly plans, and partnership contracts.

The first part of the documentation review helped us to identify eight interviewees (Appendix A, section 9.7). As the most important criterion, the interviewees were required to be acquainted with the characteristics of the partnerships and their socio-technical context. Four interviews were carried out with actors who had actually initiated the partnerships or had secretary functions (1, 2, 3 and 6). Two interviews were carried out with representatives of companies that developed projects within the partnerships (5, 7 and 8) and one interviewee provided insights into the context conditions within the sector (4). A semi-structured interview guide was used in these interviews (Appendix B, section 9.8). The initial questions had the purpose of gathering general information on the drivers behind the actors' involvement in the partnership. The following questions helped to assess the organization and mechanisms of interaction within the partnerships. These interviews were audio recorded and transcribed. To analyse the interviews, we combined deductive and inductive coding techniques which allowed us to "extract" relevant information from the interviews (Saldaña 2009). In the early phases of the analysis of the data set, we used hypothesis coding (Saldaña 2009, 122). Thus, we generated a predetermined list of codes based on our literature review. These codes regarded the type of evidence that we expected would emerge from the dataset (Table 15). We also used "InVivo", an inductive coding technique which has the purpose to highlight the striking phases of the interviewees. These phrases could reveal underlying assumptions and explanations concerning a given issue (Table 15) when new insights emerged from the transcripts that we had not accounted in our hypothesis coding. When coding the data, the authors had access to a complete list of hypothesis codes and the InVivo codes were added as they appeared. The authors used the software QSR NVIVO to manage the list of codes and save the coded transcripts.

After coding the interview transcripts, the authors grouped the patterns emerging from both types of codes into themes (Miles, Huberman, and Saldaña 2013). These themes were of three types: the characteristics of the partnerships (i.e., activities, organization, definition of roles, and projects); the actors (i.e., drivers) and the interaction between partnerships (i.e., outcomes, processes). Quotes from interviewees were used according to these themes and formed the basis for the case study and the reflections of the authors.

During the data collection phase, the main author of this article was a research fellow at the Maritime Centre for Operations and Development (MARCOD, Denmark). MARCOD is an intermediary organization, which collaborates with Danish maritime stakeholders by organizing seminars on environmental technology and advising small and medium-sized companies on how to enter into the market of environmental services and technologies. When collecting the data, the main author participated as an observer in a number of meetings of the Green Ship of the Future partnership. This interaction with maritime stakeholders was important to understand discourses vis-à-vis environmental regulations –not explicitly stated in public documentation. The meetings included technical presentations and round-table talks. In these round-table talks, the representatives of different organizations shared ideas and presented the progress of their respective projects.

Table 15 Condensed list of codes used in the analysis of interview transcripts. The complete list of codes (hypothesis and In Vivo) is 91 items, the list included here is provided for explanatory purposes

Hypothesis codes	Description	In Vivo Codes	Description
Partnership_sustainability	Explains what defines the goals of sustainability in the partnership.	PCS_driver	Drivers related to the initiation of Partnership for Cleaner Shipping
Partnership_formation	Describes the beginning of the partnership, which actor(s) took the leadership and which goals this actor had.	PCS_organization	How the actors organized within the Partnership for Cleaner shipping, i.e. meetings, roles
Partnership_driver_govt	Addresses the drivers of the government when participating in the partnership.	PCS_dynamics_activities	Which activities and projects did partners carried in the Partnership for Cleaner Shipping.
Partnership_driver_private	Explains the driver of private actors when participating in the partnership	GSF_project bubbles	How actors interacted in the Partnership Green Ship of the Future, i.e. project bubbles.

9.4 TWO DANISH PARTNERSHIPS FOR MARINE ENVIRONMENTAL TECHNOLOGY

The Danish maritime industry is represented by all actors in the shipping value chain: shipowners, equipment manufacturers and suppliers, logistic firms and advanced service providers, banking, R&D, insurance and law. The Danish government and Danish-based global incumbent shipping firms have actively participated in the creation of a national blue cluster which groups these different actors into a collaborative innovation system (Danish Government 2012; Sornn-Friese 2007). A leading role has been taken by the Ministry of the Environment, which actively promotes partnerships for environmental innovation. “In the future, the global market will increasingly demand more eco-efficient technological solutions, and Danish firms, knowledge institutions and authorities together hold many of the competencies required to develop these technologies” (Danish EPA 2014). Therefore, it is advantageous to bring together different competences in strategic partnerships (Danish EPA 2014). In this section, we focus on the role of two Danish partnerships in promoting environmental technology in the shipping industry.

9.4.1 PARTNERSHIP FOR CLEANER SHIPPING

The Partnership for Cleaner Shipping is a public-private partnership between the Danish Environmental Protection Agency (EPA) and The Danish Shipowners' Association. This partnership seeks innovative solutions to reduce air pollution from ships in a cost-efficient way, while generating green innovation from equipment suppliers through spillover effects. The main objective of the Partnership for Cleaner Shipping is to develop and diffuse technology to comply with air pollution regulations included in Annex VI of the International Convention for Prevention of Pollution from Ships (MARPOL) by the International Maritime Organization (IMO). Some of the objectives of the partnership are (Danish EPA 2010):

- Focusing attention on the importance of reducing air pollution from shipping by promoting awareness of the new regulations passed by the International Maritime Organization (IMO)
- Ensuring the visibility of these measures
- Promoting innovative frameworks for environmental/technological development so that the regulatory requirements can be fulfilled

The Partnership is directed by a steering committee. The steering committee has representatives from the Danish EPA and the Danish Shipowners' Association. The steering committee organizes regular meetings as part of the Partnership. The meetings have the purpose of deciding which project proposals to endorse and on this basis the Partnership can apply for possible funding by the Environmental Ministry. In relation to the Danish EPA, the Partnership is required to define technical solutions under existing regulations. Furthermore, the Partnership is used as a testing ground for new regulations, which may ultimately be incorporated into public environmental regulations.

Another purpose of the meetings in the Partnership is to organize activities to facilitate knowledge circulation in the maritime branch. The Partnership also organizes workshops, sometimes in collaboration with external organizations. For example, a conference organized in November 2011 targeted shipowners and equipment manufacturers to create a forum in which they could meet and present some of their solutions (Interview 1). In line with this knowledge creation, the first initiative carried out by the Partnership was to commission a research report on the environmental impact of shipping on the air quality around Danish waters. The study showed the location of the most impacted areas with air pollution and also suggested some scenarios for the future based on solutions to the problems (Interview 3).

The Partnership also has a reference group. This group does not make decisions on fund allocation but feeds political and technical discussions. Some of the companies within the reference group are free to prepare projects and request funds from the partnership.

9.4.2 PARTNERSHIP GREEN SHIP OF THE FUTURE

Green Ship of the Future (GSF) is a privately initiated partnership involving around 40 Danish marine equipment and service providers and major shipping firms and public-private organizations. The Partnership was initiated in early 2008 for the purpose of finding technical solutions to air pollutant emissions in new vessels - particularly CO_2, NO_x and SO_x. To find possible ways to reduce these emissions, the partners commissioned a set of technical studies. The first study had a container vessel as reference; the second had a bulk carrier vessel as reference, and a third study had the purpose of finding technical solutions for the retrofitting of existing vessels to comply with the MARPOL Annex VI requirements for SO_x (Schack 2009). After these analyses, the Partnership has broadened the scope of activities to partner projects, topic-based groups, and "project bubbles".

Different types of partners are involved in Green Ship of the Future: classification societies, consultants, equipment suppliers, service providers, and shipowners. Shipping and equipment firms play a central role in the Partnership. Ten equipment suppliers are members of the Partnership and their technologies and competences cover a wide area of products and services, including engine, ballast water management systems, pumps, instrumentation, and refrigeration. The Partnership includes eight large shipping firms.

In addition to the private firms, branch organizations and some government agencies are network partners: Danish Maritime Authority, Danish Shipowners' Association, Danish Maritime, and Danish Marine Group. There is also a group of associated partners, such as universities, professional schools, and the media. These academic and training partners provide the research experience and materials to perform some of the partner projects in GSF. The media partner is the industry magazine "Shipping" (Søfart).

9.4.3 INTERACTION INSIDE AND BETWEEN THE TWO PARTNERSHIPS

In this part, we analyse the development and the dynamics of the two partnerships. We focus on the scope, participation, and division of roles in order to better understand the collaborative characteristics of this new form of interaction at an institutional and actor level/perspective. Subsequently, we analyse how partnerships interact and in this way improve their impact.

9.4.3.1 Partnership for Cleaner Shipping: New ways of organising the dialogue between policy and business

The Partnership of Cleaner Shipping facilitated the development of environmental technologies by allowing private stakeholders to meet in common projects in which they could match complementarities. The partnership supported the project ideas by delivering a subvention with funds from the Ministry of Environment as shown in Table 16.

Table 16 Projects supported by the Partnership for Cleaner Shipping (Danish Shipowners' Association 2011)

Project name	Partners	Objective
NO_x reduction/low NO_x ventilation motor	MAN Diesel & Turbo	10-20 % reduction in NO_x emissions. 25-50% PM reduction
Reduction of SO_x emissions/ development of a scrubber	Alfa-Laval Aalborg DFDS MAN Diesel	Development, installation and testing of a scrubber on a DFDS Ro-Ro vessel
Selective Catalyst Reduction (SCR) system/auxiliary engine	CATCON/ Haldor Topsøe/ Bornholmtraf-ikken	Adapting a SCR system to a vessel. Technical inspiration from the car industry
Development and standardi-zation of a SCR system for vessels	RM Staal	
Development of PM filter for vessel engines	Teknologisk Institut Dinex A/S Ærøfærgerne A/S	

In the literature of partnerships for sustainability, there is a focus on the economic aspects of infrastructure building, but our study shows that the main benefits of the public-private partnership are related to the interaction between the business and the regulative authorities and more specifically between technical and regulatory issues. The collaboration in and around the projects gives firms and other actors a unique possibility to contribute to the political agenda, as in the projects in which one of the partner firms (large marine engine manufacturer) has been involved. The process characteristics of the Partnership for Cleaner Shipping are illustrated in Table 17.

Table 17 Four main elements of the Partnership for Cleaner Shipping according to the conceptual framework

Participation	Scope	Division of roles
• Danish EPA • Danish Shipowners' Association	• Environmental technology development and diffusion to comply with IMO and EU regulations	• Danish EPA provides legal support and funds for projects • Danish Shipowners' Association promotes compliance with the regulations and project proposals

For example, a marine engine manufacturer participated in two projects which were supported by the Partnership. As shown in Table 1, the engine manufacturer benefited from the Partnership's support in developing maritime engines with low NO_x emissions. The Partnership helped to find a subvention of around 35% of the project's total cost. The project gave the firm a possibility to contribute to the political regulatory agenda:

> When collaborating with the regulators in this project, we did not ask for inputs on the technical aspects, but on legal matters, on how to include technical details when proposing a new regulation, which was part of the project. We don't ask the State for input on how to develop an engine, but instead on how to make a regulation for this, and we made some papers together. We submitted it to the Partnership steering group, the shipowners had some comments, and then we agreed on how this IMO paper should look like. Then we submitted it to IMO, we contacted the Danish delegation when this was discussed in the IMO, and then regulation came out of this" (Interview 5)

The engine manufacturer's involvement in the Partnership started through networking with the Danish EPA. The new regulations set by the IMO were on the firm's agenda, but retrofitting old engines with NO_x-reducing technology was not as high a priority as developing new engines. However, the external funding and networking were seen by the top management as an opportunity to gather new ideas from shipowners and to influence policymaking:

> This project started due to the regulation controlled by the IMO on air pollution by ships. We participated in these meetings in the Danish delegation. There was a lot of work; actually, in the way regulation happens. Nobody knows about big engines from the regulatory side, so you have a lot of communication with the State administration, shipowners and suppliers on

> what is [technically] possible before the regulation. In 2008, it was decided that this kind of regulation was going to be implemented but it was not finalized. We are lucky to have some of the most progressive shipowners here in Denmark, so we could push for greener technologies. This is how this project started, because of lots of things like regulatory contacts and consumers and suppliers" (Interview 5).

As mentioned in section 9.4.1, the partnership for Cleaner Shipping is used as a testing ground for new regulation: "Obviously, we need technical solutions for both, the regulation we have agreed upon and also to form the basis of our new future regulation" (interview 2). For the Danish Shipowners' Association, the creation of a close relation with equipment manufacturers and with the government involves advantages for the association; thus, to "be part of the development, feed in the process [of technology development] and be aware of everything that is going on [in international environmental policy negotiations]" (interview 2).

From a traditional, technological perspective, low NO_x emission engines are unconventional. A change of paradigm started due to a combination of market and regulatory pressures. The design of NO_x reduction engines dates back to the 1980s, when the marine engine manufacturer's truck engines branch developed Selective Catalyst Reduction (SCR) systems in response to the 1985 US-EPA stringent standards for emissions of NO_x from heavy-duty engines and of PM from heavy-duty diesel powered trucks and buses. Similarly, certain shipowners wish to reduce their operational environmental impacts:

> Previously, the success criterion for making good engines was having high NO_x emissions, because then you had good combustion and less fuel consumption; the turning point was the regulations or the business to business customers [shipping lines] who started asking for alternatives. These customers approach us, before the emissions regulations are implemented, to design engines with lower emissions. Our customers serve large cargo owners, like Walmart, IKEA, which require shipping lines to document their environmental impacts. …They want to have a green image, and there are also customers driving this. I think they [cargo owners] believe that they cannot survive without a good environment (Interview 5).

A further advantage of this collaboration with State actors and shipowners was related to a communicational perspective. The collaboration made it possible for engine designers and manufacturers to work with the customers from the early stages of product development, making the communication with the shipowners in relation to the product development easier.

9.4.3.2 Partnership Green Ship of the Future: New collaborative forms of interaction in shipping

A milestone for the Partnership was the International Climate Change Conference (COP15) in Copenhagen (2009). COP15 was seen as an important arena in terms of future environmental regulation. It was important to produce technical studies which could influence the regulatory visions and give the shipping industry a more positive role:

> Back in 2009, the shipowners were under scrutiny because the general perception in society was that they were not doing enough for the environment. It was clear that something needed to be done about the negative publicity, but also the negative publicity came from shipowners and the industry because it was not doing enough to be green. Then at the end of 2009 was COP15. COP15 was the main driver of the low emission studies—the container ships and the one on bulk carrier. They had to be finished and ready for COP15 in order to show the world that shipping was actually doing something. COP15 was also good marketing for the project" (Interview 6).

After the COP 15 experience, the goal is now more focused on how partners can develop and test solutions through project development and communicate these externally. Formal discussions take place at four general meetings each year. In addition, technical presentations are organized during these meetings:

> What we have done now is to change the structure. We have technical presentations. We have either outside companies or partner companies come and discuss something important for the group or give presentations on a technical area, always on technical matters. Then, after lunch, we have topic-based groups (Interview 6).

The main driver of interactions among partners is common business interest. Project partners join together in topic-based groups and prepare common projects (partner projects), which are subsequently presented as either prototypes or reports. So far, the topic-based groups are: novel ship design, on board systems/systems integration, and alternative fuels:

> The new thing is having topic-based groups together with the project bubbles. If you have an idea, and if you want to discuss it with others, you can set up the bubble. We are not ready to make everything formal, we only have an idea, but you are welcome to join the discussion if you like. There is no promised outcome. It can be anything, the ideas people talk about. Then we have the topic-based groups in which companies choose which group they want to be with (Interview 6).

These topic-based groups have organized 20 projects (13 related to machinery improvement, 5 related to operation and two for propulsion). Most of the projects in machinery improvement seek to improve the combustion process. In this way, pollutants such as NO_x can be reduced. Projects in the area of operation seek to reduce fuel consumption and thus reduce the emissions of CO_2 and SO_x.

The alliances within each project implied different kinds of resources by partners: man-hours, research infrastructure, and equipment testing. The outcome of the project was usually a research report that was publically shared through the GSF website, presented at a conference, or shared as a summary in industry magazines or specialized journals. Not all the designs reported were finally manufactured and installed: “Unfortunately, so, I don’t think the whole packages of initiatives you have in GSF are implemented, part of it is implemented in a number of different vessels” (Interview 7).

GSF partners use a website to share promotional notes about their products or services; this was evident in six articles. Similarly, GSF also communicates the concept of “Green ship” with the industry through oral presentations at industry events and written summaries in industry magazines. To a minor extent, technical reports and summaries are also used as a communication strategy by GSF. Examples show, however, that the communication addresses the broad audience of the maritime industry in general (e.g., shipowners, cargo owners, manufacturers, ports). At least three communication elements were directed at shipowners. Several communication events targeted single stakeholders (like market, policy makers or NGO). Interestingly, these examples highlight the condition that the GSF has a commercial purpose with its communication strategy (rather than political). The process characteristics of the GSF are illustrated in Table 18.

Table 18 Four main elements of the Partnership Green Ship of the Future according to the conceptual framework

Participation	Scope	Division of roles
• 40 partners carrying out different activities in the shipping industry (i.e., shipping firms, equipment suppliers, classification societies) • In addition network partners (universities, professional schools, professional media, branch organizations).	• Desk studies (ship design) • Early stages of project development in networks	• FORCE technology: Coordination of the partnership • Partners: pay membership fee and participate actively in meetings and activities

9.4.3.3 Interaction between partnerships

In sections 9.3.1 and 9.3.2, we have described the two partnerships. In section 9.4.3.1 and 9.4.3.2, we have analysed these two partnerships separately. As stated above, since some actors participate in both partnerships, we will in this section analyse the interactions between both partnerships, by means of an example.

Both partnerships are important in their roles of co-creation of environmental technology and regulation but in different ways. This importance can also be seen by the way in which the two different types of partnerships supplement and complement each other.

Permeable boundaries between the partnerships and their context allow overlaps between the two partnerships. This part discusses how the two partnerships can interact through an illustrative example: the "scrubber development" project. Initially, the GSF Partnership funded a study to assess the emissions from a tanker vessel. The study also suggested alternative means of compliance with the sulphur emissions limits as stated in MARPOL. A technical feasibility study was carried out of two of these alternatives: a scrubber or LNG fuel:

> Funding was provided by the Danish environmental authority [Through the Partnership for cleaner shipping]. Green Ship of the Future was carried out before the scrubber project, I don't think the scrubber was installed but it was designed as part of the Green Ship of the Future project (Interview 7).

After this feasibility study, a smaller group joined the work on the scrubber: Alfa-Laval-Aalborg, a marine equipment manufacturer; the previously introduced MAN Diesel, and DFDS, an incumbent shipping firm operating in short shipping routes in the North Sea and the Baltic. The three firms had different drivers of developing an exhaust gas cleaning system to reduce sulphur emissions. For the marine equipment manufacturer firm, desulfurizing flue gas was a well-known procedure in other applications (Interview 8). The firm perceived it as a business niche to adapt a wet scrubber into a vessel (Knudsen 2011). MAN Diesel & Turbo was involved to provide technical support to the connections between the main engine and the scrubber. The installation and tests were performed on a DFDS vessel. This shipping firm was interested in finding a cost-effective alternative to low sulphur fuels when navigating in SECA waters. For the manufacturer and engine provider, it was of great value to have access to operational data over time. The shipowner shared the operational data with the other partners: "with the partnership, shipowners provide lots of data that they wouldn't normally provide, they know it is not going to be misused" (Interview 6).

In addition to the three previous partners, classification societies provided inputs along the process. Some of them were consulted at different stages of the scrubber development:

> Typically you involve one classification society for a specific project; then you start involving more classification societies. Obviously some of them have their own specific areas, so you cannot say it is the same set of rules, but kind of similar set of rules. Classification societies usually focus on security, reliability and similar. They focus on the safety of the vessel, that the piece of equipment doesn't threaten safety (Interview 7).

The implementation phase was partly funded through the Partnership for Cleaner Shipping. This phase involved mainly meetings and technical communications. During these meetings, the discussions turned around funding and installations, with some of the partners willing to cover some of their costs themselves –i.e., the equipment manufacturer covers the installation costs (Interview 8). Other interactions also took place at this stage:

> Of course, lots of discussions on who should pay for what; even though the project was partly funded, the participants also had to fund significant amounts. Part of the costs dealt with planning and interactions on how to deal with the installation of large pieces of equipment. There was also a lot of planning with the other partner MAN, because you had a standard engine, you did some modifications for the exhaust system, and we had to think how that effected the engine performances, which requirements should be put" (Interview 7).

The scrubber was finally in operation in 2010; the shipowner keeps record of the performance and the manufacturer uses the data to improve the design. Similarly, the operation of a wet-scrubber has helped to spot issues contributing to technical debates at a regulatory level, i.e., the measurement of scrubber wastewater parameters. A follow-up project is currently been developed by the partners for the purpose of integrating a scrubber technology able to eliminate NO_x emissions along with SO_x. The project is likely to receive support from the Partnership for Cleaner Shipping (Interview 8).

9.5 DISCUSSION

In this article, we have analysed how the agendas of public and private actors are aligned for the purpose of collaborating in the development of environmental technologies. In this section, we will discuss our findings in relation to the literature, to theory and to practice. Since we found few contributions in existing literature on the processes and outcomes of partnerships as mechanisms for developing environmental technology in the shipping industry, we have analysed two existing Danish partnerships: the Partnership for Sustainable Shipping and the Green Ship of the Future partnership.

The *Partnership for Cleaner Shipping* is a typical public-private partnership which started as a public initiative managed by the Danish Environmental Protection Agency (Danish EPA). The main driver of its launching was to support cost-effective technology to enable shipowners to comply with international regulations on air quality. This partnership has succeeded in creating a platform for close collaboration between different actors in the maritime sector in developing and testing projects.

As described in the conceptual framework, ***participation*** is about which actors participate and under which conditions (Van Ham and Koppenjan 2001). In the Partnership for Cleaner Shipping, there is an appropriate division of skills and roles between the actors in the partnership. In the first place, the Danish government has more than 20 years of experience in managing public subsidy programmes aiming at improving environmental technology development (Georg, Røpke, and Jørgensen 1992; Danish EPA 2007). The Partnership for Cleaner Shipping is linked to the eco-innovation programme set by the Danish EPA. In the second place, Danish EPA relies on the "new" role of environmental authorities vis-à-vis polluting industries. In this new role, environmental authorities become active facilitators of industrial self-regulation. This is an important contribution to the institutional perspective when analysing partnerships, as described earlier. At least in a Danish context, partnerships have proven to be a good way to implement eco-innovations in industry. Eco-innovation comprises partnerships with several industries and not only with shipping. From the logic of the previous Danish EPA programmes, a publicly sponsored partnership programme seems to be necessary to create collaboration between users (shipowners) and suppliers (equipment manufacturers) and to enable these actors to develop environmental technology (Danish EPA 2007; Danish EPA 2014; Danish EPA 2010). For private actors, it has also been important to participate in the partnership in order to get input on – for example – legal matters, on how to include technical details when proposing new regulation.

In that sense, the ***scope of the activities*** has not only been collaborative projects on technology development, but also to a great extent learning systems with the aim to improve the capabilities of the actors. The Partnership for Cleaner Shipping has been used as a collaborative platform for combining and gathering new ideas and influencing policy-making. There has been a development of ***roles*** of the public and private actors and the way in which they have been able to integrate and combine these. We can see a clear division of roles between the actors in the partnership, but also how actors have changed their traditional role and the way in which they (used to) collaborate. For example, private actors now have more focus on how to influence regulation, and the government has tried to a larger extent to influence technology development.

Green Ship of the Future is a business-to-business partnership, which started as an initiative by a group of shipowners and their suppliers. ***Participation*** in this partnership has been especially helpful for the actors involved in terms of securing that the regulations became based on knowledge of technological practice and not just theoretical paperwork. In other words, producing knowledge has been an important aspect of this Partnership. This has been done by means of producing technical studies in order to influence regulatory visions and give the shipping industry a more positive role. The COP15 in Copenhagen (2009) has been a main driver of these studies. After the COP15, the ***scope of the activities*** in the Partnership has changed from an advocacy oriented framework to an innovation and learning based partnership. The goal of the Partnership is now focused on how partners can develop and test solutions through project development and communicate these externally. The main driver of interactions among partners is a common business interest. Within the Green Ship of the Future Partnership, partners work together on different projects (e.g., the air resistance of ships and a high efficient nozzle). Alliances within each project imply different kinds of resources from the partners: man-hours, research infrastructure and/or equipment testing. In other words, the actors have retained their traditional *role* in this Partnership. The outcome of the projects are research reports, publically shared through the Green Ship of the Future website, presented at conferences, shared as a summary in industry magazines or specialised journals. To a minor extent, technical reports are used as a means of communication by the Partnership. The communication strategy has a commercial purpose rather than a political purpose. The Green Ship of the Future Partnership is a good example of a partnership that has been organised around collaborative projects. As argued by van Ham and Koppenjan (2001), these projects are limited in time and with a small number of partners.

The initially separated partnerships do have interactions through projects. For example in a project on exhaust gas scrubbers, the Green Ship of the Future Partnership allowed partners to meet and plan the project. Partners co-funded feasibility studies and later the Partnership for Cleaner Shipping provided a grant to cover expenses linked to the installation of the system. An explanation for these interactions through a project is the individual interest of each of the partners involved in the project. Some partners explained that part of their interest when involved in the partnerships was to collaborate closely with the users of their products. This user-producer interaction becomes important in the shipping industry in general and in the development and diffusion of environmental technologies in particular. The participation in different partnerships provides an enhanced playground to test these technologies, while it becomes easier to bridge the user-producer relationships.

Innovative learning through interaction between users and suppliers has largely been studied in the literature of innovation. Aside other drivers, the most important is to improve product designs to tailor the needs of the users (Georg, Røpke, and Jørgensen 1992). According to Kemp and Volpi (2008), adopters of new complex technologies need time to familiarize with these technologies. That is why the activities and the support of consultants become key elements to support this process of familiarization.

9.6 CONCLUSIONS

This article contributes to the literature by reflecting on the processes and the outcomes of partnerships established with the initial goal to develop environmental technology. In terms of processes, the partnerships are influenced by participation, scope and the division of roles among partners. Previous research on partnerships for sustainability highlights the perspectives of institutions and actors in relation to partnerships. However, taking a look into the processes from the three aspects mentioned above reveals that the differences between the perspectives become blurred as analysed in the discussion section. Therefore, rather than two levels of analysis on partnerships, the institutional and actor perspectives can be seen as complementary aspects which influence each other. Further research could test this framework in different national and industrial contexts. In particular, longitudinal case studies which also take into consideration the formation process of partnerships could supplement the study of the implemented cases presented here.

In relation to outcomes, the first salient issue is that both partnerships analysed have developed organizational forms, which have overcome the tension in traditional partnerships between open and information-based networking on the one side and closed and development-oriented collaboration on the other side. The partnerships have organized conferences and made public reports on environmental issues and solutions to create platforms of openness and awareness. To create platforms for innovation, the partnerships have a collaborative function between suppliers and end-users in the initial stages of developing new environmental technologies. This collaboration can take several forms, from forming affinity groups of suppliers interested in similar topics, to funding ideas that the group of firms have developed on their own. An understudied issue in the literature is how initially separated partnerships with similar goals interact. The study shows that partnerships create space for user-producer interaction, but these collaborative spaces are of limited scope, resources and time. By combining the collaborations across partnerships, it is possible to create a space for more complex projects like those focused on developing eco-innovations. Our suggestion for future research is to focus on how partnerships and/or the interaction between partnerships contribute to a more active role of the actors involved. In-depth case studies of organizations participating in two or more partnerships, could provide a comprehensive perspective on how the different partnerships benefit the participant firms and vice-versa.

9.7 APPENDIX A

Table 19 List of interviews by date, organization, stakeholder type and location

#	Date	Organization	Stakeholder	Duration (min.)	Purpose	Location
1	07-12-2011	Danish Environmental Protection Agency: Environmental technology		43	The interviewee is the responsible person for the Danish Environmental Protection Agency in the eco-efficient technology promotion partnerships.	Copenhagen
2	23-01-2012	Danish Environmental Protection Agency: Eco-innovation project shipping		51	The interviewee is the Danish Environmental Protection Agency responsible for the Partnership for cleaner shipping.	Copenhagen
3	23-01-2012		Shipowners' Association	62	Responsible person for the partnership for cleaner shipping in the Danish shipowners' association	Copenhagen
4	10-02-2012	Danish Maritime Authority		27	Interview with responsible of cleaner technology development in relation to harbours	Copenhagen
5	15-10-2012	Maritime engines manufacturer	Equipment manufacturer	43	Global leader in marine diesel engines design and manufacture; involved in both partner-	Copenhagen

					ships	
6	15-10-2012	Green Ship of the Future	Public-private partnership	40	Coordinator of the Green Ship of the Future partnership.	Copenhagen
7	16-10-2012	Maritime equipment manufacturer involved in both partnerships	Equipment manufacturer	27	Global leader in maritime equipment supply; involved in both partnerships.	Aalborg
8	11-12-2013	Idem as 7 (follow up interview)	Idem. as 7	40	Idem. as 7	Idem. as 7

9.8 APPENDIX B

Semi structured interview guide; an example with private firm

1) Firm sustainability strategy and involvement in the Partnership

2) How the network became a network

a. How was the network established?

b. What was the aim of the network and how has it evolved over time

3) How the network functions/ functioned?

4) Possibilities of diffusion of these technologies in the future

10
INNOVATION IN PRODUCT AND SERVICES IN THE SHIPPING RETROFIT INDUSTRY: A CASE STUDY OF BALLAST WATER TREATMENT SYSTEMS

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ABSTRACT

Eco-innovation research pays increasing attention to business models and their contribution to the diffusion of environmental technology into socio-technological systems. The extent to which a business model hampers or promotes certain types of eco-innovations remains an open question. In order to shed light on this issue, the authors develop a conceptual framework to show how a specific type of business model (Product-Service Systems) could be applied to the context of the maritime industry. With a focus on the Danish maritime industry, the case study addresses two questions: *Which business models are being used to develop, install and service the ballast water treatment technology*? And, How *can these business models add value to the ballast water treatment systems in the market?* The case shows that different business models are applied depending on whether the installation is on new or retrofitted vessels. Both installation and operation stages of ballast water treatment systems provide opportunities for collaboration among stakeholders. Based on the Eco-costs/Value Ratio model, the authors perform an analysis of on-board and port-based ballast water treatment systems with the aim to propose a possible product-service system. These results suggest that port-based systems have the highest potential for eco-efficient value creation and a possible product-service system can be designed for this kind of technology. The article highlights the point that authorities need to improve regulations to stimulate port-based ballast water treatment systems rather than on-board ballast management systems.

Keywords

Ballast water; shipping; product-service systems; eco-innovation; eco-efficient value creation

10.1 INTRODUCTION

Ballast water is essential for ship operations. Unladed ships require ballast water to keep stability and trim; fully-laden ships need it to keep an appropriate trim during rough seas (Goncalves and Gagnon 2012). More than 150 000 metric tons of fresh/sea water can be pumped in or out of ballast tanks in one operation and that water may include living organisms (Ruiz et al. 1997; Dunstan and Bax 2008). Due to these large volumes of water being transported from place to place, there is a risk that many different species are transported and are viable at the destination waters (Ruiz et al. 1997). These species are usually called invasive, non-indigenous or alien species and the broad definition "includes any species reported to have become established outside its native range" (Molnar et al. 2008). Ballast water on ships is considered as the most important vector in dispersing these invasive species throughout the world, although the dispersion risk highly depends on the vessel's type and route (Seebens, Gastner, and Blasius 2013). Alien invasive species may have economic, ecological and health impacts on marine and estuarine ecosystems. Ruiz et al (1997) provide the example of the zebra mussel's invasion in the Great Lakes, which beyond being an ecological problem led to costs of between 1,8 – 3,4 billion US dollars by the year 2000. Cholera is an example of a disease indirectly caused by ballast water, as the *Vibrio cholera* pathogen can travel in ballast water (Ruiz et al. 1997).

To control the spread of invasive species, the Ballast Water Convention was approved by the International Maritime Organization- Marine Environment Protection Committee (IMO-MEPC) in 2004. By April 2014, the convention is pending ratification by some countries – it will enter into force twelve months after the ratification of countries representing 35% of the world's merchant shipping tonnage. Meanwhile, individual countries, ports or regions have put in place local rules to prevent invasive species distribution from ballast water discharge. A significant event took place on March 23, 2012, when the United States Coast Guard (USCG) published stricter rules to prevent untreated ballast water discharge in U.S. coasts. These international and national regulations generally focus on three strategies to manage ballast water, namely, ballast water exchange, installing ballast water treatment systems (BWTS) or a combination of both. Ballast water exchange implies flushing the ballast water tanks and refilling them with saltwater in mid-ocean (i.e., more than 200 nautical miles from the shore). This water exchange reduces the number of viable fresh water organisms in the ballast tanks due to the salinity (Briski et al. 2013). Ballast water exchange is not always possible; the major constraints being geographical (i.e., some shipping routes do not operate in mid-ocean). Therefore, BWTS represent a second alternative to reduce the number of organisms to low risk levels for the ecosystem and human health. The requirement is that ships need to install a technology that is able to clean all ballast water before it is released into the harbour. Some prototypes of port-based systems receive the ballast water from the vessel instead of having to install a treatment unit on board (King and Hagan 2013). Existing on-board or port-based treatment technologies combine mechanical (filtration, separation) and biological steps (sterilization through UV, Ozone) (Goncalves and Gagnon 2012; Veldhuis et al. 2006).

Currently, twenty-eight on-board systems have received the final approval by the IMO and are ready to be commercialized (IMO 2012). This legislation will create a significant market for new BWTS. According to King et al. (2012), the market size includes 68,000 vessels whose owners require the installation of on-board BWTS before 2020. King, Riggio and Hagan.(2010) estimated a market value in the range of US $50 to $74 billion between 2011 and 2016.

Environmental technology such as BWTS is perceived to be a key sector for future economic growth at the EU level. The possibility of positioning the member states as world leaders in key areas of green technology development is explicitly stated in the EU 2020 green growth strategy (European Commission 2010). Some member states, such as Denmark, consider the maritime industry as a key sector for growth and have taken action to try and enter the BWTS market. Environmental technology for the maritime industry is mentioned in the national eco-innovation strategy (Danish EPA 2010). The Danish Partnership for Ballast Water Technologies was formed with the participation of public and private actors to find cost-effective opportunities of compliance once the convention is put into force (Danish Shipowners' Association 2013). The Danish maritime industry recognised this market opportunity and set up companies such as DESMI Ocean Guard A/S, to develop BWTS (Filtration Industry Analyst 2009).

However, the maritime industry is globalised, and any market for BWTS will also be globalised (Köhler 2014). Current data on orders for new ships shows that Europe as a whole only has 6% of the global orders (Clarkson Research Services 2013). However, BWTS may also be installed as a retrofit during a docking period. In this case, the decision about where to retrofit will be partly determined by the location of the ship at the time being, with the implication that ships on EU trade routes could be cheapest to refit in EU shipyards. This would give, e.g., Danish ship-repair yards and equipment suppliers a competitive advantage for part of the retrofit market. Since on-board BWTS are specialized equipment, the provision of maintenance services to ship operators could also be a significant market.

An important question for the Danish ship-repair yards and equipment suppliers is which business model will lead to profitable involvement in the BWTS markets. There is, however, only a limited selection of literature on business dynamics in the marine industry. Hameri and Paatela (2005) consider the dynamics of supply networks including the case of shipbuilding as a case of an industry where the structure of supply networks has changed. They find that from the end of the 1970s, shipyards changed from producing all the systems at the shipyard to a multi-layered supply network, where the specialist firms in, e.g., industrial kitchens or computer services also have other customers and are less dependent on the vagaries of the shipbuilding market. 90% of the end product value is now produced by the supplier network (Hameri and Paatela 2005). For a country such as Denmark, with a small shipyard sector but a strong reputation in ship technologies, the provision of services around BWTS installation and operation might provide the best market prospects.

This suggests that the Danish shipyard sector as a highly integrated and specialized network of suppliers has the potential to use the so-called Product-Service System (PSS) as a basis of its business models. The accepted definition of a PSS is: *"A system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models",* e.g., Mont (2001) and ELIMA (2005).

BWTS developments' overall intention is to reduce environmental impacts by drastically reducing the risk of invasive species spreading due to shipping. The required integrated offering delivered by a complex multi-stakeholder network mean that BWT technology is fully compatible with the application of Product-Service Systems (PSS). Therefore, the authors applied the PSS literature to the case of eco-innovation in the shipbuilding industry and expanded the PSS concept to explicitly consider supply networks in an industry where these relationships are complex. The results of Hameri and Paatela (2005) described above show that the shipbuilding industry already has a complex supplier network, which is therefore capable of applying a PSS approach. The results also show that the shipbuilding industry has changed its balance between OEMs and suppliers, which indicates that the industry is also capable of further changing its structure to adopt a PSS approach.

In this article, the authors address two research questions:

- Which business models are being used to develop, install and service the BWTS?
- How can these business models add value to the BWTS market?

Section 10.2 summarizes the analytical framework as well as the hypothesis. Section 10.3 presents the methods. Section 10.4 presents the case study. A discussion is presented in Section 10.5. Conclusions and suggestions for further research are presented in Section 10.6.

10.2 PRODUCT-SERVICE SYSTEMS AND THE MARITIME INDUSTRY

An emphasis on service provision rather than equipment manufacture suggests that the PSS concept could provide a suitable conceptual approach to this study. PSS has received attention as a suitable model for sustainable innovation (Boons and Lüdeke-Freund 2013). On argument is that the division between manufacturing industries and service providers has become blurred (Baines et al. 2007; Pawar, Beltagui, and Riedel 2009). In particular, many firms now view services as a source of added value and it has come to dominate the operations of firms which were traditionally considered as manufacturers. Baines et al. (2007) argue that product manufacturers and service providers have moved closer together in their structures to generate added value, a trend also identified by Wong (2004). The concept is that what is sold is not the product, but the use value which the customer derives from a product and its associated services. This involves a continuing relationship with the customer and provides a continuing source of added value for the PSS provider. An important feature is that the asset ownership is not transferred to the user, but the PSS provider contracts the asset to provide a service. In general, this involves selecting the equipment, monitoring performance and providing servicing. An example of such an arrangement could be the provision of transport services.

A manufacturer could traditionally build and sell e.g. a diesel engine, but in a PSS, a (network of) firm(s) could build the engine, install it in a ship but also monitor and maintain it while the ship is operating.

Tukker (2004) identifies at least eight different PSS types in three categories:

1. Product-oriented PSS, where the product is sold but also with an after-sales service contract,
2. Use-oriented PSS where the product is rented or leased to the user together with after-sales services,
3. Result-oriented PSS where a performance or capability is sold (functionality/function/result) (e.g., a level of power provision instead of “an engine” or “a comfortable climate” instead of “air-conditioning” and a specified availability over a specified length of time). Here, the PSS provider offers a customised mix of products and services and the user pays the amount of delivered functionality.

Ceschin (2013) shows how firms have successfully introduced PSS into markets for eco-innovations. It is found that factors for success could be clustered into four groups: the implementation of experiments in a niche, the establishment of a broad network of actors, the development of a shared PSS vision, and the implementation of learning processes. In a market such as BWTS where a demand is already being established, it is the last three factors that form the major challenges to successful market development.

When engaging in innovation towards PSS business models, new producer-customer relationships are required. Pawar, Beltagui, and Riedel (2009) describe a case in which an aero-engine manufacturer sells power. Their service guarantees a certain number of flying hours and minimises maintenance (Johnstone, Dainty, and Wilkinson 2009). They conclude that a PSS provider must create value through the combined design of a product, the service provided and the organisation to provide the service. They identify three stages: defining value, designing value, and delivering value. They argue that this will require that the gap between production and marketing is removed and that resources and capabilities which are not internal to a manufacturer are present. Thus, the collaboration with other partners may be necessary.

10.2.1 SERVICE AND PRODUCT PROVISION IN THE INTERNATIONAL MARITIME INDUSTRY

The maritime industry system connects a complex network of subsidiaries, suppliers and customers (Hameri and Paatela 2005). Figure 17 adapts Dicken's (2011) production circuit to illustrate connections between inputs, service provision, distribution, and consumption in the maritime industry. Shipping lines are responsible for providing transport services, while shipowners may be sub-suppliers to these shipping lines or can sell transport services themselves. Both own or lease different kinds of vessels, which are subsequently used for transport purposes. Vessels are the main assets that are upgraded - either by maintenance or by new additions to the fleet (Lun, Lai, and Cheng 2010).

Shipping lines require new equipment to improve the performance of their fleet. Maritime equipment manufacturers and shipyards provide ship owners or shipping lines with a variety of maintenance and installation services. These "conventional" services may range from retrofitting—upgrading existing vessels with new or improved equipment—to new builds (Hall, Jacobs, and Koster 2011). Alliances among maritime system actors are common: equipment manufacturers become suppliers to shipyards, while at the same time shipyards are suppliers to shipping lines or shipowners. Geographical proximity may influence these alliances, i.e., maritime clusters (Viederyte 2013). However, in globalized industries, such as shipping, equipment suppliers can be located anywhere in the world (Dicken 2011).

Distribution agents are intermediaries between customers requiring freight transport and service providers. Examples of distribution agents are freight forwarders, inland transport providers or logistics providers. Shipping firms are also moving into this part of the market (Antoine Fremont 2009). Companies requiring transport services may be users in different ways. Figure 17 groups them into passenger and ferry transport (including cruise ships), bulk, cargo, off-shore services, and oil and gas industry.

The shipping system is complemented by a second tier of actors which provide competences or service inputs directly needed by the industry. This second tier is represented by the boxes located above and beneath the central square in Figure 17: Technology inputs, competence development, and energy provision. Similarly, other advanced services can be placed here such as insurance, legal advice, and advertising (Hall, Jacobs, and Koster 2011).

In a third tier, Figure 1 presents the financial system and the regulatory framework. In industry, financing is characterized by an important circulation of capital, which in turn is required for investments in equipment and fleet (De Monie, Rodrigue, and Notteboom 2011). Regulation sets the standards for the different activities taking place within the system. At an international level, this is done through the IMO or the EU (for European waters). These international agencies approve conventions and directives that each nation state must translate into national legislation. It is the task of the port authorities to enforce the different conventions. Similarly, classification societies certify that all vessels comply with safety standards (Mensah 2007).

As shown by Figure 17, the maritime industry is characterised by a highly complex market structure, which has traditionally used a variety of contractual relationships between shipbuilders, shipowners and charterers who buy the transport use value of a ship, and hence can be placed in the use-oriented PSS category. An example of such a PSS is the use of bareboat charters, where a shipbuilder builds a ship and then leases it to a charterer, who then operates the ship. Another arrangement is time chartering, where a shipowner leases a vessel to a charterer for a fixed time period. The operation of the vessel may be undertaken by the shipowner or the charterer, and in current markets, firms also exist which specialise in ship management only. Hence, contractual arrangements in two directions can be identified: the application of PSS structures with elements of combined production and on-going services and in contrast, the division of shipping into specialist single activities.

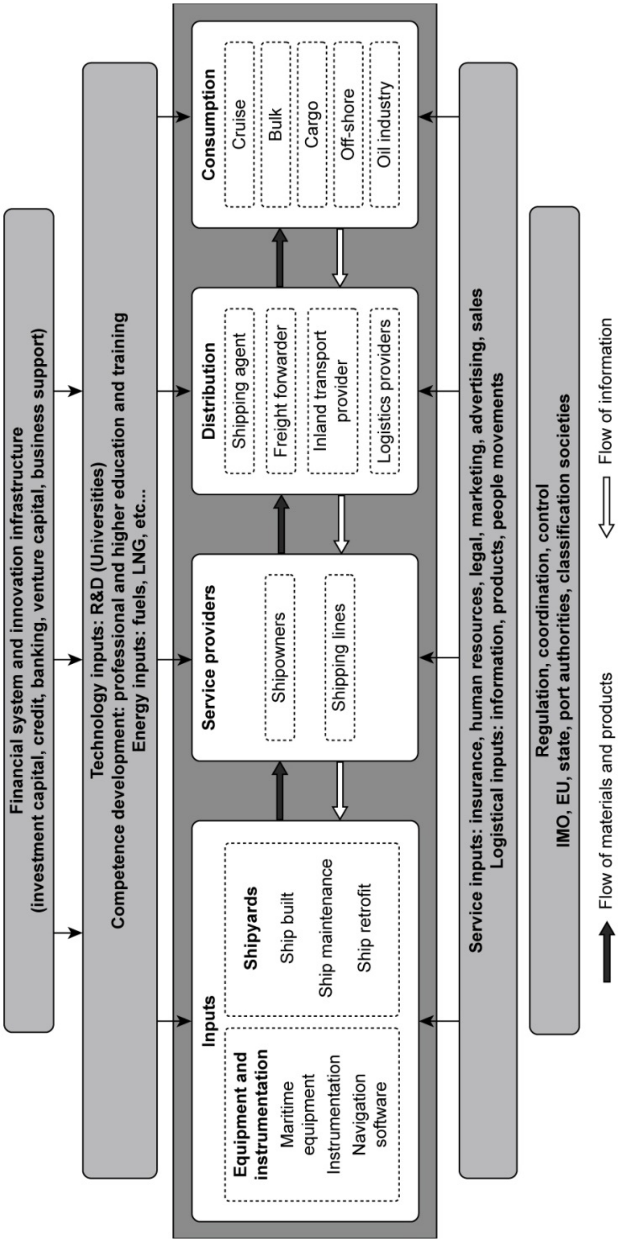

Figure 17 A proposed model of circuits of materials, products and information in the Danish shipping industry. Different actors are involved in supply and demand aspects of environmental maritime technology. Adapted from: (DMA 2006; Köhler 2011; Dicken 2011; Fremont 2009)

These arrangements apply to a complete ship and the transport service that it provides. Modern ships have a wide range of specialist machinery, which the crew cannot repair on board. Therefore, specialist firms are contracted to maintain and repair equipment in addition to production and installation. This is already the case of engines, where specialist manufacturers are not only contracted to service and repair engines, but also provide consultancy services in the design of machinery arrangements for ships. Another example is lifeboats, where a specialist firm builds the lifeboat and is also contracted to inspect and maintain the lifeboat during the operational life of a ship. Other examples in ships are ramps, lifts and also cranes, where the manufacturer builds and installs a relatively complex piece of equipment and is then contracted to maintain the equipment throughout the life cycle of the ship. A PSS can also be applied to electronic equipment such as radar or electronic control systems. Therefore, the maritime industry is one in which PSS offerings are already well-known, and institutional arrangements between shipbuilders, subcontractors, shipowners, and charterers are already developed. This means that new specialist firms who wish to enter the market for ballast water treatment equipment and services do not have to face major institutional and organizational barriers to providing ballast water treatment PSS.

10.2.2 HYPOTHESIS AND PROPOSED ANALYTICAL FRAMEWORK

The analytical framework in Figure 18 illustrates the authors' hypothesis: "Current business models contain elements of PSS in the market niche of BWTS and these elements could be a basis for increasing value in the offering of integrated services and products to the market". The framework, divided in four quadrants, describes the product life cycle in four stages (Scheepens, Vogtländer, and Brezet 2015): production, installation, operation and end-of-life (it is interesting to note that the case study did not reveal attention to the end-of-life stage of BWTS). The main actors in this hypothetical Danish BWTS PSS are represented in circles (technology and manufacturing firms) and triangles (service companies) at four different systems levels which are derived from the Multilevel Design Model (Joore 2010). The customer is placed centrally in the framework. In accordance with the PSS theory, the potential relation between these actors is included: The white arrows represent the value added to the product during its life cycle (black arrows). A linear representation of the BWTS life cycle in Denmark is depicted in Figure 19 in Section 10.4.

In accordance with the case study, the environmental issues associated with untreated ballast water discharge, placed within the societal system level, are the incentive for policymakers such as the IMO at the socio-technical system level to develop regulations addressing these issues. These regulations have spurred the development of mainly on-board BWTS technology and products, placed at the product-technology system level. Based on the case study presented in section 4, marine consultants and shipyards (represented by two triangles in the installation phase), flying squads and other contractors (represented by two triangles in the operation phase) are the BWTS service providers at the Product-Service System level. “Flying squads” are specialized staff from external maritime service firms that could travel around the world to service vessels. The End-of-life phase has not been mentioned by the stakeholders in BWTS, therefore it is assumed that this phase in the product life cycle is not taken into account during current developments of BWTS.

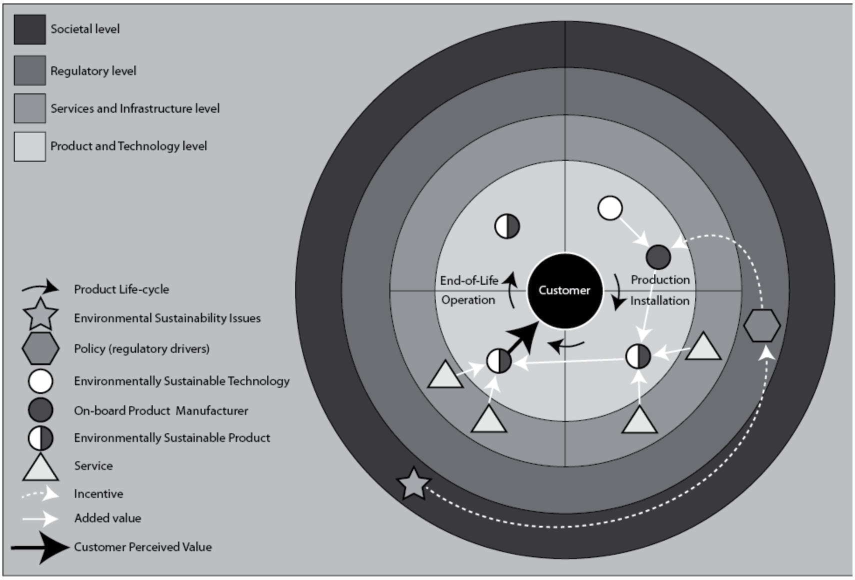

Figure 18 A conceptual framework of PSS for ballast water treatment systems within the multi-level design model

Since it is assumed that the equipment and installations for BWTS currently in development will last the full life cycle of the ship - e.g. 26 years in average for container ships (World Shipping Council 2014) - the environmental impacts of the end-of-life phase are likely to be insignificant compared to the production - and use - phases of the BWTS. This is mainly due to the BWTS energy use over a lifespan of 26 years. In Europe, it is likely that a large share of the BWTS (as part of the ship) waste materials are recycled (Ahuja, Fet, and Aspen 2011), assuming that most of the components are manufactured using (high grade) metals and plastics. This is also the case in the automobile sector, where due to regulatory drivers up to 95% of the materials in cars are to be recycled in 2015 in Europe (Dalmijn and Jong 2007). When regulatory drivers such as the IMO guidelines on ship recycling are applied to BWTS, the environmental impact over the full BWTS life cycle is reduced. Recycling has reduced environmental impacts compared to raw materials mining and processing; in LCA, the recycling of, e.g., metals yields environmental impact credits, where, e.g., landfill adds to the environmental impacts of the system

(Vogtländer 2012). However, performing a LCA of the BWTS is outside the scope of this paper.

What is more important in the context of this paper is that, during current design and development processes of BWTS, the end-of-life stage of the products/PSS appears not to be considered at all. Assuming that this is confirmed in future LCA studies on BWTS, this should not result in massive environmental sustainability issues. Nonetheless, considering the end-of-life stage during design and development is an important recommendation from an LCA perspective to current and future BWTS designers, developers, installers, maintenance providers, manufacturers, and above all, policy makers.

10.3 METHODS

The authors have considered a single-case study design to structure the results. To select the case study, the authors followed an information-oriented strategy, which is one category of selection described by Flyvbjerg (2006). In an information-oriented strategy, "cases are selected on the basis of expectations about their information content". The authors expected to present a critical case, which according to Flyvbjerg (2006) allows "deductions of the type 'if it is (not) valid for this case, then it applies to all (no) cases". The authors agree with Flyvbjerg (2006) that "context dependent case studies" –e.g., generalizable under certain conditions – are also valid means of achieving knowledge. The selection of a critical case had the purpose to increase the possibilities of generalization from a single case.

10.3.1 CASE STUDY AND SELECTION CRITERIA

In Section 10.2.1, the authors explained that the ship repair market is globalized and therefore it is challenging to set national boundaries when analysing business models. In addition, collaboration and trust building among firms have been highlighted as important factors in generating business models leading to PSS (Mougaard et al. 2013) . This endeavour of collaboration and trust building is facilitated by interaction and networking (Mougaard et al. 2013). The authors have considered business models leading to the retrofitting and building of new ships with BWTS by Danish firms as a critical case of study. The first reason is that Denmark counts with an active shipping cluster with the representation of all actors presented in Figure 17 (DMA 2006). Second, in Demark there is a political commitment to support the shipping industry as a key area of economic growth at the national level and in some regions (Danish Government 2012; NIRAS 2014). An important element in these strategies is to support cluster collaboration between national maritime equipment manufacturers and suppliers (Sornn-Friese 2007). Third, some of the most important actors in the shipping/ maritime innovation system have started collaborative network initiatives to develop and prototype environmental technologies, but also network initiatives to consider alternative business models which involve the combination of products and services (Hsuan et al. 2012; Schack 2009).

Following the research questions and the analytical framework presented in section 10.2.2, the authors have considered the case study as the business models for the production/ development, installation and maintenance/operation of BWTS within Denmark. In the analysis, focus was on three units: BWTS manufacturers (suppliers of equipment and instrumentation), maritime service companies (shipyards and consultants) and shipping companies (demand). The authors did not limit the case study to a specific BWTS technology and manufacturer despite the more than 26 systems already approved by IMO (and many more being developed). There were practical reasons for this. First, it appeared that the shipyards and maritime service companies are able to work with different providers of BWTS. Second, shipowners are free to install any of the systems currently in the market if approved by IMO. Thus, the case study focused on a general rather than a specific business model of BWTS. However, since it was not possible to interview all Danish BWTS manufacturers, shipyards, and shipping companies, the authors developed a set of criteria for selecting these interviewees and ensuring representativeness. These selection criteria are expanded on section 10.3.2.

10.3.2 DATA COLLECTION

Empirical evidence was collected between February 2012 and February 2013 through in-depth interviews, document review and participant observation. The authors carried out seven in-depth interviews as shown in Appendix A (section 10.7). Judgement sampling was performed to select these interviewees (Marshall and Rossman 2006). An initial overview of the actors involved in the Danish BWTS innovation system was performed at the outset (as explained in Section 10.2.1 and illustrated in Figure 17). As shown in Appendix A, the authors selected key representatives from different types of stakeholders involved in this innovation system to include in the sample. The sample of interviewees included one global shipping company and the shipowners' association, two BWTS manufacturers, one shipyard, one maritime equipment branch organisation, and a maritime service firm (135 employees). These interviewees were acquainted with business models involved in BWTS and were active participants in several networks of business development in the shipping industry. Although two other Scandinavian BWTS manufacturers were contacted, they did not accept to participate in the study. A summary presents the interviewees' positions within the organisation, see Appendix A. A semi-structured interview guide was prepared before the meetings. The purpose of this data collection method was to guide the conversation while leaving the interviewee free to provide longer answers (Rubin and Rubin 2012). Appendix B (section 10.8) shows a general template of the interview guide.

A document review complemented the interviews. This document review differed from the literature review presented in Section 10.2. The main difference was the kind of documentation and the sources. As Table 20 summarizes, the documents were of different categories (i.e., commercial brochures, websites and international law). To select the document source, the authors first mapped actors in the innovation system of BWTS as presented in section 10.2.1. From this map of actors, the authors considered important documentation which was collected from key organizations as shown in Table 20. A first criterion of selection was to triangulate the information arising from the interviews, for example, to complement specific data about the technology, dates, regulations, etc. A second criterion was that some stakeholders were not interviewed; either they did not give permission to include the interviews in the article or they had no time for interviews. Through a document review, it was possible to include information about their roles in the BWTS business models.

Table 20 Stakeholder and document type used as source for empirical material

Document source	Document type
International Maritime Organization (IMO)	Ballast water convention
	Environmental protection committee documentation (e.g. minutes from meetings, available through the IMODOCs website)
	BWTS technologies approval requirements and status
BWTS Manufacturers interviewed	Technical documentation and websites
Danish Maritime magazines	Newsletters
International green technology maritime magazines	
Danish Branch organizations	Position papers, technical studies
Consultants	Product catalogue
	Commercial presentations
Specialized conferences and seminars on ballast water treatment technology and regulation	Presentations

A third method was participant observation. The authors formed an insider/outsider team (Louis and Bartunek 1992). This method claims that a better analysis of an organization’s affair can be achieved when combining the experience of insiders with the critical eyes of outsiders (Bartunek 2007). One of the authors was a researcher in the Maritime Centre for Operations and Development (MARCOD). This centre provides support to small and medium enterprises (SMEs) willing to start new ventures with environmental service and technologies. As an insider, this author co-organized a seminar on “Business opportunities with ballast water treatment technologies” in March 2013. During the event, around 50 practitioners from BWTS manufacturing firms, shipyards or maritime consultants[12] shared their experiences on business models involving ballast water systems. A consultant also facilitated a brainstorm on possible services that could be associated with these business models. As a researcher in MARCOD, the author also attended two practitioner events in November 2013: the second Copenhagen international ballast water conference; and the Danish seminar on marine product service systems organized by the PROTEUS consortium (Hsuan et al. 2012). Both these events were an opportunity to understand different perspectives from the business models involved in the current ballast water treatment technologies and to identify interviewees. The authors have included some of the reflexions from these seminars as part of the case study.

10.4 BALLAST WATER TREATMENT SYSTEMS BUSINESS MODELS IN DENMARK

The findings from the case study are grouped into the following three categories (Figure 19):

- Market context and system development
- Installation new build/ retrofit
- Operation

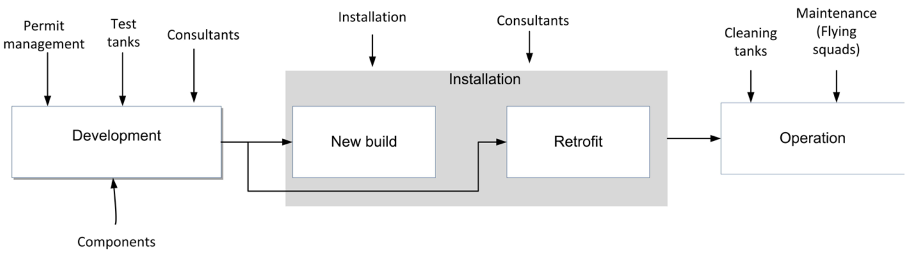

Figure 19 A linear model of BWTS production and service flows. The model comprises three main parts: development, installation and operation. The different products and services that can be provided are listed as arrows in the model.

[12] The presentations of MARCOD’s events are available at http://www.marcod.dk/arrangementer/konferencemateriale/38-materiale-fra-konference-om-forretningsmuligheder-inden-for-ballastvand

10.4.1 MARKET CONTEXT AND SYSTEM DEVELOPMENT

For maritime service firms, the current context will determine the future growth in the market of ballast water treatment technologies. The installation of ballast water treatment systems has begun, even though the ballast water convention is not ratified by the minimum number of IMO member states required. However, the installation of systems is proceeding at a very low rate and the market growth is small. This is the result of shipowners' interest in avoiding large investments before January 1, 2014. The IMO convention does not require the retrofitting of ships before that date. For this reason, most systems are currently installed on new builds, and few are installed on retrofitted vessels:

> I think we haven't really started the retrofitting yet, because we don't have the Convention in place. The convention was agreed in IMO in 2004, but we still need 30% of the world fleet to sign on, before it is entered into force. It will be enforced twelve months after the ratification. So, that's why we still, I mean, our members will not go and retrofit before they are totally sure about the future regulation. Despite the fact that the convention was agreed upon in 2004, we are still discussing amendments to the convention, so as part of that discussion we are actually working on changing the implementation dates for the existing ships. If you have a big tanker or bunker, you will first have to install equipment in 2019 or 2020. Then you are not going to do anything. We have a lot of members who will be in that situation. We see installations on new buildings (as I see it), but we don't see many retrofits (Interview 3).

Despite this apparent inertia from a shipowner's perspective, while the negotiations are going on at the IMO, shipowners are very active in their networks. There are ongoing assessments of different technologies and service partnerships with suppliers. An example is the Danish partnership for ballast water. The partnership organizes match-making meetings and specialised seminars to seek cost-efficient ways to comply with the regulations:

> No, we are more into meetings and conferences at the moment. We had a meeting about land-based solutions last time, we made together with MAERSK, DFDS and Danish Ports, and then there have been other projects as well. The projects may be supported by the [Environmental Ministry], and they have a call right now. We wait to see which projects they will support and then people will start discussions. So far, no technology development or demonstration projects (Interview 3)

Manufacturers react to this situation in three ways: manufacturing a few units with local resources and suppliers, getting the permits to commercialize BWTS ahead of the competition, and looking into innovative systems. Until the convention is enforced, most activities are centred on securing the right system permits (IMO and

USCG). Similarly, the production of the systems is at very low rates, mostly with local manufacturing (e.g. in Denmark) with most suppliers of components among local firms (e.g. UV lamps or steel components). The manufacturers have, however, acknowledged that this may not be sustainable when the demand increases considerably.

The Danish maritime branch organization (Danish Maritime) considers it to be preferable to support Danish R&D companies to look into second generation ballast treatment systems. The main reason is the large offer of first generation systems already in the market looking for permits (e.g., currently 26 with Type I approval at the IMO). Many of these systems are developed by South Korean and Japanese firms with strong connections with shipyards in Southeast Asia. A couple of Danish companies are developing "second generation BWTS". These second generation systems will be developed for direct use on vessels and not as land-based technologies adapted to the vessels (Interview 4). An example of such land-based systems is port-based ballast water treatment. In a first principle of operation, "ballast water is treated at the port of departure and discharged at the destination without further treatment". A second option is when "ballast water is taken in without treatment and treated immediately before discharge at the destination" (COWI 2012). An advantage of port-based systems is that shipowners will not have to invest in installation, maintenance or retrofitting (COWI 2012).

10.4.2 INSTALLATION

Installations can take place in two ways: in new builds and by retrofitting older vessels with ballast water treatment technology. Different business models are involved in these markets. Shipowners decide that new builds are to be delivered with the BWTS because it is easier to install the system during the construction than it is in a later retrofit (Interview 3). The date when the convention will enter into force is still uncertain. However, from the manufacturers' perspective, the market share for installation of BWTS in new builds was small in 2012:

> What we are seeing is that 2012 has been a year with very low activity in the new building market. Very few new builds have been contracted. What you can say is that in the [BWTS] market is very weak for new buildings right now (Interview 6).

Most new builds are produced in Southeast Asian shipping yards (mainly China and South Korea), with a close relation between shipowners and shipyards in terms of related services and products. Therefore, there are fewer opportunities for external service firms. The BWTS manufacturers receive an order from the shipyard, and what the shipyard needs is the system delivered in components. The shipyard then installs it, and does all the pipe work, electrical installations, etc.:

> When it comes to new builds, strictly speaking, the customer is the shipyard. But of course, the shipowner has also something to say, on which system to put on their vessels (interview 6)

In the retrofit market, more opportunities exist for collaboration between manufacturers, shipyards and other maritime service firms. For BWTS manufacturers, these opportunities exist and they are continuously looking for options of collaboration with maritime equipment installing firms. Part of this collaboration is focused on the early stages of engineering assessments (calculations, detail drawings, etc.). Then, another firm can install the system on board. All these additional services should be reflected in the quotation handed to the shipowner:

> Sometimes the shipowner will ask you to make a complete retrofit. For example [the shipowner] will ask: "What is the price to equip my vessel with this system?" Design, installation and delivery will be a total price for that delivery. We can work with the business model that we take the responsibility of everything, but then we will need to carry joint projects in collaboration with some others. But we cannot take out the whole responsibility. In other cases, we will remain, we just send the components to the dock, and we have done our part. It depends on the shipowner, on the shipyard, what they agree (interview 6)

This manufacturer-centred business model could change to a shipyard-centred model (similar to the new builds explained above). Depending on the complexity of the installation, the ship must be taken out of operation for some weeks and be serviced in a dry dock. Because this entails loss of revenue, it is an important business decision from the ship operator perspective. The shipowners may already have planned a refit at a given shipyard. In that case, the BWTS installation can be an extra task for the servicing shipyard on top of a normal service stop and the shipyard will only require the system and the technical details from the manufacturer. In Denmark, a shipyard has already installed four BWTS with this business model. The vessels had a Norwegian BWTS installed at the request of the shipowner.

Previous to the installation, calculations must be performed by an external naval architect. These calculations assess the exact location of the different modular components of the systems within the vessel. The owner approves, involving close communication with the BWTS manufacturer. Then, the installation follows as a normal part of a refit by the shipyard staff. This involves making the foundations, pipe work and electrical connections (interview 5). From a shipyard perspective, it is the shipowner who decides which system goes in the vessel, and there is no imperative to require a binding agreement with a specific BWTS supplier.

In any case, manufacturers and shipyards agree that the shipowner will have the last word on where the installation is to be undertaken. Some variables that come into play are where the vessel usually sails, what are the comparative prices of shipyards, etc. Manufacturers have considered this as problematic; they want to compete globally with other companies in Asia (for example).

Ways to tackle this are either by sending a specialist from the BWTS manufacturer to supervise the installation or by hiring other companies which have already installed the BWTS system that has been chosen. It is, however, important to have close supervision along the whole installation because "you can never teach a yard in total to do everything, that will be difficult and definitively not all yards [will be able to be trained as fast]. Maybe, some few yards will be trained on location or something like that" (Interview 6).

10.4.3 AFTER SALES AND OPERATION

The operation phase of BWTS provides some opportunities for the integration of product and services into one package. One reason is that shipowners focus their business on transport, and would welcome integrated solutions that will outsource the maintenance of ballast water treatment technology to the supplier (Interview 2). Although no formal PSS is already in place with this profile, the possibility is being considered by manufacturing and service firms:

> I think that the big players will do it themselves. But there may be opportunities in relation to the smaller companies if they could make a package so to speak. If they can say we can make sure that it can be installed and it will be working and perhaps there is a possibility (Interview 3).

The possibility is already being considered by one of the Danish BWTS suppliers:

> We will do it ourselves with our network. Likewise with the automobile shop, they don't want to earn money with the new cars but with repairs (Interview 6).

In practice, this could be translated into some partnerships in different harbours in the world, but also agreements with "flying squads". The idea is for the shipowner to purchase a "package" once the shipowner pays for the BWTS. Manufacturers consider the following requirements to set such service agreements:

> One thing which is important when you look at these… it has to be a company with certain size and experience within the industry and also very used to working globally, because we don't expect that the majority of our systems will fit in Danish repair yards or something like that. It will be global, because the shipowner will take their ships in docks where they have agreements or where it is already trading and so on. It is really global. You really

> need to team-up with companies that already have experience with this and are used to having people working in Asia, middle-East (Interview 6).

Shipyards, on the other hand, are less likely to get involved in these maintenance agreements on a long-term basis:

> The service is the responsibility of the [BWTS] manufacturer. They do that where the vessel is, we don't service the BWTS within the vessel because that is the manufacturer (Interview 5).

The reason is that, from a shipyard perspective, the tasks of the shipyard are best narrowed down to the installation. More technical and precise maintenance –not requiring a long stay in the shipyard – is a manufacturer's commitment:

> As a shipyard, we are not promoting a maker. But if someone comes to us tomorrow, an owner, they don't have an idea what to use. We will recommend this system. But one thing is what we know about installing it and another thing is working with it on the day-to-day basis. We don't know if it is easy. But we don't interfere with the choice (Interview 5)

10.5 DISCUSSION

The research questions will be elaborated based on the results presented in Section 10.4.

In relation to the first question considering which business models are being used to develop, install and service the BWTS; it can be said that different business models also operate in segregated phases of the BWTS life cycle: manufacturing, installation and operation. Manufacturing is characterised by a relatively small demand of BWTS (since the convention is not yet entered into force). The business model is organized by manufacturers with mostly local manufacturing of a few demonstration units. Installation and operation also have differentiated business models. In the installation phase, the shipyards play a major role by coordinating what is installed on board of a new or retrofitted ship. Shipyards become hubs of collaboration between shipowners, manufacturers and contractors. The business model in the operation phase of BWTS is more relevant to manufacturers and service companies than to shipyards. Manufacturers avoid a strong fixed dependency on a single shipyard that may limit the manufacturers' ability to make extensive contacts worldwide. The capability of maritime service firms to provide prompt responses through, e.g., flying squads gains a large relevance here. Once the ballast water convention is put into force and the demand of BWTS and services increases dramatically, manufacturers may well lack the staff to service the industry.

The case study results did not show that the business models in these three phases can be defined as a result-oriented PSS. A characteristic result-oriented PSS will be that in which shipowners pay by the volume of water treated and not by the BWTS, with the actors (manufacturers, shipyards and contractors) selling the product-service system to the shipowners. In the case, however, BWTS are still considered as a product; shipowners pay separately by installation and for a possible aftersales service.

The second part of the hypothesis proposes that current business models have the potential to generate value through a possible PSS. The second research question deals with this issue in more detail by explaining how these business models can add value to the BWTS market. The case highlighted the importance of rethinking the concept of BWTS, which should be seen less as a product and more as a system of services that could be built around BWTS products. In particular during the operation stage, shipowners may be interested in paying per volume of treated ballast water, while concentrating their energies on their transport business. In this way, BWTS consortia could propose complete packages of installation, service and monitoring, enabling shipowners to outsource the entire process required to comply with the proposed regulation and its potential future follow-ups. This PSS concept should be designed by a consortium to deliver the required value for the shipowner whilst minimizing the environmental impacts associated with ballast water discharge in order to maintain and improve the competitiveness of the offering. The main question is thus how to design a PSS concept that achieves competitive value for customers of BWTS, whilst minimizing the environmental impacts. In the long term, the BWTS is also expected to yield competitive value for the PSS consortium, since future regulation compliance is ensured through continuous environmental impact reduction innovation. Tukker (2004) argues that when moving from product-oriented PSS towards result-oriented PSS (moving towards a service economy) the potential for environmental impact reduction and perceived value for the customer increase.

This coincides with the eco-efficient value creation (EVC) theory (Vogtländer et al. 2013) in which the Eco-costs/Value Ratio (EVR) model is suggested as having the potential to support eco-efficient value creation (EVC). The aim of EVC is to design solutions that increase the customer-perceived value whilst reducing the relative environmental impacts. . Simultaneously creating customer perceived value for environmentally sustainable offerings ensures market penetration. Therefore a qualitative EVR analysis is performed for designing a sustainable PSS concept for BWTS in terms of EVC.

In general, two types of BWTS can be discerned: on-board BWTS where the ballast water is treated on-board before discharge and port-based BWTS where the untreated water is discharged into BW processing facilities in a port. It appears that the main business focus is on on-board BWTS, since many ports do not have a BW discharge system and the treatment facilities required for a port-based system. However, a port-based treatment facility has several advantages in terms of eco-efficient value creation:

- The ships themselves do not need to be (re)fitted with complex BWTS, reducing the investment costs for shipowners.
- A lower relative energy consumption of the ship during operation: more goods can be transported since less room and weight are required for the BWTS.
- The BWTS is used much more frequently in a port-based system than on a ship: The BWTS processes ballast water of every ship coming into the dock, whereas an on-board system only processes its own ballast water. This should result in cost reduction for the shipowners, due to a more efficient operation of the BWTS.
- The measure is implemented at the place where the problem occurs: in the ports of destination.
- Expensive maintenance such as flying squads is no longer necessary for servicing the BWTS during operation.

These advantages both potentially increase the value perceived by the customer as well as the eco-efficiency of the operation of the service. Hence from an EVR design perspective, the port-based type BWTS PSS has the highest potential for EVC. Of course, there are several issues with such a PSS concept, as yet seemingly left unaddressed by individual companies or PSS consortia:

- No standards are set (yet) by the IMO regulation on the type of connection between ship BWTS and ports.
- Such a PSS would only work well if every port had such a system installed. PSS consortia should investigate whether it would be possible to install port-based BWTS in the necessary ports in order to be able to offer a BWTS service to shipowners wanting to comply with the IMO regulation.
- Substantial investments are required to fit ports with such systems, but on the other hand, this could provide a unique competitive edge compared to on-board BWTS offerings. Although indications have been found that port-based systems tend to be more expensive (King et al. 2012; COWI 2012), costs such as the so-called flying squads have not been taken into account in these analyses. Therefore, it still remains questionable whether such port-based systems really turn out to be more expensive: *"The estimated cost of the on-board treatment seems somewhat lower than the calculated treatment cost of the best case; however, that needs to be investigated further, taking all conditions into account, to reach a more solid base for comparison between the concepts."* (COWI 2012). In terms of customer perceived value (for shipowners) and eco-efficiency, port-based systems are preferred over on-board systems.

Therefore two possible venues can be defined for PSS consortia wanting to achieve EVC:

- Push the IMO regulation directed at shipowners to ports experiencing the problems of BW discharge
- Or invest heavily in port-based systems for ports experiencing BW discharge issues, potentially giving the consortium a competitive edge over on-board BWTS manufacturers and consortia.

Both venues should result in a more service-based economy, creating competitive value for customers of BWTS whilst minimizing the environmental impacts associated with BW discharge. The proposed framework for port-based systems as an alternative to on-board systems is depicted in Figure 20.

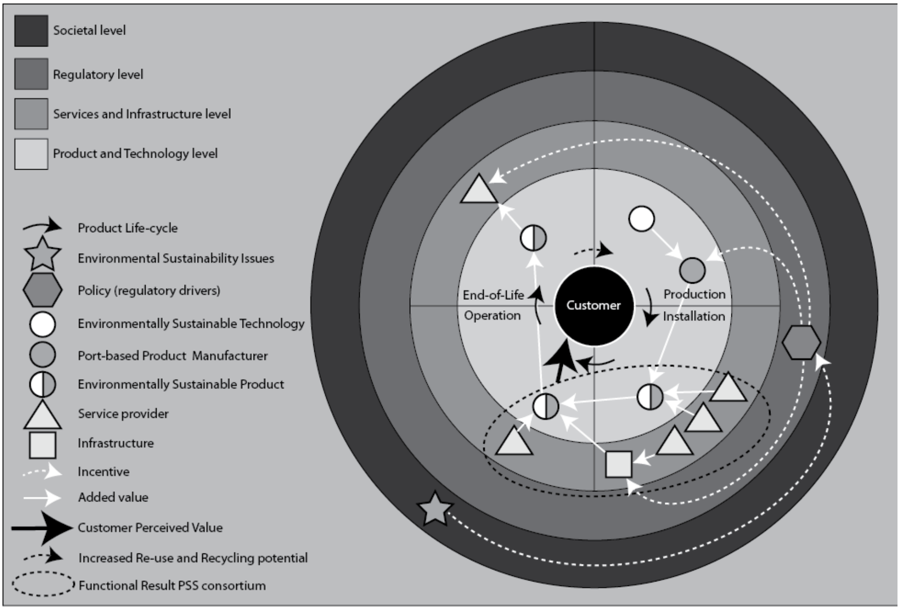

Figure 20 Proposed Functional Result PSS conceptual framework for port-based BWTS

The framework as presented in Figure 20 shows that the customer (shipowner) now also has the possibility to completely outsource the responsibility for compliance with, in this case, the IMO regulations. The consortium would be able to offer different configurations of products and services, payable by the amount of, in this case, ballast water treated. This means that there is no transfer of ownership of the products; therefore the responsibility of operation lies with the consortium. This has several benefits for the customer as well as the environment: End-of-life re-use, component re-use, remanufacturing and recycling are made easier, the product quality is enhanced, and less effort and risk are required of the customer to maintain operation. Port-based systems will also be beneficial to maritime service firms in the PSS consortia. These firms are usually hired by shipyards to carry out activities linked to the installation or maintenance of on-board systems. However, the operation of port-based systems can become an extra market for maritime service firms.

Despite these advantages of port-based systems, on-board systems are diffusing at higher rates in the international shipping industry. Since many ports do not have port-based and port-serviced BW facilities (infrastructure), and many ships will need to comply with IMO regulations, in the short term, on-board systems are the most applicable solution. Then the ships can sail to any port and discharge their BW after it has been treated on the ship. This underlines the importance of an adequate regulation development: in order to stimulate, e.g., port-based BWTS systems development and implementation, additional or different regulations are required, such as subsidizing port-based BWT facilities.

The case study material shows that Danish firms are actively engaged in developing their presence in the market for BWTS. They are dependent on relationships with operators and shipyards in Scandinavia and globally. They are applying the PSS concept for BWTS service provision to some extent, but have not yet fully developed the market potential through the PSS approach.

10.6 CONCLUSIONS AND FUTURE RESEARCH

This article has looked at business models for the case of BWTS in Denmark, using the PSS framework. This is a new market, created by international regulation from the IMO on ballast water management. Ballast water discharges have been recognised as an important environmental impact from shipping. This section first summarizes the main practical and theoretical implications, and then it provides suggestions for further research.

The article has three major practical implications: First, the case of Denmark shows that a western European maritime sector is entering into the market for BWTS. In spite of the East Asian domination of the shipbuilding industry, Western European specialist firms are still competing for equipment supply and service provision in a market which has been estimated to have a potential value of US $50 to $74 billion between 2011 and 2016 (King, Riggio, and Hagan 2010).

Second, the installation phase is driven by the shipowners' needs of installation and geographical service. The operational phase provides new opportunities for links between manufacturers and maritime service companies. Packages of products and services are especially welcomed by shipowners in this phase. While there are elements of a combined installation and service approach, the full potential of a PSS has not yet been exploited.

Finally, the EVR model has been found to be a valuable tool for developing future business strategies for eco-efficient value creation in BWTS. It provides direction for innovation on a product and PSS level, as well as for business strategies and regulation development. The model also indicates that the regulation could be refined towards stimulating port-based BWTS, instead of onboard BWTS.

The major theoretical contribution of the article has been to extend the PSS framework with the eco-efficient value creation (EVC) theory, using a qualitative Eco-costs/Value Ratio model approach. The case of BWTS in Denmark extends the literature on PSS through the consideration of the maritime industry, an example of a complex OEM-supplier structure with the business dynamics of a new market that is being created through environmental regulation. This extension of the PSS approach is generalizable to other industries with similarly complex OEM-supplier structures, where new eco-technologies are being developed for the product. Two examples of this are the development of fuel cells and batteries in the automobile industry (Köhler 2012). The in-depth case study of BWTS shows that the ballast water regulation is certainly the main factor behind the development of BWTS. This is therefore an example supporting the perception that environmental regulation is often the cause of eco-innovation (Köhler 2012; Walz and Köhler 2014). However, the regulation itself explains little about the emerging service and product-service combinations in the industry. These were identified through the case study analysis as being based on current business structures in the shipbuilding industry. In the case study, current business structures provided more opportunities for new entrants (e.g., small and medium-sized maritime service enterprises). It is not possible to draw general conclusions about the most suitable product and service combinations in eco-innovations. A case specific analysis of the combination of industrial production structures and the particular environmental regulation is necessary to determine the potential for new production structures using PSS.

Future research could be, in the first place, firm-centred perspectives which explore, for example, which capabilities are necessary to implement or develop the links between manufacturers and maritime service companies. Another research avenue for future development could highlight the impact of the regulation in the implementation of sustainable business practices. Thereby, it is essential to further investigate the feasibility of port-based BWTS versus on-board BWTS. Finally, the current business models and regulatory drivers do not consider the end-of-life phase. It would be useful to explore how the end-of-life of BWTS is expected to be handled by manufacturers and service providers in a business-as-usual and a PSS model.

10.7 APPENDIX A. INTERVIEWS TO BUILD EVIDENCE ON THE CONTEXTUAL CONDITIONS

Table 21 List of interviewees and type of organization

#	Date	Type of organization / relevance to the case	Interviewee position within the organisation	Duration (Min.)	Where was the interview performed?
1	February 2012	Maritime service company/ The company provides contracting services in its yard but also through "flying squads". Actively involved in local and national networks. Partnership with a BWTS manufacturer to carry BWTS installations.	Chief technical officer	60	Company's headquarters, Frederikshavn, Denmark
2	October 2012	Scandinavian-based global Shipping company/ Shipping company with 5700 employees worldwide Car-carrier and Roro vessels as main business area	Fleet manager responsible for a BWTS comparison assessment	*	Aalborg
3	February 2013	Shipowners' Association/ Industry branch for the Danish shipowners. Co-Coordinator of the	Consultant; Partnership spokesperson attached to Danish Shipowners'	30	Copenhagen

		partnership with ballast water (Along with the Nature Agency)	Association		
4	February 2013	Danish Maritime/ Branch organisation for maritime equipment suppliers Coordinator of Retrofit project/ member of the PROTEUS consortium/ MARCOD network and many other initiatives	Business consultant; project leader for retrofit project	58	Copenhagen
5	February 2013	Shipyard Active shipyard with 230 employees; local hub for sub-contractors; have installed several BWTS to Scandinavian customers	CEO	30	Frederikshavn
6	February 2013	BWTS manufacturer Danish manufacturer with IMO approval	CEO	52	Nørresundby, Aalborg
7	March 2013	BWTS manufacturer American BWTS manufacturer but with business relations with Danish shipowners and shipyards	CTO/ Country representative	40	Frederikshavn, subsidiary of American BWTS manufacturer

(*) Communication with this source was through email.

10.8 APPENDIX B. TEMPLATE OF SEMI-STRUCTURED INTERVIEW GUIDE

Semi-structured interview guide with shipping liners/ shipowners

1) Firm's and IMO ballast water convention (Interviews with shipping liners/ shipowners)
    a. Firm's strategy for compliance
    b. Systems suiting firm's needs
    c. Collaboration with manufacturers and authorities
2) Pure-ballast water treatment system (interviews with equipment suppliers)
    a. Background of its development
    b. Relation with the Danish partnership for ballast water
3) Ballast water treatment systems
    a. Installation
    b. After sale service
    c. Consultants/ ship architecture design
    d. Spare parts
4) New services
    a. Retrofitting
    b. Collaboration with shipyards
    c. Opportunities for suppliers

11
THE FUNCTION OF INTERMEDIARIES IN COLLABORATIVE INNOVATION PROCESSES: RETROFITTING A DANISH SMALL ISLAND FERRY WITH GREEN TECHNOLOGY

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ABSTRACT

Intermediaries are actors who perform several functions during innovation processes, i.e., brokering and networking. The functions of initiation and coordination of innovation processes have not been analysed in details yet. In this article, the aim is to analyse: How do intermediaries support collaborative innovation processes taking place in green maritime technology projects? The case study of a Danish small island ferry retrofit shows that intermediaries are important to stage the collaboration between actors. They can provide functions to the incipient network as foresight, brokering, increasing network connectivity, and scanning of information. However, intermediaries can have also a proactive role in shaping the emerging innovation pathways. In this case study, intermediaries negotiate each partner's role and define the goals of the project. The results contribute to the broader eco-innovation literature by analysing intermediation in innovation with a process perspective.

Keywords

Innovation intermediaries; Intermediation; eco-innovation; demonstration projects; Collaboration; Green maritime technology; Ferry; Denmark

11.1 INTRODUCTION

In technological development, demonstration projects are innovation initiatives with a high degree of uncertainty (Frishammar et al. 2015). When demonstration projects are carried out in collaboration among different organisations, they become important devices to learn about new environmental technologies which are not mature enough to compete with conventional technology in the market (Geels 2011). Because of their collaborative character, the actors participating in these initiatives often engage in open innovation processes (Chesbrough 2003). Inter-organisational collaboration can lead to challenges such as cognitive barriers, different norms or incentives, information and managerial gaps among partners, etc. (Klerkx and Leeuwis 2009). Partly to address some of these challenges, innovation intermediaries are suggested as nodes in inter-organisational networks which can "perform a variety of tasks in the innovation process" (Howells 2006). This variety of tasks implies diverse broad functions as for example: diffusion and technology transfer (Roxas, Piroli, and Sorrentino 2011), innovation management (Hargadon 2002), "architects", co-creators, managers, and enablers of collaborative processes with a high degree of uncertainty on the outcomes (Agogué, Yström, and Le Masson 2013).

Despite the comprehensive literature on the role of intermediaries in innovation, the functions of intermediaries are not well known in collaborative innovation processes related to the development of demonstration projects of green technologies. The following research question is addressed in this connection:

How do innovation intermediaries support collaborative innovation processes taking place in green maritime technology demonstration projects?

A case study design is applied with an innovation process perspective (Van de Ven et al. 1999) to understand the functions that intermediaries play in collaborative demonstration projects. The context of the case study is the Danish maritime sector, in which incumbent members from the value chain of the shipping industry have joined various nationwide partnerships and networks for development of green technology. These initiatives were first inspired by changes in the international environmental legislation, which pushed the shipping industry to innovate in terms of how to reduce the emissions of air pollutants (SO_X and NO_X) but also how to design eco-efficient vessels and equipment to reduce operational costs. In the municipality of Frederikshavn in Northern Denmark, medium-sized enterprises (SMEs) and large firms supply products or services to the local yards or to shipping companies. These firms have found a market niche in the design and development of eco-friendly small island ferries (Mosgaard, Riisgaard, and Kerndrup 2014b;

Mosgaard, Riisgaard, and Kerndrup 2014a), but have also an increasing interest in retrofitting larger ferries or any other type of vessels with green technology.

The case study is about the green retrofit of the ferry linking the small Danish island of Læsø with the town of Frederikshavn. The analysis covered the whole project period (2010-2014). As explained with greater detail in section 11.3, an innovation process perspective follows the analysis of key events that shaped the project. With a basis in the conceptual framework presented in Section 11.2, the authors analyse the functions played by the two innovation intermediaries Frederikshavn Business Council and the Maritime Centre for Operations and Development (MARCOD) during these key events.

The structure of the article is as follows. The conceptual framework is presented in section 11.2, and elaborates on the role of intermediaries with a focus on the initiation and development phases of the innovation process. In section 11.3, the authors present the research methods. The findings and discussion is in section 11.4, while the conclusion on the article is in section 11.5 that also presents suggestions for further research.

11.2 CONCEPTUAL FRAMEWORK

The conceptual framework combines the literature of innovation processes with that of the functions of intermediaries. The purpose of combining the two set of theories is to achieve a better understanding of how demonstration projects are initiated, how collaborative networks are established and what influences innovation pathways during the development of products. The literature on intermediation provides a better understanding of the functions played by the intermediaries in these processes.

Innovation processes are defined in this article as the set of events which take place to create and modify new products, processes, or services. These events occur through a journey composed of three general periods: invention (initiation), development, and implementation (Van de Ven et al., 1999). Current models of innovation processes acknowledge the iterative and retrofit loops between these three general cycles (Rothwell 1994). In the period of initiation, several solutions to a given problem may be proposed; then a filtering of these solutions takes place with the intention to have a possible product. External "shocks" or factors can motivate the selection of one of the possible solutions until the firm managers allocate resources for the next period (Van de Ven et al. 1999). The period of development implies improving the ideas from the previous cycle of invention. Management provides resources for this improvement, and in this period, several convergent or parallel activities and products are generated –so-called innovation pathways (Garud, Tuertscher, and Van de Ven 2013). The period of implementation implies introducing the innovation into the market, through several activities as, i.e., transferral to potential customers and diffusion to a large number of users (Van de Ven et al. 1999).

Demonstration projects are key learning elements in a subsequent full-scale implementation or commercialization of the product (Frishammar et al. 2015). Following this scope and from an innovation management perspective, a collaborative demonstration project covers the cycles of initiation and development, but not the cycle of implementation, when the product is meant to be commercialized and diffused to a wide market of users (Van de Ven et al. 1999).

Whereas the firm is the usual locus of innovation processes (Pavitt 2006), from an open-innovation perspective, innovation processes can spur out of the organisational boundary in multi-party networks or communities, as the firm can benefit from external research and development (R&D) by intellectual property (IP) and knowledge exchange (Chesbrough 2003; Garud, Tuertscher, and Van de Ven 2013). Innovation intermediaries function as nodes that can perform different functions to facilitate the exchange of knowledge, among other activities in networks (Hansen and Klewitz 2012b; Johanna Klewitz and Hansen 2014). In this article, the focus is on demonstration projects with inter-organisational collaboration mediated by intermediaries –multi-party networks (Garud, Tuertscher, and Van de Ven 2013). Sections 11.2.1 and 11.2.2 present the functions of intermediaries during the initiation and development periods.

11.2.1 INTERMEDIATION IN THE INITIATION PERIOD OF INNOVATION

The initiation cycle is preceded by the "gestation" of the innovation ideas, which can span over several years (Van de Ven et al. 1999). Characteristic activities during the initiation period include idea generation and assessment, concept development, and market analysis (Herstatt and Verworn 2001). This process is usually chaotic and is filled with trial and errors (Kim and Wilemon 2002). One reason for this chaotic beginning is the recombination which is the main mechanism behind the initiation period. Recombination implies drawing ideas from different sources and combining these ideas in new ways; i.e., other organisational units, different organisations, and different sectors, which can eventually lead to a creative solution to the problem (Hargadon 2002).

In collaborative innovation initiatives, intermediaries can perform different functions to support the network during the initiation period. In case no inter-firm collaboration is in place, a first group of intermediary functions relate to how to initiate collaboration and joint projects between firms (Lefebvre 2013):

Broad networking: The intermediary organizes several activities with the purpose that organisations get to know each other, discuss complementary aspects, and eventually strengthen their relations overtime to initiate joint R&D projects. Examples of activities are one-day workshops or study tours.

Setting up permanent workgroups: These groups are set with a reference to the network's main themes and focus areas. The intermediary invites firms working under the themes. Challenges appear for firms with limited R&D resources or no possibilities of allocating resources to the project.

Setting up temporary ad hoc groups based on (emerging) sub-themes: Workgroups are initiated around themes suggested by the network members, rather than predefined by the intermediary organisation. The intermediary has the function to decide which firms to invite to the workgroup meetings, with the selection criterion that the firm will provide a meaningful contribution to the workgroup.

If the collaboration is in place, the intermediary can provide other functions with the goal of diffusing knowledge among partners of the network (Agogué, Yström, and Le Masson 2013). The following are brokering functions (Howells 2006):

Foresight, forecasting and technology road mapping: The intermediary support is to define the needs and requirements that the firm should have to keep up to date with the newest technological developments (Klewitz, Zeyen, and Hansen 2012). Market forecasting has been suggested as one example (Lichtenthaler 2013). With a case study of the fashion industry, Tran et al. (2011) suggest that foresight and forecasting cover the analysis of trends and competition and the organisation of site visits to identify new developments.

Scanning and information processing: The intermediary facilitates knowledge circulation into the firms within the innovation system. This is the case of joint research centres that build absorptive organisational capacity in SMEs to participate in open innovation processes along with other organisations in the innovation system. Examples of the activities that they perform are knowledge intelligence services (gatekeeping, technology watch, road mapping), organizing study days, keeping technical repositories, technical libraries, etc. (Spithoven, Clarysse, and Knockaert 2011).

11.2.2 INTERMEDIATION IN THE DEVELOPMENT PHASE OF INNOVATION

A milestone of the development period is the allocation of a budget from the partner organisation(s) to the project activities. Once the budget is in place and organisations start to develop the innovation, several possible prototypes can be developed in divergent innovation pathways. Prototypes become important to connect people and contextualize the product in the social setting (Garud, Tuertscher, and Van de Ven 2013). The creation of different prototypes as a result of different innovation pathways may result in setbacks or in more successful products, which will ultimately be improved to launch to the market (Van de Ven et al. 1999). Therefore, Garud, Tuertscher and Van de Ven. (2013) have defined the development phase as one in which many actors are involved and not all of them face a win-win situation.

Innovation intermediaries can support the partners during the development period by providing the following functions:

Testing, validation and training: Some intermediaries can provide infrastructure support in the form of test chambers, laboratories, prototyping, and pilot testing facilities. Other functions of intermediaries are validation of the technology being developed and joint training in the use of these new technologies (Howells 2006).

Knowledge processing, generation and combination: From this perspective, intermediaries are organisations or individuals with a broad palette of skills and knowledge from different industries. In this way, the intermediaries are able to "recombine" knowledge from different industries (Gassmann, Daiber, and Enkel 2011; Hargadon 2002). This process of recombination has been extensively analysed by Hargadon (2002) through the knowledge brokering model of innovation. This model implies that intermediaries (organisations or individuals) gain access to the resources from multiple institutional, organisational domains (small worlds), which are unknown to other domains. Later they share these resources and knowledge in new contexts (industries, sectors). Gassmann, Daiber, and Enkel. (2011) present examples of service organisations in three categories: innovation multipliers (service organisations that multiply their technological specialization in different domains), innovation leveragers (contribute to cross-industry projects by applying methodological and technical knowledge from previous projects), innovation broadeners (often lack in-house capabilities but rely on their methodological skills and networking to find appropriate ideas for inter-industry recombination projects).

Accreditation and standards: The types of activities that innovation intermediary organisations carry out are: setting specifications or providing advice on standards or formal verification of standards (Howells 2006).

The conceptual framework position collaborative demonstration projects in the periods of initiation and development according to Van de Ven et al. (1999). The conceptual framework also summarizes the main functions of intermediaries in both periods.

11.3 RESEARCH DESIGN AND METHODS

A case study strategy is followed in order to present a descriptive analysis of the role of intermediaries in an innovation process. Case studies provide an in-depth understanding of the unit of analysis, resulting in complete and rich accounts, while at the same time making it possible to draw generalizable conclusions that are applicable to other contexts (Flyvbjerg 2011). The authors have wished to analyse one example of collaborative environmental demonstration projects, from which insights could be generalized under given situations.

11.3.1 CASE STUDY

A single case study design has been applied (Yin 2003). The boundaries of this case were defined as the innovation processes taking place in the project "Green Læsø Ferry" in the period of 2010-2014. The authors selected the case following an information-oriented selection: *"cases are selected on the basis of expectations about the information content"*(Flyvbjerg 2011). In Denmark, several initiatives are trying to build collaborative innovation projects in the shipping industry (Rivas-Hermann, Smink, and Kerndrup 2014). In these initiatives, maritime suppliers and shipowners can join together to develop new prototypes (Mosgaard, Riisgaard, and Kerndrup 2014a). However, the case study presented is not about radical innovation of new ship construction, but a case study of the intended innovation through demonstration projects of green retrofit of small island ferries. The Maritime Centre for Operations and Development (MARCOD), which is located in Frederikshavn in North Denmark, is in charge of the "Green Læsø Ferry" retrofit project. One of the authors has been research fellow at MARCOD, and has been closely interacting with the project facilitators since the end of 2011.

The case is also relevant from a theoretical perspective, because the innovation intermediaries played a key role in the initiation of the collaborative innovation network. In addition, it was possible to present the innovation process in its integrity from a time perspective. This aspect was inspired by a longitudinal analysis of the innovation process research that seeks to address the issue of organisational change, development, growth and evolution over a period of time. An element in the analysis of change is the understanding of different key events, which shape these changes as a way to answer the questions (Van de Ven and Huber 1995; Van de Ven and Poole 1995).

11.3.2 EMPIRICAL DATA AND ANALYSIS

The collection of empirical materials was an adaptation of the research approach known as systemic recombining that is characterized by a "continuous movement between the empirical world and the model world" and is abductive rather than inductive or deductive (Dubois and Gadde 2002). To follow this abductive method, the authors first achieved an initial understanding of the case study through observation over a period of time (2011-2014), as one of the authors participated in weekly meetings in MARCOD, where the project Læsø Green Ferry was discussed. This understanding guided a literature review including the subjects of SMEs and eco-innovation barriers and drivers. The review had the purpose to guide an interview with a consultant from MARCOD, who was facilitating the demonstration project in 2014. After this exploratory interview, the authors modified the literature review by focusing on the innovation process and the role of intermediaries.

The updated literature review provided new propositions that were turned into a semi-structured interview guide covering five topics: the project definition and scope, internal processes in the organisation, external actors, collaboration process, and the function(s) of the intermediaries in the project. This guide was used for nine additional interviews with a mean length of 90 minutes. As described in Appendix A, the interviewees were selected using a combination of informed and snowball sampling (Rubin and Rubin 2012). The final sample included all the facilitators from the intermediary organisations, the technical officer and the director of Læsø Ferry, staff from firms that participated in the initial phases of the project, and staff from firms that developed or installed products on board the ferry.

In addition to interviews and observations, the authors carried out a document review with the purpose to triangulate the data (Miles, Huberman, and Saldaña 2013). The documents were provided by the intermediary organisations MARCOD and Frederikshavn Business Council. The documents included email communications, meeting minutes, a catalogue of products and services, excel list of firms with interest in the project, power point presentations, technical and financial quotes, and formal contracts.

To analyse the empirical data, the authors used a combination of two methods. The purpose of both is to identify the key events that build the innovation process, the role of intermediaries and other actors. The first was to synthetize the case study through matrices and event-action diagrams (Miles, Huberman, and Saldaña 2013). The second method was to prepare a coding guide (codebook) to analyse the interview transcripts (Saldaña 2009). The literature review provided a set of codes that were turned into interview questions. The question codes were complemented with theoretical codes from the literature on innovation processes and innovation intermediaries. Examples of these codes were: "com_drivers" (drivers for the firm to engage in the project) and "ext_agreements" (type of agreements between the partners in the project). With this initial set of codes, the authors analysed the interview transcripts. This analysis brought new emerging codes as well, following the method of grouping codes into categories and themes (Saldaña 2009).

11.4 ANALYSIS AND DISCUSSION

The authors present the functions of intermediaries in the initiation and the development of the demonstration project used as a case study (Sections 4.1 and 4.2). In the last Section (4.3), the authors review the conceptual framework in relation to the intermediaries' roles in the innovation process and particular challenges.

11.4.1 FUNCTIONS OF INTERMEDIARIES DURING THE INITIATION OF THE COLLABORATIVE DEMONSTRATION PROJECT

Frederikshavn Business Council was involved in EU-funded Interreg maritime projects with Scandinavian partners before the formal start of the demonstration project "Green Ferry". These projects had the purpose to prepare the Nordic maritime industry for new regulations in the use of low sulphur maritime fuels. During this period, the first intermediary played a role of foresight by reflecting upon the local changes in the market that may introduce the demand of new products and services for the shipping industry, as vessels shall be retrofitted to adapt to the new low sulphur fuel in the Baltic and North Seas. The period can be considered a "gestation" period as nurturing of ideas and inspiration was required to initiate an innovation process (Van de Ven et al. 1999).

Inspired by this potential market, the Business Council in collaboration with the Municipality of Frederikshavn hosted the Maritime Business Conference at the end of 2009. During this conference, the local participants initially discussed the idea to develop a 1:1 scale demonstration project of a green ship in Frederikshavn to "demonstrate" what the local companies would be able to supply and install. The intermediary had the function of "broad networking"; as the conference had an open character, any input was welcomed and the main purpose was to generate some ideas for joint R&D activities (Lefebvre 2013).

At the outcome of the conference, the participating companies were interested in finding a ship for a demonstration project, and the possibility was to find a shipowner willing to participate in the consortium by providing a ship for retrofitting. The Business Council first approached the Ministry of Defence without success. The Municipality of Frederikshavn contacted the Business Council and suggested that the retrofit project could be done in the ferry connecting Frederikshavn with the island of Læsø. The vessel, built in 1997, had a scheduled maintenance in 2012. This maintenance was seen as an opportunity by suppliers and service companies to tender their services (including the "environmental" technologies upgrades):

> Yes, we had a deadline because the ferry should go to dry-dock maintenance, and we had to settle what type of [environmental] technology should be installed on board. Everything should be ready and finished by the end of the

> year [2011] because the docking was planned to take place in February 2012 (Interview 2).

The ferry company expected that by the time the ship was going on dry-dock maintenance it was possible to have a detailed offer of technologies for retrofitting the ship, but also the project could bring some external subventions for optimizing the energy use on board:

> We convinced the management to participate in the project, but the agreement was that our involvement should not cost us money. The project should be able to sustain itself in a relatively short timeframe (Interview 4)

The Business Council then invited some companies to participate in an ad hoc workgroup of marine suppliers interested in participating in the green retrofit of the Margrethe Læsø ferry. The creation of the ad hoc group generated a great expectation among local suppliers, as illustrated in Table 22 by the number of local firms participating in the initial activities. Given the open characteristics of the setting, where the idea was proposed, environmental improvement had a broad meaning, and with each participating firm trying to include their services and products in the initial concept of the green ship. As the facilitator from the Business Council puts it:

> In the initial catalogue we made, some companies talked about insulation, others about ballast water, others about the use of water on board or how to improved the propeller system, the engines, and one mentioning the exhaust cleaning system (Interview 3).

At this time, some participating companies were motivated to sell their products and to have a reference case for marketing purposes (Interview 2). As one SME explained:

> It was important for us that the demonstration ship was this ferry because it was located in Frederikshavn, and it was not a large ship. If we followed a conventional innovation process, the first thing we wanted was primary tests, what we do in-house. Then we could improve the concept and bring it into the ferry. Our technology on board the ferry becomes useful for demonstration and test purposes (Interview 9).

Other participants wanted to continuously improve their products in different settings:

> When this project came up, we were already involved in initiatives in Norway, so we just wanted to keep going in our previous track, we had already

> the knowledge. Yet, we want better products every time. So basically one must keep an eye on what is better on the market than what we have now. We considered the Læsø project as an opportunity for R&D of new equipment and products. So, it wasn't that we were thinking on something for the occasion. We planned to bring something in, which was very well known and proven, Læsø ferry was not a guinea pig for us (Interview 8).

The mechanism of intermediation differed here from two other strategies proposed by Lefebvre (2013) in the collective exploration mechanism as "broad networking" or "setting up permanent working groups". The coordination of the ad hoc group brought some challenges to the intermediaries. In the first place, the facilitators perceived frictions between partners, who had overlapping offers in the kind of products and services that they could deliver (Interview 2).

The Business Council expected that the sub-groups of companies within the larger ad hoc network delivered technical proposals and budgets; i.e., the companies delivering solutions on lighting and energy supply would be one sub-group. The issue with overlaps of offerings did not disappear in these sub-groups. When asked why they never sent the quotes to the facilitators, one of the firms answered that in their perspective they were "competing" in a tender rather than developing a joint initiative with the other participating firms. Here the intermediary, the Business Council, had the function of "collector" once more, as it collected these different technical proposals and then left the ferry company with a last decision on what was feasible.

Table 22 What is a "green" retrofit? Products and services initially offered by firms interested to participate in the consortium

Firm	Number of employees	Proposed product/ services
Læsø ferry K/S	10-15	• Docking and vessel
MAN Diesel & Turbo	>500	• Upgrading current engines to Tier II • Installation of Humid Air Motor (HAM) to reduce NO_x formation • Shaft generator with fluent frequency • Optimization of propellers • Improvements of the speed pilot • Optimization of gear steering • Gas operation
Norisol	>500	• Calculation of heat loss • Installation of flue exchange in the exhaust system • Optimization of insulation in the technical installations

RM Staal A/S	<10	• Installation of NO_x reduction system
Scanel International	>250	• Inspection, measurements and survey report • Illumination hardware • Energy optimization of the lighting system, HVAC and Cooling systems • Control systems
Elektromarine	>100	• Energy monitoring devices, frequency monitoring, electrical switchboard
Silentor	<10	• Noise reduction
Thorø Industry & Skadeservice	50-200	• Cleaning of ventilation ducts
Industrial Refrigeration firm -Aarhus (*)	>10 000	• HVAC system
Electronics firm - Skive (*)	>500	• SEMS (Ship Energy Management System)

The Business Council supported the ferry company to decide which technical options were feasible. Both organizations narrowed down the project to three aspects: reduction of noise, improvement of propulsion, and improvement of the lighting system. None of these three options materialized in concrete projects. The noise reduction and propulsion improvement did not present an acceptable payback time at first, but the company has plans to implement it the next time the propeller blades have to be replaced due to sand erosion from sailing in shallow waters. The lighting system exchange is planned to be implemented along the road by use of the ferry company's own electricians, avoiding expensive external companies for this job. In general, green projects in small island ferries have experienced a drawback in terms of a government policy to support island economies by relieving island ferry companies of fuel taxes. This increases the payback time for energy saving projects by five to ten years in actual green retrofit projects. In the context with no fuel tax, some ideas of green retrofit needed further external funding to be implemented and work as demonstration installations.

As this set of events shows, even with the support of the intermediary to scan information, the power of decision of the ferry company was strong in the collaborative network. It was the ferry company that determined which kinds of innovation pathways to follow. As one intermediary consultant put it: "I had difficulties to steer the project in a given direction. I could not force the partners to make certain decisions. We had to wait for the decisions from the ferry company and then act accordingly" (Interview 10). This quote calls for a reflexion of why intermediaries should be the ones handling these tensions in demonstration projects.

11.4.2 FUNCTIONS OF INTERMEDIARIES DURING THE DEVELOPMENT OF THE COLLABORATIVE DEMONSTRATION PROJECT

After the selection of partners and technologies, as mentioned in section 4.2, the intermediary MARCOD took a lead role in the development of a Ship Energy Management System (SEMS). In parallel, the technical officer from the ferry company took the initiative to retrofit the Heating Ventilation and Air Conditioning System (HVAC). This set of decisions marks the start of the development phase, not only because a budget was raised for the SEMS, but also because as part of the development of SEMS other associated products were developed, i.e., the HVAC. This situation also seems to correspond to the assumption of Van de Ven et al (1999) that different divergent and then convergent pathways of product development can take place within the same project.

The project SEMS was the initiative of a new consultant working for MARCOD, an electrical engineer with previous experience in a major shipping company that followed similar retrofits in their fleet. This shipping company needed a baseline to benchmark the accomplishments of the retrofits concerning the energy efficiency of the vessels. The consultant translated the same approach to the retrofit project and proposed it as a project idea. In the background of the first "pathway", the key function of knowledge recombination is carried out by a new consultant from MARCOD. Knowledge recombination implies that individuals connect ideas from different fields, institutions, and organisations to generate innovations (Hargadon 2002).

In order to further develop this project idea, the consultant from MARCOD contacted a Technical Institute, which provides consultancy, training and safety certification in a broad field of domains, including monitoring devices. Both organisations – in collaboration with the Læsø Ferry company – prepared an initial project idea proposal. The proposal was based on a similar project from the Danish Technological Institute named "energy flexhouses", a system for domiciliary use. This original system had a user interface to demonstrate energy consumption.

Later, a student from the Maritime and Polytechnic College from Frederikshavn (MARTEC) was writing her engineer thesis in collaboration with a large manufacturer of electronic equipment located in the city of Skive. The project involved technical options to measure the energy use on board a ship. The student attended a MARCOD seminar and was then invited to present her project to the facilitator of the Green Ferry project. The consultant from MARCOD knew about the electronic manufacturer and was aware of their work; he considered that their software could complement the technical proposal that MARCOD was preparing with the Danish Technological Institute. Since this key event, MARCOD, the Danish Technological Institute and the electronic manufacturer decided to collaborate in a new proposal in which all three were involved:

> I thought that this was an opportunity for us to have money to develop the software. At the time there was one year gone, and we needed to rewrite the application to make it fit for the development of the software not the hardware (Interview 10).

After some months, the three partners and the ferry company agreed on the concept: an interactive monitor system that informs the users about the energy consumption on board the ship. The given name was Ship Energy Management System (SEMS):

> It is a monitor system. A marine control and management system needs approvals and these approvals cost a lot of money and take lot of time. But if we develop a monitoring system, is up to the engineers on board the ship to decide what to do with the energy use, our product just shows the data and the users can take a decision on what to do. This is very important for us, we don't want to switch off the lights. We don't want to control anything. We just want to make them aware on how they are using the energy, for them to optimize the way they operate the ship (Interview 6)

After this function of connecting different organisations, MARCOD had a more active role in the process to consolidate the connectivity between the members of the ad hoc network for developing SEMS. The increasing connectivity was carried through in three main activities:

First, defining roles for each partner and inviting an external partner to support the incipient network. During the initial development of SEMS, the partners had a commitment about each organization's role. The electronics company became a member of Danish Maritime (marine equipment branch organization), as a condition to have Danish Maritime as a fourth partner in the application for innovation funds. The partners agreed that Danish Maritime's role should be that of coordinator of the activities and regarding the marketing of the project. The marketing support was not at all clear for the electronics company: "*I'm not sure if it was a good idea to have support on marketing. We have our marketing department and we are very keen on marketing*" (Interview 6).The Danish Technological Institute should provide technical support on the software/ user interface. Finally, the Læsø ferry company collaborated with the electronics company in the installation of hardware.

A second activity by MARCOD was improving the communication between the members of the network of firms working on SEMS. In the time between applying for funds and receiving the subvention, the roles of the partners changed. Suddenly, the electronics firm considered that all the responsibilities fallen into their hands: applying for the project, coordinating the activities, delivering the software and doing the installations: "*We thought that we were just going to supply the know-how but we are now controlling the whole project*" (Interview 6). The consequence was that the electronics firm started with the project but lacked some inputs from the other partners, in for example, how to set-up SEMS in a way that could be compatible with other technology that could later be installed on board (i.e. LED lightning):

> We have missed some inputs from some people some others that were also involved in the whole retrofit project. We thought it was part of the cooperation. We thought that the whole "green ship" project was big, but suddenly it was a small project. We haven't been in contact with any other company besides MARCOD and the Danish Technological Institute. It will be very nice if different companies supplying systems for the ship could work together and more closely discuss how to configure the different equipment in a way they are compatible from the start. I'm sure there would be minor problems of this kind. But if it is possible to work with those suppliers from the start these kinds of problems could be avoided (interview 6).

The third function was raising funds to sustain the network's project and supporting the ad hoc group in collaborative product development. This function implied writing a project application with detailed accounts of technical, economic and marketing aspects. The intermediary also provided support by contacting the partners to fill in the application forms and meeting the potential funders. The Danish Maritime Fund provided a grant to develop SEMS. The subvention covered half of the hourly expenses for the electronics company. The provision of this grant was a milestone in terms of new functions for the intermediary organisation enhancing network connectivity. To create a well-functioning ad hoc group means new tasks in the development phase; which existing literature fails to explain these functions.

The intermediary must be able to orchestrate the different activities of the ad hoc group in a way that complies with the subscribed commitments. In the case of the SEMS ad hoc group, MARCOD began to coordinate the different activities carried out by partners of the sub-projects through one-to-one meetings and visits. Suddenly, they decided to interrupt this mechanism as it brought some challenges, including in terms of how to follow up on the compliance of the initial commitments of all actors involved in the sub-project or how to speed up decisions in the project in general.

The second pathway (HVAC development) shows that bilateral relations between industries can generate innovation through knowledge recombination without the support of the intermediary, but later the intermediary plays the role of broker. During the last months of 2012, the ferry company's chief technical officer assessed that the ventilation was not working properly. Some pumps were running out of time and needed an overhaul to save energy. He had good referrals of a large company specialized in industrial and maritime refrigeration based in the city of Aarhus, which he contacted. The engineer then suggested to use this excess heat for the use on board the vessel:

> They had the engines and also boilers to produce heat. I asked why they were doing that. They answered that they have always proceed in that way. I thought that it was ridiculous and I suggested to take the excess heat from the engines and use it for heating the vessel. Then we continued the tour and found this big empty space where we could install the heat exchanger. And then we were talking about ammonia as refrigerant for the heat pumps. So the project turned from changing heat pumps into a massive HVAC project (Interview7)

The engineer presented the project idea to the top management, they were positive about the involvement in the HVAC project in the Margrete Læsø ferry, but suggested the engineer to use of its interest hours to work on it. Interest hours are distributed internally between the employees, to work in activities that not necessarily are for short-term profit but can bring benefits in the long term: " *So this is a development project, also is a development project intern in our firm, and that is another way to get the resources instead of sending the bill to Læsø ferry*" (Interview 7). One type of benefit is the knowledge generated about the product that can be applied to other ships with similar situations. Other benefit is the possibility to optimize the HVAC system once installed, they have already experience with live-monitoring of other refrigeration equipment in e.g. fishing vessels. The constant internet-based monitoring allows the firm to develop big-data analysis of the performance of the equipment overtime.

The collaboration between the Læsø ferry and the industrial refrigeration firm implied negotiations with authorities to approve the use of ammonia in the HVAC system. The ferry technical officer was in charge of contacting external actors in order to facilitate the negotiations and improve the acceptance:

> For all these organizations I'm only a supplier who tries to sell something. If the ferry superintendent contacts them, it will be like, 'I'm the guy of the vessel, I need some help'. So it is easier if the superintendent does something as a first connection: 'Look I have this friend at [industrial refrigeration firm], we are trying to do this project. Is it OK if we meet together with him? (Interview 7)

In line with these safety approvals, the HVAC system partners approached MARCOD for support. The approval of an independent third party was part of the process to get the operation permits from the authorities and the classification society. MARCOD contacted a technical approver organisation, FORCE, which showed interest in the project.

11.4.3 THE ROLE OF INTERMEDIARIES IN COLLABORATIVE ENVIRONMENTAL PROJECTS: KEY LESSONS FROM THE CASE STUDY

Two organisations acted as intermediaries during the project period (2010-2014): Frederikshavn Business Council and the Maritime Centre for Operations and Development –MARCOD. Their mechanisms and their intermediation roles differed because they participated in different periods of time, but also because the consultants in both organisations have different competences and provide different types of support to their target groups (Table 23).

Table 23 Intermediary organisations involved in the project Læsø Green Ferry

Organisation	**Frederikshavn Business Council (Erhvervshus Nord)**	**Maritime Centre for Operations and Development (MARCOD)**
Period of time facilitating the project	End of 2009- summer 2011	Summer 2011-2014
Type of organisation	Public/ private association supporting local firms in the municipality of Frederikshavn, including the harbour cities of Skagen and Sæby.	Public/ private knowledge and consultancy centre established in 2011 as a non-profit organisation with seed funding from public and private grants.
Activities	The Council has eight business consultants who provide different kinds of services to the member SMEs within the municipality. These services include coaching on entrepreneurship, management and markets.	The centre supports individual maritime service industries, for example, one-to-one sparring on developing new products, services and markets. MARCOD also supports maritime networks in Northern Denmark harbours; these services include among others the projection of joint R&D and market projects.

Organisation	**Frederikshavn Business Council (Erhvervshus Nord)**	**Maritime Centre for Operations and Development (MARCOD)**
Funding	Membership fees The Business Council also receives public funding from the Danish State and the European Union to carry out different kinds of applied projects which aim to create growth in the local economy, but are not tied to a specific sector, among others entrepreneurial women projects and fisheries market and product improvement.	Public and private grants – i.e. large maritime firms, regional authorities.

Intermediaries had a broad range of functions during the initiation and development of the demonstration project (Figure 21). In contrast, other case studies on innovation intermediaries have constantly focused on one function of intermediaries i.e., forecasting (Chunhavuthiyanon and Intarakumnerd 2014; Lichtenthaler 2013), scanning and information processing (Malik 2012), brokering (Feller et al. 2012; Tan et al. 2010), and networking (Colombo, Dell'Era, and Frattini 2014) without describing other possible combinations.

During the development period, a different intermediary (MARCOD) acted as project coordinator instead of the Business Council. This new intermediary has as part of its organisational mission to become a maritime cluster management organisation in the long term, and the Læsø ferry project was an important first step to gain concrete experience in coordinating a collaborative innovation project. This organisational aspect also had an influence on the type of intermediation proposed in the development of the demonstration project with more bilateral relations between the intermediary and the firms in the consortium, as seen from the SEMS project. Similarly, the aspect of organisational capabilities within intermediary organisations (Konttinen et al. 2011) is a possible explanation of why the function of knowledge recombination took place at the outset of the SEMS project. The intermediary MARCOD had a part-time consultant with previous technical experience in energy efficiency management on board vessels. The consultant from the Business Council had an experience in business plans, but then hired temporarily an external assessor from a maritime service firm to give ideas and carry out the function of scanning and information processing.

Initiation

Function	Activities
Foresight and forecasting	• Foresight about regulatory push in the shipping industry: sulphur regulations on fuels • Forecasting new products/ services to respond to the demand rising from this new regulation
Scanning and information processing	• Filtering technical options for the demonstration project • Scoping the project
Brokering (Collector)	• Collecting proposals of ships where the demonstration project could be developed • Collecting more specific technical proposals • Elaborating a detailed budget
Broad networking	• Organizing maritime business conference • Initial idea of a 1:1 scale demonstration: the green ferry retrofit
Setting up adhoc groups	• Inviting to open meetings where several suppliers participate • Organizing an in situ visit on board the vessel • Preparing a catalogue of technology to be installed in the demonstration project

Development

Function	Activities
Knowledge recombination	• The consultant from the intermediary organization MARCOD used his previous knowledge to propose the project SEMS
Brokering	• Intermediaries provide potential solutions for a SEMS prototype • Intermediaries select the solutions and partners • Finding a third party approver for the HVAC system
Increasing connectivity	• Invite relevant external partners • Defining partner role in the development of SEMS • Fundraising
Following up adhoc groups	• Orchestrating adhoc group activities • Following up initial commitments

Figure 21 Functions of intermediaries in the demonstration project "Læsø green ferry"

11.5 CONCLUSIONS

The guiding research question was: When and how do intermediaries support collaborative innovation processes taking place in environmental demonstration projects?

Two innovation intermediaries (Frederikshavn Business Council and MARCOD) played different functions in the environmental demonstration project (Læsø Green Ferry retrofit) presented in this case study. The first intermediary supported the creation of an ad hoc group that became the basis for a demonstration project. The organisation of this group was possible because the intermediary had other functions (forecasting and broad networking before organising the ad hoc group; brokering along with the formation of the group). The second intermediary supported the ad hoc network to increase its connectivity and begin the development of two products: a ship energy monitoring system and a closed-loop HVAC.

In addition, the results contributed to the understanding of how intermediaries increase the network connectivity during the development phase of innovations. Intermediaries can play simultaneous functions in innovation processes. Some of these functions become key steps to initiate and keep collaboration in a network of companies, as for example, during the development phase of SEMS, the intermediary had the functions of increasing connectivity in the network, while at the same time provide brokering. While individual functions discussed in the case are consistent with literature, the interaction between these different functions provide a closer understanding of innovation processes in collaborative demonstration projects. In the development phase, the knowledge recombination function has a close interaction with the functions of brokering as ideas from one organization (not necessarily involved in the project) can be beneficial for the project provided the persons with the ideas can be connected with others partners in the project (i.e. in the development of SEMS, the an external student provided good ideas to the electronics firm in the consortium which later turned into the basic concept of SEMS).

The intermediaries' various functions also influenced the innovation pathways. This was evident from the beginning of the Læsø Green Ferry Retrofit, when the intermediary played a key role by finding a ship to retrofit, inviting companies to join the ad hoc group, collecting technical offers from the partners, etc. The ferry company had the last and final decision on which type of product would be part of the retrofit and discarded technical sound offers (i.e. LED lighting on the car deck). The innovation pathways were in some ways the result of fulfilling the ship-owner's financial and technical needs rather than a consensual plan by all the companies that showed an initial interest in the project. The financial and the organizational context of the ferry company also had an influence on these decisions. The solution might well be feasible for other ship types. A conclusion from this finding is that, in collaborative demonstration, the primary goals can shift due to the innovation pathways undertaken as new ideas emerge over time and new partners join the network, which is a similar situation for all innovation processes. An additional intermediary function should be that of defining each partner role and secure a clear goal of the work performed by the network. As seen from this case, the intermediary must have experience in negotiating these evolving partners' roles.

One limitation of the research approach was the overall attention to the intermediaries' function in the collaborative innovation network. This strategy hindered the analysis of the functions of other actors in the actor network. The authors were conscious about this choice, as previous research on eco-innovation in small island ferries has focused on the actor network configuration, but disregarded the analysis of innovation intermediaries, i.e., Mosgaard et al. (2014b; 2014a).

A second limitation was the focus on the initiation and development of demonstration projects. The intermediaries' contribution was not analysed in terms of the diffusion/ commercialization of these innovations. Further research could analyse the role of intermediaries in the diffusion of innovations resulting from collaborative demonstration projects. Similarly, the case study also indicated the importance of the context; therefore, further contributions from other sectors and countries could provide a better indication of which other roles intermediaries play and how these roles influence the innovation pathways

11.6 APPENDIX A- LIST OF INTERVIEWS

Table 24 List of interviews and purpose

#	Date	Stakeholder	Purpose
1	25/03/2014	MARCOD	Business consultant and main facilitator for the project Læsø green ship between August 2013 and May 2014
2	28/05/2014	Frederikshavn Business Council	Project facilitator during 2010
3	28/05/2014	Frederikshavn Business Council	Project facilitator between January and June 2011
4	16/06/2014	Læsø ferry	Ferry company technical officer, involved during the whole life cycle of the project 2010-2014
5	16/06/2014	Læsø ferry	Ferry company director 2013-2014
6	12/06/2014	Electronics and controlling equipment supplier	Firm involved in the development of the energy monitoring system (SEMS)
7	22/05/2014	Refrigeration firm	Firm involved in the retrofit of the HVAC system
8	03/06/2014	Metal work and electrical maritime and offshore supplier SME	Local supplier involved in the project during 2010-2011. Proposed LED lightning retrofit and installed samples in the ferry car deck
9	03/07/2014	Metal work SME	One of the local SMEs that initially shown great interest in the project but after some months decided to step-down.
10	01/07/2014	MARCOD	Main facilitator of the project between January 2012 and May 2013. Among other functions, was the main motivator to start the energy monitoring system

PART V
CONCLUSION

Comprised of two chapters, Part V is the concluding discussion of this thesis. The discussion chapter is organized in four sections, which relate to each research question (Chapter 12). While, the final chapter presents the research's contribution and suggestions for further research (Chapter 13).

12
DISCUSSION

In the research I addressed the question: *How can maritime suppliers deliver product and service eco-innovations to the maritime industry?* Standing from a constructivist tradition in qualitative research, I present evidence by joining together pieces of knowledge, obtained from qualitative methods such as in-depth interviews, observations and document reviews. Participants in the study included shipowners, authorities, maritime equipment manufacturers, maritime service firms, shipyards, branch organizations and cluster management organizations. As explained in the research design, the data was collected and analysed in four research articles, which at the same time address four research sub-questions:

1. *What are the drivers for developing environmental technologies in the maritime industry?*
2. *How can maritime service and product suppliers create value and partnerships to fulfil the demands for environmental technology from markets and new regulations?*
3. *How can collaborative eco-innovation processes be organized at the project level for environmental technology in the maritime industry?*
4. *How to improve competence and collaboration among cluster stakeholders for the provision of environmental product and services to the maritime industry?*

The overall finding of this research was that Danish maritime suppliers can deliver environmental products and services to the maritime industry if they are able to evolve as value co-creating networks. Some key strategies can facilitate this evolution. The first strategy is to ensure that shipowners and operators (as end-users of environmental technology) become active actors in the co-creation of the environmental technology, along with their supply networks- The second strategy is encouraging greening partnerships (set-up by e.g. public or private actors) to allow shipowners to set formal collaborations with suppliers, with the purpose of initiating the development of environmental technologies. These partnerships have some elements of shared-value creation, in particular when large shipping firms address social-issues as air pollution, but also strengthen the maritime cluster. The third strategy can be implemented at a project level within these partnerships, where intermediary organizations can coordinate collaboration between shipowners and supply networks, in particular when the development of maritime environmental technologies is a long and complex innovation process. In this process of collaboration the suppliers can increase their competences and thus set new business models. In this chapter, I synthetize and interpret these findings by addressing the research questions.

12.1 WHAT ARE THE DRIVERS FOR DEVELOPING ENVIRONMENTAL TECHNOLOGIES IN THE MARITIME INDUSTRY?

All four articles in the thesis touched upon the drivers for eco-innovation in the maritime industry. In Rivas-Hermann and Remmen (2015) we analysed the influence of the SECA on the market, the technology and on the internal business drivers for the adoption of environmental technologies by the short sea shipping industry. The creation of partnerships for greening the Danish maritime industry was greatly influenced by the IMO's approval of the North European SECA, but also by the interest of shipowners to improve their public image vis-à-vis environmental issues (Rivas-Hermann, Smink, and Kerndrup 2014).

The creation of a SECA in the waters of Northern Europe, influenced national authorities, shipowners, equipment and service suppliers to identify technology solutions in order to comply with the sulphur limits in fuels as stipulated in MARPOL Annex VI. The focus of this regulation suggests that the priority by these stakeholders will be to develop or adopt the technologies which will allow compliance with the standards within a short time frame. However, the technological improvement process will require longer laps of time for development and compliance (Rivas-Hermann and Remmen 2015). In Denmark, this bias towards developing end-of-pipe technology was perceived in the type of projects developed. An example of this bias can be seen in the Partnership for Cleaner Shipping, where shipowners together with some equipment suppliers received financial support for the development of scrubbers, selective catalytic reduction (SCR) and to a minor extent, LNG propulsion technology (Rivas-Hermann, Smink, and Kerndrup 2014). Other regulations such as the "International Convention for the Control and Management of Ships' Ballast Water and Sediments", had a similar effect on developing/adopting end of pipe technology (Rivas-Hermann, Köhler, and Scheepens 2014). The literature classifies end of pipe technology as an incremental eco-innovation, which seeks to slightly modify existing processes or products (Machiba 2010; Remmen and Thrane 2007a).

The high price of maritime fuels is one factor that could facilitate the adoption of process-oriented, cleaner technologies linked to the propulsion systems in ships. Since 2013, fuel prices decreased considerably as a result of the fall of international oil prices. However, the industry perceived this situation as a temporary fluctuation, with the perspective of increasing prices in the future (Vogdrup-Schmidt 2013; Vogdrup-Schmidt 2015; Grønvald Raun 2014) In addition, financial models predicted constantly increasing prices for heavy fuel oil and low sulphur fuels which will ensure compliance with MARPOL Annex VI requirements (e.g. MDO, MGO). These fuels are also linked to engine modifications and other types of retrofits on the vessel that adapt to the new type of fuel (DNV 2012; Aalbu et al. 2013). In this way, the high prices of low-sulphur fuel motivate shipowners and equipment suppliers to look for compliance alternatives besides end-of-pipe technologies. Similarly, high heavy fuel oil prices will push shipowners to reduce fuel consumption and use less fuel (Rivas-Hermann and Remmen 2015; Rivas-Hermann, Mosgaard, and Kerndrup 2015).

These findings provide a better understanding of the options available for value propositions that supplier networks in Northern Jutland could deliver to fulfil the demands of shipowners as end-user actors. It is likely that shipowners will be interested in two types of value propositions: one linked to end-of-pipe or process technologies which allow ships to be within the SO_X emissions thresholds of MARPOL Annex VI. Another could be developed around technologies to improve the energy efficiency in vessels, which provide fuel savings while at the same time complying with the existing SECA regulations. Following the logic of incremental eco-innovations, these technologies will probably not introduce large modifications into the existing propulsion systems in ships, but instead could be adapted as modules to the existing systems, as is the case of exhaust gas scrubbers. One possible type of value proposition could be products or services around the development, installation and maintenance of these modular systems. This leaves room for novel collaboration between suppliers to deliver value propositions such as retrofitting vessels with environmental technology to reduce fuel consumption (Rivas-Hermann, Mosgaard, and Kerndrup 2015). Other studies argue that more radical eco-innovations can have a potential demand. Mosgaard, Riisgaard and Kerndrup (2014a) highlight the opportunities linked to the construction and retrofitting of small ferries and off-shore supply vessels with composite materials. Hence, it is possible for suppliers who have the competences and interest to participate in cluster initiatives related to both incremental and radical initiatives.

Chapter 8 also highlights the relationship between market pull and self-regulation as drivers for eco-innovation. The investments on end-of-pipe technologies required by environmental regulations will not bring a return in the same way as technology aimed at reducing fuel consumption. The market context of the maritime business is characterized by excess in offer and low incomes for shipping companies, thus it is less likely that shipowners will invest in environmental technology not required by law. However, my results indicate that it is here where the market and self-regulation become relevant. The role of market in business to business relations, is sketched by a number of voluntary programs designed to share information with business-to-business customers on the environmental performance of vessels (i.e. Clean Shipping Index). The participation in these programs brings benefits to shipping firms by attracting customers willing to green their supply chain (Rivas-

Hermann and Remmen 2015). This finding is further developed in the research report included in Appendix B (Rivas-Hermann, Smink, and Hirsbak 2015), where we inquired about voluntary programs implemented by the maritime industry to reward shipping companies which have adopted environmental technologies on their ships and thus improved the performance of these ships on certain environmental parameters. These voluntary programs are not based on the ISO 14020 series of standards on Eco-labels (except the German scheme Blue Angel), for this reason, rather than aiming at the end-consumer market their potential lies in business to business markets: e.g. large cargo owners willing to purchase transportation service through a shipping company who charters/ owns green ships. Improving the general industry image, was also highlighted as the initial aim to start the Green Ship of the Future partnership (Rivas-Hermann, Smink, and Kerndrup 2014):

> COP15 was the main driver of the low emission studies—the container ships and the one on bulk carrier. They had to be finished and ready for COP15 in order to show the world that shipping was actually doing something. COP15 was also good marketing for the project" (Interview 6).

In a SC perspective, shipping firms are also suppliers to end-customers. In particular cargo owners with business strategies that oversights on the sustainability of the supply chain (Noci and Verganti 1999). Possibly, these end-customers will prioritize a value proposition which integrates green transportation of goods. In synthesis, these findings indicate that business to business customers create incentives for the installation of environmental technology, which is aligned with previous findings, i.e. (Horbach, Rammer, and Rennings 2012).

12.2 HOW CAN MARITIME SERVICE AND PRODUCT SUPPLIERS CREATE VALUE AND PARTNERSHIPS TO FULFIL THE DEMANDS FOR ENVIRONMENTAL TECHNOLOGY FROM MARKETS AND NEW REGULATIONS?

The second sub-question deals with value-creation through partnerships between networks of suppliers and shipowners. Danish shipowners seek to develop environmental technologies along with their suppliers to tackle some of the emerging environmental problems generated by shipping. In addition to improving the energy efficiency of their vessels by developing retrofit packages for the existing fleets (Rivas-Hermann, Smink, and Kerndrup 2014; Rivas-Hermann, Mosgaard, and Kerndrup 2015). Formal multi-stakeholder partnerships are one way that shipowners can co-create new markets and products along with their Danish suppliers. This is not to say that Danish shipowners or operators do not simply acquire the technology, as in any conventional business transaction, where the end-user pays for a product/ service, etc. Instead, while acknowledging this could be the case of some companies, I further inquired how shipowners co-created environmental technologies along with their suppliers.

The analysis of the two partnerships, Partnership for Cleaner Shipping (PCS) and Green Ship of the Future (GSF), sheds light on how this co-creation process was characterised. Both the PCS and the GSF can be considered as networks for the greening of the industry, which goal is to bridge relations between actors (public or private), with the possibility of creating outcomes such as the mentioned pilot projects, but also to enhance the capacity of the actors to deal with environmental issues (Lehmann 2006). These partnerships were similar in the sense that they allowed shipowners and suppliers to create new forms of cooperation which combined open with closed oriented collaboration. Open collaboration characterized those activities which purpose was creating competencies on environmental regulations and technologies between maritime stakeholders and other societal actors Some examples of these activities include conferences, seminars and reports available through their websites. Additionally, both partnerships also facilitated “closed” collaboration among partners through project bubbles in GSF, developing joint project proposals for receiving external grants in PCS, prototype creation and testing in PCS (Rivas-Hermann, Smink, and Kerndrup 2014). On the other hand, these partnerships are not isolated “spaces”: we found that similar public and private actors circulate between both partnerships, which allowed cross-fertilization of ideas and synergies between the PCS and GSF. This interaction becomes critical to initiate and develop demonstration projects for environmental technology. One relevant example was the scrubber project, in which the end-user (large Danish shipping firm) collaborated with an engine manufacturer and marine equipment supplier (both with offices in Northern Jutland). The shipowner installed the scrubber and tested it in sailing conditions. Tests on operational conditions provide different insights than those form computer models, thus allowing suppliers to progressively improve the design of the equipment until it was ready for commercialization (Rivas-Hermann, Smink, and Kerndrup 2014). One salient aspect of these demonstration projects, is that they seem to comply with the characteristics of value-creating networks (Lusch, Vargo, and Tanniru 2010), characterized as “temporal structures” which focus on end-customer value and purposeful co-operation between suppliers to co-produce value-offerings. This is addressed with more details in sub-question 3 (see section 12.3).

Chapter 10 inquired about value propositions beyond initiation and demonstration projects. The results shed light on business models for technology and innovation management, which I defined as “a ‘narrative’ that facilitates the interaction and convergence of actors around a new venture” to “understand how technology is converted into market outcomes” (Zott, Amit, and Massa 2011; Doganova and Eyquem-Renault 2009). The case study presented in Rivas-Hermann, Köhler, and Scheepens (Rivas-Hermann, Köhler, and Scheepens 2014) analysed the business models of Danish ballast water treatment systems suppliers. Business models linked to ballast water treatment systems (BWTS) can be seen not as a single model, but as a combination of models related to the different phases: manufacturing, installation and operation phase of the equipment. During the installation, shipyards play the main role by coordinating what is to be installed on board the new ship. Shipyards turn into hubs of collaboration among shipowners, manufacturers and contractors. During the operation phase, the manufactures I interviewed, aim for a global offer of after-sale services, and thus they have an interest in creating long term alliances with Danish maritime service suppliers which could send specialized technicians on service missions abroad. This interest raises opportunities of collaboration between BWTS manufacturers and service suppliers to develop joint services. However, the question is how to propose a business model which brings a value proposition for all involved: equipment and service suppliers, and shipowners alike. One business model for eco-innovations which could increase end-user perceived value is PSS (Tukker 2004). The case highlighted that currently there is no business model described as a result-oriented PSS, instead actors still perceived BWTS as a product, with shipowners paying separately the cost of the equipment from, for example, possible after sales service packages. Focused on the operation phase of BWTS, the case highlighted the importance of rethinking the concept of BWTS, which should be seen more as a system of services built around the equipment. We proposed a result-oriented PSS around port-based BWTS, in which during the operation stage, shipowners would pay per unit of water treated. The development of port-based systems is at early stages, with only preliminary assessments underway, our claim is that suppliers and end-users in the maritime industry would benefit from the diffusion of port-based systems. Shipowners will outsource the installation, operation and maintenance to the PSS consortium (Rivas-Hermann, Köhler, and Scheepens 2014). Shipowners and operators, as end-users, will likely benefit from the value-proposition embedded in such result-oriented PSS for port-based BWTS. Besides the possibility to outsource the management of the BWTS to the PSS consortium, the other aspects of the value propositions for a port-based BWTS are: less investment costs as on-board systems are not necessary to install, less energy consumption for the ship during voyages, BWTS are used more frequently on port, cost reduction for the shipowners and more efficient use of the BWTS. The insights from the case study about BWTS could provide insights for the analysis of other types of environmental technologies (as those concerned with air emissions in the Danish partnerships PCS and GSF). However, such analysis will imply a closer look into the production structures and the particular environmental regulation to assess whether similar PSS-oriented business models could be applicable (Rivas-Hermann, Köhler, and Scheepens 2014).

12.3 HOW CAN COLLABORATIVE ECO-INNOVATION PROCESSES BE ORGANIZED AT THE PROJECT LEVEL FOR ENVIRONMENTAL TECHNOLOGY IN THE MARITIME INDUSTRY?

The third sub-question "zoomed" into the processes that leads supply networks to evolve into value networks. In Chapter 11 we looked into the initiation and development periods of the green retrofit of the ferry Margrethe Læsø (Municipality of Frederikshavn) with a focus on intermediary organizations as hubs for coordinating these processes of collaboration in networks (Rivas-Hermann, Mosgaard, and Kerndrup 2015). The case presented a different set of actors as those participating in the PCS or GSF. The project was initiated and facilitated by two intermediary organizations: the Business Council of Frederikshavn and MARCOD. At the outset of the project, the goals overlapped with similar projects as those carried out in PCS and GSF because the idea was that partners jointly created a product/ service concept and then tested this concept before further development and commercialization (Rivas-Hermann, Mosgaard, and Kerndrup 2015; Rivas-Hermann, Smink, and Kerndrup 2014).

The supply network (SN) was represented by maritime service firms that provided products and services to the maritime industry as an end-user. This included metalwork firms, electrical installations, lighting equipment suppliers, propeller manufacturers, software and control, marine instrumentation and exhaust and pipe installations. These maritime service firms represent a SN because they share a relationships based on previous joint activities, some of them being part of Maritime Network Frederikshavn, or personal connections. As stated by Braziotis et al. (2013): "*The SN focus is on the web of relationships. In terms of configurations, it was seen as an enhanced or wider view of one or more SC, incorporating indirect relationships and a subsidiary or satellite organizations in addition to core members*". The focus of my inquiry was not the analysis of the SN and their relationships, because the Læsø ferry retrofit case study proved more valuable in generating insights about the roles of innovation intermediaries in the SN: actors "that perform a variety of tasks in the innovation process"(Howells 2006). During the initiation period of the demonstration project, the first intermediary (Frederikshavn Business Council) played a key role in creating a common vision between the suppliers, generating ideas on what the value proposition they wished to create could look like and inviting the end-user to participate along with the suppliers in the co-creation of value-propositions. Here resides the importance of the web of relationships within the SN, as innovation intermediaries may be the nodes in the network that will contact and motivate supply firms that hitherto had not been active suppliers to collaborate with other firms in the cluster. This aspect of relying on the potential of non-active firms is another characteristic of SN (Tokman and Beitelspacher 2011). As the case presents, the web of relationships resulted in the large participation of suppliers in the initial meetings and the offerings for the possible retrofit of the ship (Rivas-Hermann, Mosgaard, and Kerndrup 2015).

The “development” period of the demonstration project was marked by a definition of the specific technologies to be installed and tested on board the ship, but also was the turning point by which the SN turned into a value network. The broad SN turned into a narrower group of firms which designed, installed and tested three technologies as part of the retrofit package conceptualized during the initiation phase of the project. These technologies are the energy consumption monitoring system (SEMS), LED lighting and HVAC unit. The value proposition of the consortium was better defined as a retrofit package which will reduce the energy consumption in the vessel and thus reduce operational costs. The intermediary organization (MARCOD) recombined ideas between organizations and people, which resulted into valuable inputs for the shipowner and the suppliers during the development and testing of technology. The intermediary was also important in linking the consortium with external partners who could improve competences and the outcomes of the project by i.e. facilitating access to funds, promoting the project during a later commercialization or supporting the regulatory approval of the prototypes. The results from the Læsø ferry case study suggest that this SN has the potential to turn into value creating network: “*temporal structure with an explicit strategy to focus on end-customer value and purposeful cooperation between suppliers to co-produce value-offerings, exchange service offerings, deliver added-value products and services to the end customer, and co-create value*” (Lusch, Vargo, and Tanniru 2010). The results illustrate that joint demonstration initiatives within the SN and mediated by innovation intermediaries can lead to a value network.

12.4 HOW TO IMPROVE COMPETENCE AND COLLABORATION AMONG CLUSTER STAKEHOLDERS FOR THE PROVISION OF ENVIRONMENTAL PRODUCT AND SERVICES TO THE MARITIME INDUSTRY?

The fourth research sub-question deals with the improvement of competences and collaboration among maritime cluster stakeholders for the provision of environmental product and services. This was a crosscutting aspect in all the cases and links the results with the overall problem definition in the context of region Northern Jutland and its maritime cluster. In Denmark, public actors have great influence on strengthening clusters through different approaches. These “strengthening” approaches range from co-funding activities of cluster management organizations to being active members in partnerships and to setting framework conditions for the improvement of the cluster competences through strategies such as investing on training for the workforce and basic education (Styrelsen for Forskning og Innovation 2015). As introduced in section 1.2.1, the overall strategy by national and regional authorities is to provide framework conditions to "strengthen" the different branches in the maritime cluster with the purpose of improving the cluster's competitiveness at the international level (Sornn-Friese and Iversen 2014; DMA 2006). One of the strategic "branches" in the maritime cluster is that of cleaner shipping and its associated environmental technologies (section 1.2.1). This type of top-down cluster "strengthening" strategy has resonance with the literature of regional cluster development and as such, their main point is to connect otherwise spread actors and knowledge into a common strategic sector and theme. The connections between actors will eventually result in better competencies and thus further innovation, productivity and economic growth in the region (Zimmer et al. 2014).

However, developing environmental technologies for the maritime industry is not an activity which will generate the same type of revenues and return on investments as for example developing navigation instrumentation or propulsion equipment. Instead, it is a risky business which depends upon a combination of drivers to ensure that a demand exists to motivate suppliers to develop this kind of technology (Rivas-Hermann and Remmen 2015). The results from the case studies suggest that cluster "strengthening" in the branch of maritime environmental technology is not only explained as the outcome of public policies and investments (the top-down intervention). Instead, in order to "strengthen" the competences and collaboration among actors in the cluster, three factors could play a major role by complementing the public policy interventions: i) cluster initiatives as mechanism to initiate and develop environmental technologies ii) active participation of end-users and key suppliers in the cluster initiatives and iii) support and steering provided by innovation intermediary organizations.

The combination of these three aspects is not linear, as e.g. generating cluster initiatives are not a preliminary condition so that end-users and key suppliers collaborate on cluster initiatives. Instead, the case studies portrait that this is a complex and long iterative process, where some activities which originally are not intended to improve the cluster's conditions can ultimately influence collaboration and competences among stakeholders. An example is the partnerships described in Rivas-Hermann, Smink and Kerndrup (2014). The original objective of both the PCS and GSF was not to strengthen the Blue Denmark maritime cluster and turn it competitive. Instead the public and private actors joined these partnerships pushed by the emerging environmental regulations and the market conditions which required the development of cleaner technologies (Rivas-Hermann and Remmen 2015). The conventional definition of cluster initiatives is that of collaborative actions between research, private and public actors with the main aim to improve the cluster competitiveness (Ketels and Memedovic 2008). Hence, the partnerships for greening the Danish maritime industry are not cluster initiatives in the strict sense that their aim was to improve the cluster's competitiveness. However, this became one of the side effects of the partnerships when suppliers and end-users were able to develop new business relations, initiate some joint projects and in some cases test new products before commercialization (Rivas-Hermann, Smink, and Kerndrup 2014). Further, the PCS and GSF can be considered cluster initiatives from an "intermediary" approach as suggested by Laur, Klofsten and Bienkowska (2012), because they connect key players (i.e. suppliers, research centres), target groups (i.e. end-users as shipowners) and support groups (public actors) into a shared vision and reaching common objectives. This characteristic was also shared by the demonstration project retrofitting Læsø ferry (Rivas-Hermann, Mosgaard, and Kerndrup 2015). End-users and suppliers actively participated in both partnerships, thus demonstrating these actors' interest in building collaborative relationships and competences in the national and regional maritime clusters. In the case of end users (e.g. short sea and global shipping firms), one element which points in this direction is that instead of simply purchasing a product from some of their global suppliers –as in this case environmental technology—, shipowners preferred to co-create along with their Danish suppliers new technologies and markets (Rivas-Hermann, Smink, and Kerndrup 2014).

In the case study presented in Rivas-Hermann, Mosgaard and Kerndrup (2015), the end-user was an active co-developer of the service package named "green retrofit". This active involvement was characterized by selecting along with the suppliers the type of equipment to be tested on the ship or supporting the suppliers in the design of new instrumentation –i.e the SEMS and the HVAC. The other key actors in the Northern Jutland region's maritime cluster are suppliers, as introduced in section 1.3. These suppliers have joined at least six different maritime service networks spread around the region. One of those networks is Maritime Network Frederikshavn, which originated the cluster initiative of green retrofitting. This case provides insights which can possibly be generalized into similar networks in the region's cluster and elsewhere in Denmark. The first insight is how the close interaction between the end-user (ferry company) and the suppliers increased competencies in both sides regarding the new technologies being developed. For example, the electrical company which supplied the SEMS system was able to develop a new product line in the company (interactive energy monitoring system) for a new market segment (Rivas-Hermann, Mosgaard, and Kerndrup 2015). The second insight is about the participation of the cluster's most internationally oriented suppliers in a cluster initiative as the Læsø ferry retrofit[13]. This also points in the direction that joining into collaborative projects together with other suppliers in the cluster, is a way of co-creating new value propositions in the form of new technologies and services.

[13] See section 1.2.2 for a description about these firms. i.e. MAN Diesel & Turbo, Scanel, Vestergaard Marine Service and the electronics firm DEIF.

Research on cluster management emphasizes the importance of cluster initiatives as "instruments" to bring together different kinds of stakeholders into a shared vision to improve the competitiveness of the cluster (Zimmer et al. 2014; Laur, Klofsten, and Bienkowska 2012; Lefebvre 2013). In line with this literature, my case studies contribute to a better understanding on how to "steer" innovation activities in the cluster in a particular direction –e.g. product and service eco-innovation by analyzing the role of innovation intermediaries. Actors in the cluster outsource the responsibility of organizing joint R&D projects in the cluster to innovation intermediaries. In Rivas-Hermann, Mosgaard and Kerndrup (2015), this was "outsourced" to Frederikshavn Business Council and then to MARCOD. The reason was that members of the FMN (local business network) considered that both organizations had the resources to cover the expenses associated with setting the cluster initiative "green retrofit". In the national cluster initiative, GSF, the partnership had a professional secretariat which handled the organization of meetings, seminars and taking the minutes. However, partners were required to invest their own resources to participate in the joint activities as desk studies, etc. (Rivas-Hermann, Smink, and Kerndrup 2014).

In the literature, creating shared-value by improving local clusters' conditions is characterized when firms carry out actions which seek to improve the framework conditions of supply networks in a cluster. The improved cluster conditions can take many forms as public-private partnerships that improve infrastructure or market conditions, or improve procurement benefits to firms in the cluster, or attract competent suppliers and workforce. As a compensation, the firms which invested in enabling cluster development will benefit from better quality of inputs into their own production process (Porter and Kramer 2011). The findings of the fourth question could also be interpreted according to the second mode of shared-value creation: enabling local cluster development. An insight is that local cluster development can also be achieved by improving collaboration and competences among suppliers and end-users through the three factors presented above: i) cluster initiatives ii) active participation of end-users and key suppliers in cluster initiatives and iii) supporting and steering by innovation intermediaries.

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CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The purpose of this thesis is to understand how maritime suppliers can evolve into networks of value co-creation by delivering product and service eco-innovations to the maritime industry. The first contribution of this thesis, is proposing a conceptual model to analyse and understand current research on value creation in supply networks. With the exception of the stream of business models for eco-innovations, i.e (Ceschin 2013), the issue of value co-creation is not of primary concern in the overall literature of eco-innovation or is often neglected. In this thesis, I address this gap by unveiling value co-creation as a way to motivate stakeholders in clusters to collaborate and increase their competences in the provision of environmental products and services. Key stakeholders in the cluster include main suppliers which are nodes in the networks, and end-users (consumers) which become important in the process of co-creating new products and services.

I positioned the research design in a constructivist tradition and relied on a qualitative multiple-case study as an inquiry strategy. This had implications on how the conceptual framework was developed and used in relation to the empirical data. The conceptual framework was the result of combining theoretical inputs from the literature review and the empirical insights from the data collection. This process directed the selection of the case studies presented as results, which at the same time had the purpose of uncovering specific elements within the conceptual framework. In this way, the conceptual framework suggests a connection among three streams of research on eco-innovation, which are used separately in the literature. These include eco-innovation drivers (Rennings 2000; Rubik 2005; Cleff and Rennings 1999), development of eco-innovations in networks (Hansen and Klewitz 2012; Klewitz, Zeyen, and Hansen 2012) and business models for eco-innovations (Boons and Lüdeke-Freund 2013; Ceschin 2013). The connecting logic was inspired by the analysis of the innovation processes in supply networks through the adaptation of the level of networks in Garud, Tuertscher and Van de Ven (2013), but with a focus on the networks of suppliers in clusters rather than individual firms or communities. One challenge in the research design was that each case study inquired about different types of eco-innovations, hence, the application of the conceptual framework was not possible for one particular type of eco-innovation, e.g. in a longitudinal way. Further research could address this challenge and contribute to test the propositions provided in the conceptual framework. For example, longitudinal case studies could be valuable to uncover value co-creation along the innovation process for specific eco-innovations. In particular, critical case studies could be useful to provide further generalization (Flyvbjerg 2006). However, such research should be aware that longitudinal case studies would require the observation of the phenomena along a considerable time frame —see for example Van de Ven and Poole (1995). As an alternative, other studies could test the propositions of this conceptual framework in other units of analysis than the level of networks of suppliers. Case studies at the firm level are appreciated, if they could unveil the nuances of the process of shared-value creation from an organizational level.

A second contribution of this thesis is providing a better understanding of the greening of the maritime industry from the perspective of value creation through the development of maritime eco-innovations. Emerging research is concerned with different aspects greening the maritime industry such as environmental governance (Lai et al. 2010; Venus Lun et al. 2015), role of individual actors in the supply chain (Acciaro et al. 2013; Lindstad, Asbjørnslett and Pedersen 2012) or organizational aspects for the adoption of cleaner technologies (Jafarzadeh and Utne 2014; Krozer, Mass, and Kothuis 2003; Österman and Magnusson 2013; Balland et al. 2013). While these areas of research provide a good understanding of factors which influence the greening of the maritime industry, they neglect to explain the influence of supply networks in maritime clusters in the greening of the industry. The results in this thesis showed that cluster initiatives allow shipowners and their suppliers to collaborate and develop new competences while co-creating environmental technologies. Relationship building is one of the key premises behind the creation of value networks and is the basis for cluster initiatives and better steering by cluster management organizations. Further research could contribute in a better understanding of the cluster-based relationships, for example, between the main suppliers and sub-suppliers, including SMEs. Network analysis could be particularly useful to characterise the cluster networks in terms of boundaries, complexity and dynamics, following, for example a case study methodology as in Halinen and Törnroos (2005).

In addition, the results indicate that the process of co-creation works in the direction of greening the industry. The value networks could become "niches" of experimentation of new technologies and learning before commercialization. These "niches" are relevant because they go beyond the supply chain and attain actors from the entire clusters (another name I used in this thesis was cluster initiatives). Possible further research[14] will take a closer look at these cluster initiatives or "niches", with

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[14] In the initial stages of this research I was interested in this area of inquiry, in particular relying on the Multi-level perspective on sustainability transitions (Geels 2002) to better understand the role of these niches to analyse a possible transition of the industry towards sustainability. However, the later problem analysis pointed in other direction as reflected in this thesis. In this thesis I did not include the conference article Rivas-Hermann (2012), which provide some of my theoretical reflections on this.

particular emphasis on their relevance for a possible transition to cleaner shipping. Such research would be based on a systemic perspective of the technology being analysed (e.g. (Coenen and Diaz Lopez 2010)) to better understand the relations among actors in the supply networks and end-users in relation to the overall industry. One possibility is relying on the multi-level perspective on transitions (Schot and Geels 2008; Geels 2002), and analyse the relation of these cluster initiatives for particular technologies with the regime of the industry (i.e. regulations, competing technologies), but also with overall landscape conditions. This will shed light on the possible trajectories of eco-innovations. Another possibility is analysing individual technologies from a Technology Innovation System perspective (Coenen and Diaz Lopez 2010). Research of this type will focus on some of the emerging radical eco-innovations which have a potential for joining actors in the cluster, but at the same time face several challenges before they are ready for commercialization, i.e. composite materials, hybrid-propulsion technology (as i.e. sails), electrical engines and batteries or decommissioning of vessels and integrating the materials into industry loops (see for example Litehauz (2013)).

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APPENDIX A: TABLES AND FIGURES

Table 25 Status of selected IMO conventions dealing with environmental aspects of shipping 1969-2015. *Source*: Adapted from Comtois and Slack (2007a) and updated with IMO (2015)

Conventions	Date of entry into Force	No of Contracting States/ Parties in 2015	% world tonnage in 2015
MOVEMENT OF HAZARDOUS GOODS			
NUCLEAR 1971 (Movement of hazardous goods–civil liability)	15 July 1975	17	18,88
SOLAS 1974 (Emergency, movement of hazardous goods)	25 May 1980	162	98,60
MARPOL 73/78 (Annex I/II) (Oil discharge and movement of hazardous goods)	2 October 1983	153	98,52
MARPOL 73/78 (Annex III) (Movement of hazardous goods)	1 July 1992	141	97,79
HNS Convention 1996 (Movement of hazardous goods)	Not intended to enter into force	14	14,14
WATER QUALITY			
MARPOL 73/78 (Annex V) (Water quality – waste)	31 December 1988	147	98,03
MARPOL 73/78 (Annex IV) (Water quality)	27 September 2003	134	90,74
BWM Convention 2004 (Water quality- ballast water)	Not yet in force	44	32,86
AIR QUALITY			
MARPOL: Protocol 1997 (Annex VI) (Air quality)	19 May 2005	79	95,22
SHIPS END OF LIFE			
Hong Kong Convention	Not yet in force	3	1,86

Table 26 Type of ships in maritime freight and passenger transportation. Source: Adapted from Branch (2007)

Type of ship	Main characteristics	Capacity
Tankers	Carry oil, fuel oil, heavy diesel oil, lubricating oil	Cat. 1 oil tankers PREMARPOL (20000 -30 000 dwt*) Cat 2 MARPOL tankers (20 000 -30000 dwt) Cat 3 tankers (5 000 -20 000 dwt) Ultra large crude carriers (ULCC) (300 000 - 500 000 dwt) Very large crude carriers (VLCC) (150000-299 999 dwt) Suezmax tanker (120 000-149 999 dwt) Aframax tanker (80 000- 119 999 dwt) Panamax tanker (50 000-80 000 dwt) Parcel tankers (30 000 - 80 000 dwt) Gas tanker
Bulk carriers	Iron ore, coal, fertilizer grain, steel slabs, bauxite, alumina, rock-phosphate, grains	Panamax bulk carrier (50 000 -79 999 dwt) Capesize dry bulk carrier (80 000-170000 dwt) Handymax (35 000 - 49 999 dwt) Handysize (20 000 - 34 999 dwt)
Floating production, storage and off loading facilities (FPSO) and floating storage units (FSU)	Both types of vessels used in connection with off shore oil and gas facilities	
Coaster	All purpose cargo carriers operate around coast	

Type of ship	Main characteristics	Capacity
Container vessel		First generation (1100 TEU**) Second generation (2000-3000 TEU) Panamax (3000- 4000 TEU) Post-Panamax (4000-5000 TEU) Fifth generation (6400 -7500 TEU) Sixth generation (8000-9000 TEU) Seventh generation (12500 -15000 TEU) Near future (18 000 TEU)
Fruit carrier		
General cargo ship		
OBO (Ore/ Bulk/ Oil) ships	These are multi purpose vessels which accommodate different kinds of cargo	270 000 dwt
Passenger vessel	Examples are the Roll-on/roll-off (RORO vessel), ferries, cruise ships	
Platform supply vessels		
Pure car and truck carrier (PCTC)		A modern PCTC can convey between 5 500 and 5800 cars, or a combination of 3200 cars and 600 trucks
Refrigerated vessel	A vessel category in decline as refrigerated cargo is nowadays shipped by fridged containers.	
Timber carrier		
Heavy lift shipping	Service of for example, off-shore fields, equipped with erected cranes, yachts	
Navy and military vessels		

*Deadweight tonnage (dwt) is the standard measure of how much weight can a ship safely carry

**TEU stands for Twenty-foot Equivalent Unit which is a standard measure for container ships and container terminals

APPENDIX B: REPORT ECO-LABELLING FOR THE PROMOTION OF WIND-ASSISTED PROPULSION IN CARGO SHIPS

sail

AALBORG UNIVERSITY
DENMARK

WP5: Policy and Legislation

Activity 5.3 Environmental Ship Indices

Eco-labelling for the promotion of wind-assisted propulsion in cargo ships

Project funded by the European Community under the North Sea Region Programme 2007-2013

The Interreg IVB North Sea Region Programme

European Union The European Region

Project Acronym: SAIL
Deliverable: 5.3 **Due Date:** February 2015 **Delivery date**: May 2015
Authors: Roberto Rivas Hermann, Carla K. Smink, Stig Hirsbak

Preface

This report has been written on the basis of the work Aalborg University (AAU) has carried out in the S@IL project (Sustainable Approaches and Innovative Liaisons) with regard to work package 5 on Policy and Legislation.

From July 2012 to June 2015, 17 partners from 7 North Sea Countries have worked on the S@IL-project. The aim of the project was to stimulate and facilitate the transition process towards a sustainable shipping sector with focus on alternative propulsion systems for (freight) sailing, so-called “hybrid sailing concepts”.

As part of the work package on Policy and Legislation, AAU has focused on Environmental Ship Indices. It has been investigated how we can develop an eco-label scheme for the promotion of wind-assisted propulsion technology in the shipping industry. Furthermore, we have had a closer look at ports and to what extent ports encourage ship-owners to improve their environmental performance. We have investigated so-called EcoPorts and what requirements they impose on ship-owners. The results of our work are presented in this report.

The report is aimed at people that are interested in the transition process towards a sustainable shipping sector and what role eco-labels can play in this transition.

Aalborg, June 2015

Roberto Rivas Hermann, Carla K. Smink & Stig Hirsbak

1 INTRODUCTION

The environmental performance of the shipping industry is increasingly regulated by international conventions that countries translate into national laws. The International Convention for the Prevention of Pollution from Ships (MARPOL) was approved by IMO in the late 1970s to regulate emissions to water, avoidance of hazards from spills, and solid waste. In addition to MARPOL, other environmental conventions and international regulations are already being enforced. The IMO published voluntary guidelines to comply with CO2 emissions limits in new ships – the Energy Efficiency Design Index (EEDI) to reduce the CO2 emissions of the next generation of vessels. During operation, ships sailing in certain geographical areas shall comply with the new MARPOL Annex VI limits of SOx and NOx emissions. In the EU, the EU ship Recycling regulation, which entered into force on 30 December 2013, frames ship end of life. This EU specific regulation ensures environmental and health protection in the process of dismantling of ships. Moreover, a number of additional country/ port specific regulations –based on national legislation and not in International conventions-, seek to reduce the environmental impact of vessels in specific domains -as noise, use of pollutant haul paint, etc. (Johansen and Fet, 2011).

Despite this broad regulatory framework based primarily on international conventions, some factors contribute on the shipping industry still being the focus of societal concerns regarding health and environmental hazards. In the first place, the regime of the industry, which allows ships to be registered in countries others than the country of owner, this aspect known as “flagging”, allows for example a relaxed enforcement by the flag state of existing international conventions. Then, the difficulties associated to monitor compliance by port-state authorities during the short times a vessel docks on a port-of call. Third, the business model involved in the shipping business which allows the shipping firms to lease vessels in order to fulfil the demand, in occasions these vessels are under standards as the owners have no interest to invest in expensive environmental technologies source. Finally, free riders profit of enforcement gaps with the purpose to reduce operational costs.

1.1 INVOLVING BUSINESS CONSUMERS AND END USERS IN ENVIRONMENTALLY RESPONSIBLE SHIPPING

The shipping industry and environmental NGOs have acknowledged that the challenges, as described in the introduction, cannot solely be solved through legislation or the improvement of enforcement mechanisms. End consumers and business customers (i.e. cargo owners) can drive ship-owners to commit to build and operate greener ships. In other sectors (i.e. food retail) eco-labelling schemes start to be popularized among end-consumers (Howard and Allen, 2010; Thøgersen et al., 2010; Uchida et al., 2014). Indirectly, end-consumers can become a driver through civil society organizations, which demand environmental responsibility to corporations. In this way, business customers can establish organizational changes which take closer look to the business' environmental impact through the value chain, among others: environmental management systems, green procurement programs (Lai et al., 2010).

In the last few years, cargo owners and shipping firms have started to participate in voluntary schemes based in public release of information –e.g. the well-known Clean Shipping Index (CSI) and other type of environmental schemes, which are analysed with more details in this report. Some of these voluntary programs incorporate elements of eco-labelling. For example in the CSI, individual ships are rated according to 22 criteria and this rating is translated into an operational performance label. Business consumers (i.e. cargo owners) can then choose the best performing vessel based in the information provided by the rating system. CSI is not the only type of voluntary environmental program, which focus is on cleaner ship design and operation. An overview by Pike et al. (2011), highlights other similar programs which seek to promote the adoption of cleaner technology (i.e. to reduce air pollutants emissions) and cleaner fuels. These voluntary programs include a system of incentives (in some cases provided by ports which participate in the programs), in other cases the incentive comes from the market –and business consumers.

Eco-labels and in a broader sense Environmental Product Information Schemes (EPIS) have been introduced as a communication tool with the aim of providing both professional and private consumers, and policy makers with information on environmental characteristics of products and services (Scheer et al., 2008). The introduction of both instruments also reflected a changing perspective in environmental policy towards a more extensive use of so-called marked based instruments. The aim is to encourage supplier and consumer behaviour change through market signals rather than through explicit command & control regulation regarding pollution control levels (Rubik, 2005).

The EU Eco-label, a voluntary label, was established by the EU Commission in 1992 was inspired by the mother of all Eco-labels, the German Blue Angel (launched in 1978). The eco-label thinking is expressed in a communication in 1989 from the Commission[15] under the headline prevention by products: *"The minimizing of waste at product level must consist in taking account of the environmental impact of the entire product life cycle. It must be ensured that products placed on the market make the smallest possible contribution, by their manufacture, use or final disposal to increasing the amount or harmfulness of waste and pollution haz-*

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[15] A Community strategy for waste management. "Communication from the Commission to the Council and to Parliament". SEC (89) 934 final, 18 September 1989

ards." The communication therefore proposes an introduction of a Community ecological labelling scheme, which was launched through a Community regulation in 1992, is still existing and known as the EU Eco-labelling scheme (http://ec.europa.eu/environment/eco-label)

The intention of the eco-label is to identify and to promote products and services, which have a reduced environmental impact throughout their production cycle and to give the consumer an environmental choice. The intention is to award products and services superior to legislation. The minimum criteria to be met should, as a main rule, cover around one third of the market and/or ensure visibility on the market. It is assumed that if the consumers prefer the eco-labelled product, then the rest of products suppliers will also be encouraged to participate in an eco-label scheme. As result, after three years the minimum criteria will be raised, assuming that e.g. more than 50% of the market can meet the criteria. The EU label schemes should in that sense be working like a pull and push mechanism.

In ISO terminology, the EU Eco-label scheme and Blue Angel are a Type I label – a business-to-consumer label, meaning an environmental labelling programme that is "a voluntary, multiple-criteria-based third party programme that awards a licence, which authorizes the use of environmental labels on products indicating overall environmental preferability of a product within a particular product category based on life cycle considerations[16]". Type I labelling is part of the ISO 14020 series of standards (see Appendix A). Several eco-labels are based on this series of standards, and therefore, some European countries and group of countries have launched similar eco-labels, an example is the Nordic Swan[17] in Scandinavia.

ISO (International Standards Organisation) has since 1999 published two other types of Labels, namely Type II and Type III labels (Appendix A for more detailed explanations about these categories of eco-labels).

Type II labels "Self-declared environmental claims" are the most widespread. A Type II Self-declared environmental claim is a statement, symbol or graphic that indicates an environmental aspect of a product, a component or packaging[18].

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[16] 14024:1999 clause 3.1 - Environmental labels and declarations – Type I Environmental labelling – Principles and procedures

[17] http://www.nordic-ecolabel.org/

[18] 14021 clause 3.1.3 NOTE An environmental claim may be made on product or packaging labels, through product literature, technical bulletins, advertising, publicity, telemarketing, as well as through digital or electronic media such as the Internet. Environmental labels and

Type III labels, a business to business label also called "EPD's – Environmental Product Declarations" is a pure LCA based type of labelling, but open up for relevant environmental information not covered of LCA data e.g. if a product has been awarded the EU Eco-label.[19]

Figure 1 illustrates examples of mandatory and voluntary EPIS schemes. The mandatory schemes are referring to EU CE conformity marking and symbols and sentences with regards to dangerous chemicals. The voluntary schemes are the ISO types of labelling and other voluntary schemes not meeting ISO label requirements, which is the case for the nearly all schemes within the shipping sector.

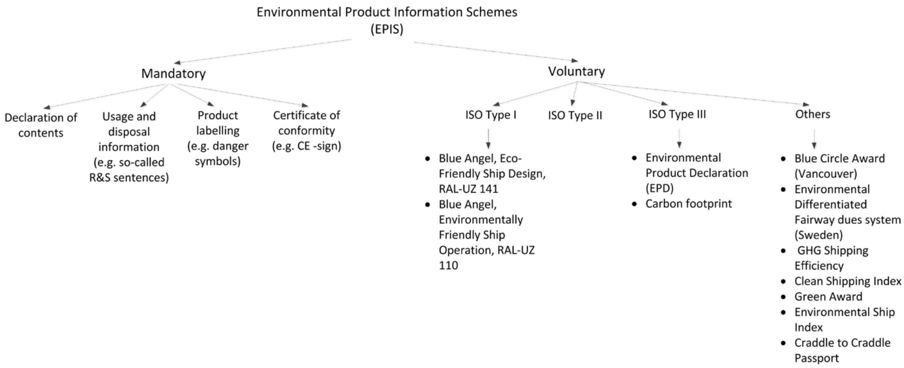

Figure 1 Classification of Environmental Product Information Schemes (EPIS) and relation with the shipping industry

1.2 SCOPE OF THE REPORT AND STRUCTURE

As stated above, market actors (e.g. end-consumers, business customers, and banks) can become a driver that demand environmental responsibility from shipping companies. These market regulations, i.e. the ways in which market actors (those actors that have a commercial relationship to a company) exert pressure on companies with regard to their environmental performance (Smink, 2002, p. 84), can be a useful way to encourage a greening of industry. Information is an important condition for the promotion of green markets. Eco-labels can play an important role in provid-

declarations - Self-declared environmental claims (Type II environmental labelling) (ISO14021:1999)

[19] ISO 14025: Environmental labels and declarations — Type III environmental declarations — Principles and procedures

ing the market this information. However, it is not easy to develop an eco-label, especially not in a globalised industry like the shipping industry. This report addresses the question:

How to develop an eco-label scheme for the promotion of wind-assisted propulsion technology in shipping?

This main question is divided in two sub-questions:

- *What could be the focus areas of an eco-label scheme to promote wind-assisted propulsion technology?*

- *To what extent do ports encourage ship-owners to improve their environmental performance?*

The report is structured as follows: the authors review existing voluntary and eco-label schemes for promoting cleaner shipping in order to provide insights to the first question (section 2). In the case, the authors discuss on general design characteristics of the Ecoliner (section 3) and benchmark these design characteristics against the verification criteria of "The Blue Angel", which is a type I scheme that awards the eco-label in the categories of "Eco-friendly ship design" and "Environmentally friendly ship operation" (section 4.1). At the outset of this benchmark analysis and relying on the general principle for eco-label design Type II- ISO 14021, the authors suggest ECO-SAIL as a new type of eco-label which focus is on the use of wind-assisted propulsion on ships. The role of incentive providers (among them ports) is looked in relation to the proposed ECO-SAIL eco-labelling scheme (section 5).

2 OVERVIEW OF EXISTING MARITIME TRANSPORTATION ECO-LABELLING SCHEMES

In this section we discuss the general characteristics of voluntary schemes and product eco-label relevant for the shipping industry. The databases of the Global Eco-labelling Network (GEN) and Eco-label Index (www.eco-labelindex.org) provided a comprehensive list of labels. We identified several eco-labelling schemes, which are relevant for maritime cargo transportation. In Figure 1 we grouped them accordingly to if they are consistent with the ISO 14020 series of standards. In Appendix B we provide a presentation of each scheme.

The detailed description of the different eco-labels presented in Appendix B shows that the actors in the shipping industry (e.g. ports, shipping companies, cargo owners) have settled several voluntary schemes, which do not follow the requirements of ISO 14020 (Type I, II or III). The common characteristic in these schemes is that they have technical criteria for assessing the environmental performance of individual ships. Ship-owners voluntarily participate in the schemes by submitting the data requested by the schemes. As result, the organization behind the scheme grades the ship according to the technical criteria (the responsible for the grading is a port as in the case of the blue circle award, an independent NGO in the case of the clean shipping index, etc.). In response to this grading, the ship/ship-owner receives incentives, which are meant to motivate investments in cleaner technologies. The incentives can be diverse: from reduced port-fees (in the case if the environmental differentiated fairway dues system in Sweden) (see also section 5), reduced prices by services delivered by maritime service firms participating in the scheme, to the possibility to attract more business to business customers who also have access to the database and are willing to contract the services of shipping with good environmental performing shipping firms (as in the case of the Clean Shipping Index, CSI).

Eco-label schemes that are not based on ISO 14024 are not widely diffused in the shipping industry and thus they overlap in many areas. For example, a shipping company can be part of the CSI to gain a good reputation among some cargo owners from Northern Europe, but at the same time participate in the Green Award scheme (promoted by some ports around the world). As the shipping companies are key actors in the supply chain (by delivering transportation and logistical services), then cargo owners willing to green their supply chain could have more challenges to identify those shipping companies with a better environmental performance, if the variety of green ship voluntary schemes is complex. A different scenario would be if the schemes were based in international accepted standards as ISO 14020.

However, only three eco-labels are inspired according to the ISO 14020 series of standards but these do not have the same diffusion and acceptance as the voluntary schemes that are not based on the ISO 14020 series of standards. The Blue Angel (Type I) and the Cradle-to-Cradle Passport (Type II) are the only labels with a direct relation to the shipping industry. The Blue Angel eco-label offers two kinds of awards for ships: one is meant for ship design (and applies for new ships) and the second is for the operation of already sailing ships. The Cradle-to-Cradle (C2C) Passport is an industry self-declaration from the shipping company Maersk, which claims “Recyclability” of the ship. Here the distinction between both types of eco-labels becomes evident, while type II is linked to one particular shipping firm, the type I eco-label is open to all shipping companies willing to have their ships labelled with the Blue Angel eco-label. In principle the Blue Angel should have a better acceptance in the shipping industry supply chain, e.g. cargo owners willing to green their supply chains would prefer contracts with shipping firms which fleets are Blue Angel certified. However this is not the reality, in the section 4 we explain what could be an alternative for an eco-label based on the ISO 14020 series of standards and what would make it more accepted scheme (internationally and along the supply chains relying on maritime transportation).

3 ECOLINER: MULTI-PURPOSE CARGO VESSEL

To prepare this section, the authors reviewed technical reports elaborated as part of the other work-packages in the SAIL project, in particular the technical and economic feasibility studies of the hybrid-propelled vessel Ecoliner. Some of these reports are publically available through the consortium website www.nsrsail.eu, other documents are available internally for members of the consortium.

3.1 THE TECHNICAL SPECIFICATIONS, SAILING ROUTE AND TYPE OF CARGO

The Ecoliner (Figure 2) is a desk ship designed by Dykstra naval architects[20] (The Netherlands). The Ecoliner, a multipurpose cargo and bulk vessel, combines a Diesel engine (3000 kW) along with four sailing rigs (Dynarig mast, with a capacity of 4000 m^2, 8000 deadweight tonne (DWT) and maximum speed of 12 knots). The speed can reach up to 18 knots depending of the climatic conditions (i.e. waves, wind and current).

The propulsion system also counts with an engine and propeller in order to secure constant speed but also to increase the wind in contact with the sails. Hence, the vessel secures less fuel consumption as compared as if only relied on engines to achieve the same speed. The combination of both technologies, wind-assisted propulsion along with the engine also reduces the emissions from the vessel. A computer simulation takes into account several climatological criteria and speeds of sail and concluded that the average fuel consumption rate for the Ecoliner is 6,9 ton/day, with larger variations expected depending on the weather conditions. In comparison, engine propulsion alone consumed 10, 7 ton/day. The Ecoliner includes four sailing rigs, which provide a combined area of approximately 4000 m^2; one person controls these rigs automatically from the bridge. The material is Dacron, a sailcloth relatively inexpensive and with a proven lifetime of over 100 000 miles without deterioration (see Appendix C for more design specifications).

20 http://www.dykstra-na.nl/

Figure 2 A sketch of a sailing Ecoliner vessel. Source: Dykstra Naval Architects (2013)

Since no prototype of the vessel is sailing at the moment, the desk studies suggest three suitable routes for the prospect Ecoliner:

- A clockwise round-trip of the North Atlantic
- Europe- South America
- US west coast- Japan

3.2 VALUE PROPOSITION OF THE ECOLINER

The value proposition of the Ecoliner is the reduction of the total costs (fuel costs +operational costs OPEX + capital costs CAPEX) when comparing to a vessel sailing exclusively through diesel engine propulsion. The CAPEX+ OPEX for the Ecoliner is higher than a conventional vessel running on fuel for all increasing speeds. However, this higher CAPEX cost is compensated by the lower fuel costs for the Ecoliner at increasing speeds. In consequence, the use of less fuel also means less pollutant emissions as SO_X, NO_X and greenhouse gases (Figure 3).

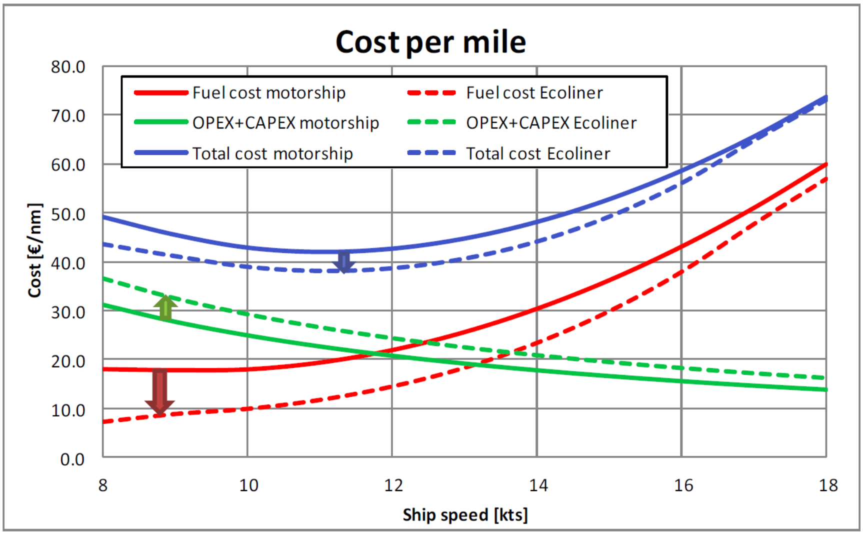

Figure 3 Cost per mile as a function of speed for a motor ship and the Ecoliner. Source: Dykstra Naval Architects (2013)

4 ECO-LABEL SCHEME FOR PROMOTING WIND-ASSISTED PROPULSION

According to the analysis presented in section 2, the Blue Angel is the only Type I eco-label scheme based on the ISO 14020 series of standards. In section 3 we present a benchmark analysis of the Ecoliner multipurpose cargo vessel in relation to the Blue Angel eco-label. We consider that a comparison between the Blue Angel and the Ecoliner is valuable as this is one type of vessel with expected good environmental performance and thus with the potential to raise the interest of actors in the supply chain, however we also analyse the shortcomings of the Blue Angel for ships as the Ecoliner. Based on the outcomes of the benchmark analysis, in section 4.2 we propose a labelling scheme based on ISO type I.

4.1 BENCHMARK ANALYSIS: THE ECOLINER AND THE ECO-LABEL BLUE ANGEL

The Blue Angel is the only European Type I Eco-label that is awarding an Environmental Label for Environmentally friendly Ship Operation[21]". The goal of

[21] Basic Criteria for Award of the Environmental Label Environmentally Friendly Ship Operation

awarding the Blue Angel eco-label for environmentally friendly ship operation is to reduce emissions and pollutant discharges from ocean-going ships into the marine environment. The Blue Angel eco-label may be granted for all ocean-going types of ships, provided that they comply with the requirements. The Blue Angel Standard is managed by four entities (Blue Angel, 2015):

1. The Environmental Label Jury is an independent decision-making body composed of representatives from environmental and consumer associations, trade unions, industry, trade, crafts, local authorities, science, media, churches and federal states
2. The Federal Ministry for the environment Nature conservation and Nuclear Safety is the owner of the label. It regularly informs the public about the decisions of the Environmental Label Jury
3. The Federal Environment Agency with its "Eco-labelling, Eco-declaration and Eco-procurement" department acts as office of the Environmental Label Jury and develops he technical criteria of the Basic Award Criteria for the Blue Angel
4. RAL[22] GmbH is the label-awarding agency

RAL has chosen a "flexible" approach because the basic criteria are to be taken into account for all types of new and existing ships. For this reason, the Blue Angel is as an ideal platform or model for developing basic criteria to promote hybrid sailing technologies, which is the purpose of this report. RAL has set criteria for issuing the Blue Angel eco-label according to two categories: "Eco-friendly ship design" (RAL-UZ 141) and "Environmentally friendly ship operation" (RAL-UZ 110). In Appendix C we present a list of these criteria for both categories.

4.1.1 ENVIRONMENTAL-FRIENDLY SHIP DESIGN

The criteria for "Eco-friendly ship *design*" are proposed for new ships and cover four categories:

- Environmental protection in ship design
- Structural protection from accidental environmental pollution,
- Reduction of operation-related emissions
- Criteria for tanker constructions.

RAL-UZ 110, Edition January 2010 (First edition was from 2002)

[22] RAL is the German Institute for Quality Assurance and Certification (www.ral-guetezeichen.de)

The first three categories apply to the Ecoliner; however only in one of them the Ecoliner design could make a difference from conventional vessels, and thus become an attractive option for ship-owners/operators wishing a new ship according to the Blue Angel criteria. The Ecoliner design highlights lower fuel consumption as compared to similar only fuel-powered vessels. This characteristic is eventually rewarded through the category "Reduction of operation-related emissions". In particular, five aspects deal with the emissions originating from the use of fuels: Sulphur emissions (SO_2), Nitrogen Oxide (NO_x) emissions, particulate emissions, Carbon Dioxide (CO_2) emissions, reducing emissions during time in port. The requirements for these aspects indicate compliance with IMO standards (i.e. MARPOL Annex VI, but also non-enforced standards as the Energy Efficiency Design Index (EEDI) and Environmental Operation Design Index (EODI). Hence, the assessment of whether a ship deserves the award is based on the emission threshold of the given ship, irrespective of which kind of technology is used to achieve that aim, e.g. if the ship uses sails or engines running on LNG. This threshold approach does not contribute as incentive for the development of alternative ship designs, which integrate e.g. wind propulsion.

4.1.2 ENVIRONMENTAL SHIP OPERATION

The Blue Angel eco-label in the category "Environmental friendly ship *operation*" is aimed for ships already in operation, and the requirements for delivering this label are grouped in three categories:

- Policy and management of the ship-owning company
- Ship design and ship equipment
- Ship operation management and ship operation technology.

Some issues are relevant when comparing the requirements from the Blue Angel eco-label with the design characteristics of the Ecoliner (Appendix C, Table 6): the first category focuses on the ship operator and not on the ship design. Hence, if the ship operator has a proper environmental management system, personal management system and personal development; here the Ecoliner does not make a difference with other conventional ships, for example a ship that eventually runs on HFO[23] engines. A similar situation occurs with the second category, "Ship design and ship equipment", where focus is on the hull protection (i.e. only the parameter on hull stress monitoring applies to the Ecoliner): if a ship runs on diesel engines proves that is designed according to this criterion, it will also gain points as if the Ecoliner proves this criterion. It is in the third category, "Ship operation management and ship operation technology", where the Ecoliner could have a relative

[23] Heavy Fuel Oil.

advantage over conventional ships, in particular three criteria (SO_X, NO_X, and CO_2 emissions). These three criteria require compliance with IMO standards, MARPOL Annex VI for SO_X and NO_X, and the Energy Efficiency Operational Indicator (EEOI) for CO_2 emissions. The challenge for the Eco-liner's wind-assisted propulsion technology is that these criteria focus on emissions thresholds based on engines that run on fossil fuels.

4.2 THE SAIL PROPOSED LABELLING SCHEME: ECO-SAIL

The intention of the labelling scheme is to promote environmental friendly ship design and operations by providing a market driven incitement for ship cargo companies to implement hybrid technologies on existing and new ships.

Based on these premises, the following shall be conditions for issuing the eco-label:

- The ECO-SAIL label should be an ISO type I label – based on life cycle thinking and a third party operation. The main reason is that the EU Eco-label regulation is built upon a Type I approach, and thus provides additional access to the Global Eco-labelling Network (GEN). The Type I approach will give the ECO-SAIL label a fair chance to be recognized.
- An international ECO-SAIL label should be aligned with the objectives of the two Blue Angel eco-labels for shipping. The first of these objectives deals with the design of eco-friendly ships: "implement as many environmental innovations as possible for reducing releases into the marine environment already during the planning phase for a sea-going ship". The second Blue Angel eco-label deals with ship operations and the objective is "to reduce emissions and pollutant discharges from ocean-going ships into the marine environment". Both categories of the Blue Angel are based on comprehensive background material (see Appendix C)
- An independent and impartial Jury from trade, cargo, port, retail and researchers shall develop the criteria set.
- The label shall be demand driven e.g. though alliances with big European retail chains and organization like Fairtrade

5 DEMANDS MADE BY PORTS

As described in the introduction, it has been acknowledged that a more environmental-friendly shipping industry cannot solely be achieved through legislation or the improvement of enforcement mechanisms. End consumers and business customers can drive ship-owners to commit to build and operate ships in a more sustainable way. In this section, we focus on the role ports can play in this regard. Shipping has an environmental impact both in ports, as well as in the immediate vicinity of the ports. Examples of these impacts are noise from ship engines and machinery used for loading and unloading and exhausts of particles, CO_2, NO_x and

SO_2 (OECD, 2011). Ports have a responsibility in ensuring a clean environment in port areas. A maritime eco-label, as the proposed ECO-SAIL (see former sections of this report), enables ports (and other stakeholders) to encourage ship-owners to improve their environmental performance and by this improve the environmental performance of ports. Many ports around the world have committed themselves to improve their environmental performance. As we will analyse in this section, some ports cooperate with shipping companies to also reduce environmental pollution from ships, other ports focus solely on activities in the port area.

In this report, we have chosen to investigate ports that join EcoPorts[24], a label that ports can achieve to show they have some kind of environmental management system. By means of analysing their website, we will investigate to what extent these ports make demands on ships with regard to their environmental performance.

5.1 ECO-PORTS

According to the EcoPort website the vision of EcoPorts *"has been to create a level playing field on port environmental management in Europe through the sharing of knowledge and experience between port professionals."*(EcoPorts, 2015a)

EcoPorts were established in 1994, and since 2011 it has been integrated in the European Sea Ports Organization (ESPO). The aim of the network is to exchange views and best practices across Europe in order to improve the environmental performance of the sector. In order to join the network the port must complete a SDM (Self Diagnosis Method). The EcoPorts SDM, is a checklist, against which the ports can self-assess the environmental management program of the port in relation to both European and international standards. Any port completing this SDM will be accepted into the EcoPort network. According to EcoPorts (2015) this is done as an award for providing the data. Thus, the EcoPorts SDM25 is a type II label (see also section 2). However, a port can obtain additional credit by submitting the SDM for analysis and obtaining a PERS (Port Environmental Review System26) certification, which is a port-sector specific environmental management standard. PERS verifies that the ports' environmental management programme is in line with the

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[24] http://www.ecoports.com

[25] The fact that certification is not necessary and the network membership is based on self-assessment is a weakness. As we recommended with regard to the ECO-SAIL label, it is preferable to have a label based on third party operation and with an independent and impartial jury.

[26] See for more information on PERS certification:
http://www.ecoports.com/templates/frontend/blue/images/pdf/PERSBrochure2011.pdf

requirements set by the EcoPorts PERS. PERS certification is valid for 2 years and can be independently certified by Lloyd's Register (EcoPorts (2015a).

At the time of writing (June 2015) there are 71 ports registered in the EcoPort network, see Figure 4.

Figure 4 EcoPorts as of March 2015 (EcoPorts, 2015b)

All the ports have completed the SDM and 20 ports have a PERS certification (EcoPorts (2015a). Next to PERS certification, some ports do also have ISO 14001 and/or EMAS certification. Number of certified ports and the combinations of certifications is shown in Table 1.

Table 1 Number of Ecoports with certifications as by June 2015. Source: EcoPorts (2015b)

Certification	Number of ports
No certifications (SDM only)	20 ports
PERS	20 ports
ISO 14001	38 ports
EMAS	5 ports
PERS + ISO 14001	6 ports
ISO 14001 + EMAS	5 ports
PERS + ISO 14001 + EMAS	1 port

5.2 ECO-PORT STRATEGIES

The number of EcoPorts changes, but at the time of our assessment (June 2015) there were 71 EcoPorts listed on the website; http://www.ecoports.com/map. Every website was visited and the first step was using their own search engine – simply searching for "environment", "sustainability" or "environmental". If no results came up a manual search was carried out. In the cases where environment/sustainability was identified on the website a manual skimthrough of documents to assertain the level of enviromental involvement. The results can be placed into five categories:

1. No result (i.e. website not available (in English))
2. No apparent focus on environment
3. Some mention of environment
4. Focus on the environment, but no apparent inclusion of ships in their strategies
5. Focus on the environment, and inclusion of ships in strategies

8 out of 71 ports do not have an English version of their website. These ports have not been analysed any further. 22 out of 71 ports fall within the second or third category. Some ports show a copy of their (PERS/ISO 14001) certification without any further comments; other ports in these two categories have a general description on sustainability and Corporate Social Responsibility (CSR) without going into detail how they as a port work on these sustainability issues. Among the ports in these categories, there are also ports that do have ISO14001 certification.

The ports in the fourth category (36 ports) are more specific about their environmental activities. The environmental strategy of these ports can be labelled "comply with existing regulations" or "move beyond compliance". An example of the first strategy is the implementation of a Port Waste Plan, since ports in the European Member States are, under the European Directive (2000/59/EC), required to make a Port Waste Plan. An example of the latter strategy is the use of electric vehicles in the port estate in order to reduce greenhouse gas emissions. However, common to both strategies is that these ports solely focus on the environmental performance within the port estate. The ports in this category are typically very clear about what environmental aspects they monitor (typically air, water, noise and waste pollution).

Out of the 71 examined ports, five ports make demands on the environmental performance of ships. Common to all these ports is that they apply lower port fees for ships with lower pollution. JadeWeser Port (Germany) (SDM registration only), for example, applies lower port fees for ships with lower sulphur emissions; they apply the Environmental Ship Index (ESI) (see appendix B for a description of this label) to provide financial incentives for ships that protect the environment (JadeWeserPort, 2015). JadeWeser Port is also involved in developing international standards for the use of cleaner fuels such as LNG. Unfortunately, there is no information available regarding the level of discounts or which level of sulphur emission or ESI points will prompt the discounts. Also the ports of Bremen/Bremerhaven (PERS certified) have introduced the ESI. Since 2012, shipowners are paying lower charges if they despatch highly environmentally friendly vessels in Bremen and Bremerhaven (Bremenports GmbH, 2013). In the ports of Bremen/Bremerhaven, it is the top 25 vessels that will receive a discount, see Table 2.

Table 2 Summary of available discounts at Ports of Bremen (Port of Bremen, 2010)

Measurement	Level to achieve discount	Discount
Environmental Ship Index	30-40 points	5 % discount
Environmental Ship Index	≥40 points	10 % discount

The sulphur content of the fuel and the nitrogen emissions of the vessels have been taken into account in the port charges of the Port of Turku (Finland) (ISO 14001 certified) since 2006. For granting a reduction of the charge[27] it is required that the port is given an acceptable certificate or specification of the sulphur content of the fuel and nitrogen emissions of the vessel. The price reductions are also applied in waste management (Port of Turku, 2015).

Both the Port of Gothenburg (ISO 14001 certified) and the Port of Stockholm (ISO 14001 certified) state very clearly on their website, that – in conjunction with the new more stringent sulphur regulations that apply from 1 January 2015 – they have revised their discount systems[28]. In Gothenburg, the port charge has been differentiated according to the Clean Shipping Index (CSI) (see also section 2) and the ESI. The port also awards ships that make the switch to LNG. The port discounts are summed up in Table 2.

[27] Details of the price reductions to be granted can be found here: http://www.portofturku.fi/portal/en/charges/

[28] The Port of Stockholm has applied differentiated fees since the 1990s and the Port of Gothenburg since 1998.

Table 2 Summary of available discounts at Port of Gothenburg. (Port of Gothenburg, 2015)

Measurement	Level to achieve discount	Discount
Clean Shipping Index	Green standard	10 %
Environmental Ship Index	≥30 points	10 %
Switch to LNG		20 % through to December 2018

In the Ports of Stockholm the environmental rebates are the following (Ports of Stockholm, 2015a):

- A funding contribution of € 108.495 will be offered to every vessel that carries out restructuring work to enable the vessel to connect to electricity at the quayside. This applies for the quays where Ports of Stockholm offers quayside electricity connection capabilities
- The port fee for LNG vessels will be discounted by € 0,0054 per unit of gross tonnage. For a vessel calling at Stockholm every second day the rebate will be around € 54.247 annually
- The discount for reduced emissions of nitrous oxide will follow the seven-level scale applied by the Swedish Maritime Administration. For a normal-sized vessel operating daily calls this will mean a discount of between € 325.486 to € 433.981 annually, depending on the amount of nitrous oxide emissions.

In that sense, the Ports of Stockholm goes a step further than some of the other ports in this category.

Next to the differentiated fees for ships, the port of Gothenburg states it will be carbon neutral by 2015. At the time of writing, their website does not state whether it has been achieved yet (see also the environmental report of the port[29]). Even though the carbon neutrality seems to only apply to the port estate, their environmental work does happen in collaboration with the terminals, shipping companies and the land based transport operators. The port does also reward and compensate for green investments. Also the ports of Stockholm have some very concrete overall environmental targets that not only focus on the environmental activities in the port estate, but also include ships (Ports of Stockholm, 2015b):

[29] www.portofgothenburg.com/about-the-port/sustainable_port/sustainability

- Energy consumption will be 50 percent less by 2025
- Zero fossil fuel carbon dioxide emissions by 2025
- All purchasing of goods and services will have environmental requirements by 2016
- Reduced material consumption and increased proportion of recycled material in buildings and facilities
- Reduced environmental impact in choice of materials
- No hazardous substances in buildings and facilities by 2020
- 100 percent of all materials must be sorted at source and the proportion of waste sent to landfill will successively diminish
- *Ensure that the major shipping company customers operating via ports of Stockholm use Ports of Stockholm's environmental improvement services by 2020*[30]
- Increase the number of environmental improvement services by 100 percent by 2020

5.3 CONCLUSIONS

In this section we have analysed to what extent ports that are members of the EcoPorts network make demands on ships with regard to their environmental performance. In total 71 ports are registered in the EcoPorts network, but since 8 of the ports don't have an English version of their website, we have analysed 63 ports. By means of an assessment of the website of these ports we come to the realisation that 34 % of ports (22 out of 63 ports) do not have apparent focus on environment or only some mention of the environment on their website. For the purpose of our study, these ports have not been analysed any further. In total 41 ports focus on the environment on their website and 5 of these ports do also include ships in their strategies.

Since we only executed an analysis of the website of the ports that join the EcoPorts, we cannot conclude that 34 % of the registered EcoPorts do not have apparent focus on the environment; we can only wonder why ports decided to join the EcoPorts network but not decide to share information on their environmental strategies on their website.

On the other hand 65 % of the ports that join the EcoPorts (41 out of 63) do focus on the environment and of these ports 8 % (5 out of 63) do make demands on ships with regard to their environmental performance. Common to these 5 ports is that they apply differentiated fees for ships.

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[30] Text in italics by the authors of this report.

Out of the 5 ports that make demands on ships with regard to their environmental performance, one ports does only have a SDM registration, one port is PERS certified and three ports are ISO 14001 certified. But there are also ports in the EcoPorts network that are ISO 14001 and/or EMAS certified, but do not mention the environment on their website. Thus, there does not seem to be a correlation between having a certified environmental management system or the EcoPort label and promote the environment on the website.

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APPENDIX A: ISO 14020 STANDARD ON ENVIRONMENTAL LABELS AND DECLARATIONS

The authors referred to the ISO 14020 series of standards on environmental labels and declarations, which are international recognized benchmark against which business can prepare environmental labelling, which are increasingly used in products and in advertising. We present in this section a short introduction the ISO 14020 series of standards on Environmental labels and declarations. This description will be the background for analysing which labelling scheme will be best for a ship like the Ecoliner.

According to the ISO 14020 series of labelling standards, an Environmental label and an environmental declaration are defined as a claim, which indicates the environmental aspects of a product or service[31]. ISO 14020 includes 9 principles and principle 1 expresses very well the expectation to claim "*Environmental labels and declarations shall be accurate, verifiable, relevant and not misleading*"[32].

14024:1999 Environmental labels and declarations – Type I environmental labelling

A Type I environmental labelling programme is a voluntary, multiple-criteria-based third party programme that awards a licence, which authorizes the use of environmental labels on products indicating overall environmental preferability of a product within a particular product category based on life cycle considerations[33]. A good example is EU Eco label scheme[34] (the Flower) and the Nordic Eco label[35] (the Nordic Swan). The Global Eco labelling Network (GEN) is organization for ISO type I schemes (see http://www.globaleco-labelling.net).

ISO 14021:1999/AMD 1:2011 Environmental labels and declarations – Type II environmental labelling

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[31] ISO 14020:2001 Environmental labels and declarations – General principles clause 2.1
[32] 14020 clause 4.2.1
[33] 14024 clause 3.1
[34] http://ec.europa.eu/environment/eco-label/the-eco-label-scheme.html
[35] http://www.nordic-eco-label.org/

An environmental claim is a statement, symbol or graphic that indicates an environmental aspect of a product, a component or packaging[36]. Type II is the most widespread used type of labelling and in this the category you will find many misleading claims. The standard sets some examples of what is considered as a misleading claim (Table 4). In order to prevent misleading environment market claims the Nordic Ombudsmen issued in 2005 new guideline on ethical and environmental marketing claims[37].

Table 4 Examples of misleading and preferred claims according to ISO 14021:1999/ AMD 1:2011

Misleading claim	Preferred
"This new and improved product is better for the environment" "This product uses green electricity" "This product is ozone-friendly"	"This product uses 20% less electricity in normal use than our previous model". "This product has replaced its aerosol ingredients with an alternative that does less to harm the ozone layer"

The standard sets criteria for each claim labelled in the product. Figure 5a and Figure 5b list all the claims having criteria within the standard. The most well-known claim in the standard is the Mobius loop (Figure 1c). Figure 1d claims recycled content and the symbol used in the packaging of aluminium cans.

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[36] 14021 clause 3.1.3 NOTE An environmental claim may be made on product or packaging labels, through product literature, technical bulletins, advertising, publicity, telemarketing, as well as through digital or electronic media such as the Internet.

[37] http://www.consumerombudsman.dk/Nyheder-fra-FO/Media-releases/newnordicguidelineet?tc=9E6C43D351DE4F29B6F4570D45826A9F

(a)

7.2 Compostable
7.3 Degradable
7.4 Designed for disassembly
7.5 Extended life product
7.6 Recovered energy
7.7 Recyclable
7.8 Recycled content
7.9 Reduced energy consumption
7.10 Reduced resource use
7.11 Reduced water consumption
7.12 Reusable and refillable
7.13 Waste reduction

(b)

- Biomass
- GHG
- Offsetting
- Disposal and recycling
- Renewable material
- Renewable energy
- Sustainable
- Product "carbon foot-print"
- Carbon neutral

(c) (d)

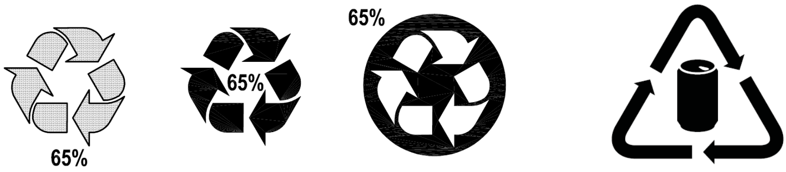

Figure 5 Types of claims that could be used in Type II eco-labels. (A) According to ISO 14021:1999 and (B) According to Amendment 1:2011 (c) Mobius loop (d) recycled content claim found in aluminium cans

ISO 14025:2006 Environmental labels and declarations — Type III environmental declarations

A Type III environmental declaration is providing quantified environmental data using pre-determined parameters and, where relevant, additional environmental information[38]. Type III is a pure LCA based type of labelling, but open up for relevant environmental information not covered of LCA data e.g. if a product has been awarded the EU Eco-label.

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[38] 14025 clause 3.2 NOTE 1 The predetermined criteria are based on the ISO 14040 series of standards, which is made up of ISO 14040 and ISO 14044. NOTE 2 The additional environmental information may be quantitative or qualitative

The requirements of Type III will expand in 2016 because the influence of the EU Commission and the Joint Research Centre. The main consequence is Type III eco-labelling will be linked to an open source generic LCA data and Product Category Rules for a number of product groups e.g. building material (with materiel overlap with ship building – steel and wood, etc.) and become implemented step by step through the Environmental Footprint approach which is in the test stage, but soon will be in the implementation stage.

APPENDIX B: RELEVANT ECO-LABEL SCHEMES FOR CARGO MARITIME TRANSPORTATION

Schemes based on ISO 14020 series of standards (Type I, II or III)

The Blue Angel

The respected German eco-label “Der Blaue Engel” has two categories dealing with shipping. The label is given by a non-for-profit consortium involving representatives from the Federal Ministry of Environment, Nature Conservation, Building and Nuclear Safety, the certification organization RAL, the Federal Environmental Agency and the Environmental Label Jury (an independent decision making body formed by civil society representatives). Both categories have a set of quantified criteria in order to apply for the label. Given the widely diffusion of the eco label “The Blue Angel “ among the public, ships with this label can benefit of greater market appeal.

The first category in The Blue Angel on shipping is about Ship design and construction. It is awarded to eco-friendly ship designs that implements environmental standards during the design and construction of the ship. The scope includes four points:

- Environmental protection in ship design
- Structural protection form accidental environmental pollution
- Reduction of operation-related emissions
- Criteria for tankers

The requirements are in line with applicable international regulations of safety. A great emphasis is put in the third point, which includes the installation of environmental technology, which is not required by law (example Sulphur and Nitrogen Oxides reduction equipment in some areas), but is a requirement to obtain the eco-label.

The second subcategory within The Blue Angel is Ship Operation. It is awarded to individual ships that during operations demonstrate reduction in emissions to both air and water. Ships with German and foreign flags can receive the eco label and have to fulfil a set of criteria, which includes:

- Policy and management of the ship-owning company
- Ship design and ship equipment
- Ship operation management and ship operation technology

In the third point the following environmental aspects are addressed:

- Air emissions
- Solid waste
- Wastewater
- Liquid emissions (i.e. bilge oil, ballast water, lubricating and hydraulic oils, cleaning agents)
- Noise and sound emissions

Environmental Product Declaration

Environmental Product Declaration is a verified document based in the ISO 14025 standard (environmental declarations). The declaration is for specific products and the set of criteria to be assessed are listed in the EPD international system. All products issuing an EPD are also listed in the website (Figure 6a). A vessel, for instance could apply for an EPD label provided that it complies with all the award criteria. Earthsure is the EPD for North America, and is administered by the Institute for Environmental Research and Education (IERE). Earthsure is based on an LCA. In order to ensure that similar products are assessed in comparable ways, IERE publishes category rules for each product (PCR). In case no PCR exists, the applicant has to make sure to prepare the PCR as part of the application process.

(a) (b)

Figure 6 Environmental Product Declaration (a) Logo of the international EPD system, which lists all the products that issue and environmental product declaration (b) Earthsure is the EPD eco-label in North America

Schemes not based on ISO 14020 series of standards

Other voluntary schemes relate to maritime transportation but are not based on the ISO 14020 series of standards. These three schemes share the similarity that authorities categorize ships according to an environmental parameter (SO_X and NO_X in the case of the Swedish system), and then reward the ships that fulfil or surpass the threshold included in the environmental parameter. The reward is typically a reduction in port-due fees (as the case of the Swedish and Canadian scheme), a simplification in the paperwork and a fast-track process for port-calls (in the case of the US scheme).

Other eco-labels directly related to maritime transportation have a focus on emissions reduction (NO_x, SO_x and CO_2), with an exception the Clean Shipping Index which also includes operational criteria which are not only emissions (i.e. hull paint, or bilge water handling). This kind of voluntary schemes is the most popular among ship-owners and cargo owners (Wuisan et al., 2012). In the same way, NGOs (as the North Sea Foundation) actively promote these schemes as market instruments to convince ship-owners to invest in green technology.

Cradle-to-Cradle passport (Maersk):

This is an example of Type II environmental labelling. Cradle-to-Cradle passport is an inventory of the materials used for the construction of ships (specifically the Maersk Triple-E class). The inventory allows proper locating the ship's recyclable components so the recycling process is carried. According to the ISO 14021 standard, Cradle-to-Cradle will be an example of the environmental claim "Designed for disassembly".

Blue Circle Award

The program awards shipping companies with vessels calling into the Port of Vancouver. The shipping firms have to apply to the award with each individual vessel once a year or during each port call. The port authorities published harbour fees categorize the vessels calling into port into bronze, silver and gold. These fees are reduced as compared to the normal price requested to vessels not falling into these categories. The requirements to be granted the blue circle award is demonstrated efforts to reduce the emissions, or the quality of fuel.

The scheme is part of the air component within the Port Metro Vancouver EcoAction Program –which has similar initiatives for land, water, noise monitoring, habitat enhancement and marine mammals.

Environmental differentiated fairway dues System

The system is an addition to the fairway due fees which are normally paid according to each vessel gross tonnage, and loaded/ unloaded cargo. One aspect of environmental differentiation is the sulphur fee, where the sulphur content is calculated according to the percent by mass. When this figure is between 0-0,2 %, the fee is 0 Swedish Krone (SEK); when the % is between 0,21-0,5 the fee is 0,20 SEK per unit of vessels gross tonnage. Above 0,51 % of sulphur the fee is 0,70 SEK. Another aspect of environmental differentiation are Nitrogen Oxide emissions, whose fee is calculated in a similar way as for the sulphur oxide emissions. The goal of the scheme is incentivize the ship-owners to install environmental technology to reduce the emissions of both SO_X and NO_X.

Shipping Efficiency - A to G GHG Emission Rating (ISO Type II)

The A-G GHG Emissions Rating provides a systematic and transparent means of comparing the relative theoretical efficiency and sustainability of the existing fleet of approximately 70,000 existing ships (including the majority of the world's container ships, tankers, bulk carriers, cargo ships, cruise ships and ferries) by measuring a ship's theoretical CO2 emissions per nautical mile travelled.

A vessel's GHG Emissions Rating is presented using the standard European A - G energy efficiency scale and relative performance is rated from A through to G, the most efficient being A, the least efficient being G. ShippingEfficiency.org is an initiative launched by the Carbon War Room and Right Ship. Learn more: Shipping Efficiency - A to G GHG Emission Rating website.

Clean Shipping Index

The Clean Shipping Index is a Swedish-initiated eco-label and clean ship database, which seeks to facilitate business customers to find the best environmentally performing vessel. The vessels listed in the database shall comply with a set of 22 environmental criteria, which includes for example, how well the vessel performs in terms of emissions to air, water, etc. After filling an online questionnaire for each vessel, a third party verifies that the vessel performance is in line with the introduced values. Then the vessel is listed in the online database, and is benchmarked with similar vessels (i.e. a cargo ship with a cargo ship). The potential business customer (a cargo owner willing to purchase a ship service) can have access to the database and can decide to fleet with the best performing shipping liner. The Clean Shipping project is behind the index as a non-for-profit organization, participant pay a membership fee, which is intended to cover operational costs.

Green Award – the pride of oceans

The Green Award is a scheme that certifies that a vessel has an environmental and safety performance above the regulatory thresholds. The scheme is open to tankers, bulk carriers, chemical tankers, container ships and also inland barges. It is managed by a private foundation, which is formed by a Committee, a Board of Experts, a Board of Appeal and a certifying Bureau Green Award. Key actors of the shipping industry are represented in all these bodies, for example SIGTTO, INTERTANKO, INTERCARGO but also NGOs (North Sea Foundation).

A given ship can become awarded the Green Award after a certification by the Bureau Green Award. The survey includes safety and environmental criteria. Once a vessel is certified with the green award, it is listed in an online database (publically available). These vessels can obtain fees reductions in associated ports (i.e. Rotterdam, Hamburg). Associated marine service providers (i.e. environmental and safety consulting firms) also provide reduction in services. By January 2015, a total of 244 ships hold a green award. http://www.greenaward.org/greenaward

The Environmental Shipping Index (ESI) (ISO Type II)

The Environmental Shipping Index is a voluntary scheme focused on air pollution by ships. It is an initiative launched by the World ports climate initiative. The environmental criteria addressed by the index are SO_X and NO_X emissions and greenhouse gases. The index is calculated with an algorithm where all three criteria are taken into account. The values range from 0 to 100. A 0 value implies the ship complies with applicable standards, and a value of 100 is a ship with the best performance above applicable standards. The data is provided by the ship-owners, and an audit is subjected at the request of an incentive provider. In these cases, independent auditors are requested to carry the audit. Several major ports around the world provide incentives to ships registered in the scheme.

http://esi.wpci.nl/Public/Ships

Schemes indirectly related to shipping transportation and not based on ISO 14020 series of standards

Several eco-label schemes include a quantitative analysis of the product/ organization environmental impact and are backed-up by a national/ international recognized organization. In these cases transportation is included in the quantification of emissions, or other type of environmental impact. These eco-labels schemes certify if a product or organization is CO_2 neutral or engages in offsetting emissions. They share the similarity that the quantitative assessment is done through an LCA or carbon footprint analysis. The first example in Figure 7 is the Carbon Neutral Award, which is given to businesses (rather than products). The labelling process involves four steps: an audit to define the annual carbon footprint. Then this assessment provides a conclusion whether the firm needs to offset some of the emissions, the certifying agency then provide some options for offsetting, and if accepted them the business can obtain the label. The last step involves publicizing the company achievements and using the label. The label is issued by a consultant organization, which relies on standardized ISO methods for the LCA analysis and the issuance of the eco-label.

The second example in Figure 7 is Carbon Neutral Product Label, which is an Australian based eco-label (but can be issued to products from other countries). The certifying body is a for-profit organization Carbon Reduction Institute. The label can be issued to both products and organisations; the process of labelling involves a similar process as the Carbon Neutral Label.

The third example in Figure 7 is the Carbon Reduction Label. The scheme is administered by the Carbon Trust, an independent third party, which among other commitments advices firms about sustainability. The eco-label can be of two types: Reducing CO_2 label (which indicates that a firm takes the measures to reduce the carbon footprint), and CO_2 measured label, which indicates that the product(s) or service(s) are carbon neutral. The carbon footprint analysis is based in the British Standard PAS 2050.

(a) (b) (c)

Figure 7 Global reaching carbon neutrality eco-labels incorporating transportation in the LCA or carbon footprint analysis. (a) Carbon Neutral Label (b) Carbon Neutral Product Labelling (c) Carbon Reduction Label

APPENDIX C: SELECTED DESIGN SPECIFICATIONS OF THE ECOLINER

Main particulars	
Length o.a.	138,00 m
Length p.p.	135, 50 m
Length w.l.	138, 00 m
Beam mld.	18, 20 m
Depth main deck	10, 20 m
Ballast draft	4, 50 m
Draft max	6,50 m
Performance (engine-only condition, range and speed will differ when using sails only or when motor sailing)	
Range	25 days
Design speed	12 kts

Capacities	
Cargo hold No1	3 950 m^3
Cargo hold No2	4 730 m^3
Cargo hold No3	4 320 m^3
Cargo hold total	*13 000 m^3*
Main propulsion	
4 Dynarig masts, total of approx.. 4000 m2	
4 hydraulic yaw systems, yaw radius of 180^0	

APPENDIX D

Table 5 Blue Angel, Eco-Friendly ship design. RAL-UZ 141

Category	Type of specific criteria
Environmental protection in ship design	Protection of bunker tanks On board use of materials
Structural protection from accidental environmental pollution	Redundant power systems Emergency towing system Hull stress monitoring
Reduction of operation-related emissions	Sulphur dioxide emissions Nitrogen oxide emissions Particulate emissions Carbon dioxide emissions Reducing emissions during time in port Refrigerants Extinguishing agents Waste avoidance Waste disposal and waste incineration Black water (sewage) treatment Grey water treatment Bilge water treatment Ballast water treatment Use of lubricating and hydraulic oils Application of antifouling products on the hull Application of antifouling products on seawater cooling systems Corrosion protection measures Use of dosage systems for cleaning agents
Criteria for tanker constructions	Protection of cargo tanks

	Use of an online loading computer Installation of a gas detection system Inert gas systems on takers Inerting of ballast water tanks and void spaces Emissions from the cargo during loading and unloading Tank design Cargo traces in wash water Cargo tank residues

Table 6 Blue Angel, Environmental friendly ship operation requirements. RAL-UZ 110

Criteria	Obligatory requirements
Policy and management of the ship-owing company	
Environmental management	Implementation of the international safety management (ISM) code And ISO 14001
Personnel management	Different requirements regarding the crew on board the ship: • The crew is part of the collective agreement provisions of the International Worker's Federation • The crew's certificate of competence is issued by a country on IMO's white list of standards on training, certification and watchkeeping • Environmental training
Personnel development	Training based on IMO STCW-95-Code. Additional requirements include systemic identification of additional areas for training, training once every two years on current developments related to legal provisions relevant to the ship, ship handling simulator
Ship design and ship equipment	
Hull stress monitoring	*Optional* installation and operation of a hull stress monitoring system to monitor the stress on the ship's structure
Emergency towing system	Valid for tankers 20000 dwt or more according to SOLAS Convention. Applicable for ships constructed on or after Jan. 1st 2010
Ship operation management and ship operation technology	
Sulphur dioxide emissions	Compliance with MARPOL Annex VI rules regarding sulphur content in marine fuels (e.g. shall not exceed 1,5%). Additional requirements regarding the use of scrubber and emission monitoring instrumentation.

	Possibility to use scrubbers if these are of the type closed-loop.
Nitrogen dioxide emissions	Compliance with MARPOL Annex VI regarding NO_X emissions.
Carbon dioxide emissions	Recording ship operational efficiency according to EEOI, development of a ship energy efficiency management plan (SEEMP), provision of technical data of the ship and ship operation consumption data for research on energy efficiency
Other climate-relevant and ozone depleting emissions	Compliance with MARPOL Annex VI, regulation 12 on the installation of systems which contain substances with an ozone-depleting potential –ODP or CFC
Waste disposal	Compliance with EU Port reception facility directive 2000/59/EC, which requires ships to dispose their waste on land
Waste incineration	Gas exhaust values as defined by MARPOL shall be met for waste incineration. Ships carrying more than 15 persons shall keep a Garbage Record Book
Black (sewage water)	Compliance with MARPOL Annex IV as specified in MEPC 159/55. In addition, chlorine and halogenated compounds shall not be used
Grey water	Similar requirements as for black water
Bilge water	Compliance with MARPOL Annex I, the residual content of bilge shall not exceed 15 ppm
Use of antifouling paints on the hull	Compliance with the IMO "International convention on the Control of Harmful Anti-fouling systems on ships"
Ballast water treatment	The ship is not required to comply with the IMO Ballast Water Convention as this is not yet entered into force. The shipowner shall however keep a ballast water management plan in accordance with IMO resolution A. 868 (20).
Lubricating and hydraulic oils, biodegradable	As there are no international binding obligations, the Blue Angel label requires the use of biodegradable lubricating and hydraulic oils in accordance with the criteria for lubricants RAL-UZ 64 or hydraulic fluids RAL-UZ 79 in all on board systems approved by the manufacturer.
Cleaning agents	Cleaning agents should be used in a diluted form through a system that delivers well-dosed portions. An optional requirement sets extra points if the systems operate with biodegradable lubricating and hydraulic oils.

Sound emissions	Requires compliance with IMO code on Noise levels aboard ships, and the IMO Code on high speed craft (HSC-code). As additional requirement, Blue Angel suggests regular maintenance and servicing work for a check of sound levels.
Environmentally sound recycling	The shipowner and operator shall comply with the requirements set in the Hong Kong convention, in particular with the provisions set in MEPC 179 (59) of 17 July 2009 –Guidelines for the Development of the Inventory of Hazardous Materials.

SUMMARY

The maritime cluster in Region Northern Jutland faces the challenge of improving collaboration and competencies among suppliers in order to obtain the economic and societal benefits of accessing the emerging market of maritime eco-innovations. A key issue for exploration is how to create value in the development and commercialization of eco-innovations, while at the same time improving collaboration and competences among local suppliers. This thesis addresses the question: How can maritime suppliers deliver product and service eco-innovations to the maritime industry?

The results are presented in four articles. The first article focuses on how regulation influences eco-innovation by interacting with other drivers (e.g. market, technology and business internal aspects) in the maritime industry. The second article focuses on how partnerships create arenas for co-creation of eco-innovations between maritime suppliers and other actors. The third article inquires how business models support the development and implementation of eco-innovations through value propositions. Finally, the fourth article focuses on how intermediaries initiate and stimulate the development and implementation of eco-innovations through facilitation and project management.

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