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Eco-Innovation Drivers in Value-Creating Networks: A Case Study of Ship Retrofitting Services

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Abstract: Previous studies discuss how regulatory, technological and market drivers increasingly challenge manufacturing industries to adopt eco-innovations. However, the understanding of the process by which eco-innovations are developed and commercialized as a result of these drivers is not yet well established, in particular because these drivers are perceived differently by the end-users and their suppliers. In this paper, we address the following research question: How do eco-innovation drivers shape processes in value-creating networks? To answer this question, we carried out a case study purposely selected to understand how eco-innovation drivers, such as regulation, market pull and technology, interact and affect the eco-innovation decisions in a given industry. We analyzed the processes in an eco-innovation initiative about retrofitting old ships, contextualized in the maritime equipment and supply industry. The paper makes two novel contributions: First, we develop a framework that can support supply-network eco-innovation initiatives to deal with changes at the regulatory, market and technology levels. The framework includes elements, such as value co-creation to explore technological opportunities emerging from the interaction of the drivers or value proposition development to align multiple actors' interests in the network and agree on shared expectations to exploit the opportunities. Second, we contribute to the emerging research area on eco-innovation processes by highlighting the lesser-known role of value-creating network dynamics. Value-creating networks can be a platform for the development of more radical eco-innovations if actors in the networks can align their value creation and capture objectives.

Keywords: eco-innovation process; value-creating network; maritime technology; business ecosystem; eco-innovation drivers; eco-innovation practices

1. Introduction

Research about eco-innovation has moved beyond understanding what drivers or barriers face companies in the development/adoption of technologies with economic and environmental goals [1]. Instead, more attention is paid to opening the "black box" of the eco-innovation process [2–4]. As a result, the understanding of eco-innovation is broadened, and recent contributions indicate that eco-innovation can be the outcome or be a process itself [1].

Previous studies highlight that changes in the external environment, such as the implementation of new regulations, the change in consumer preferences or technological advantages, drive the eco-innovation process [5–7]. Eco-innovation literature in particular stresses the importance of technological push, market pull and regulatory push/pull as drivers of eco-innovation [8] and provides a comprehensive knowledge base of eco-innovation drivers [9–11]. However, this literature often fails to explain how these drivers influence and shape the eco-innovation process, including its activities and events. Meanwhile, extant research about eco-innovation processes highlights that changes in the environment (technology, regulations, market) can affect stakeholders' relations within collaborative networks [12,13]. Multi-stakeholder eco-innovation projects are an area of increasing interest in the literature [12,14]. One such collaborative multi-stakeholder setting is value-creating networks [15]. Value-creating networks can be a platform for providing customized products, high-quality services, social fraternization and special treatment (e.g., customization) [15]. A value-creating supplier network can be a particular mode of organizing innovation activities aimed at creating value for customers [16]. In this paper, we intend to contribute to the literature on eco-innovation taking place in value-creating networks of suppliers from a process perspective.

A process perspective includes activities and actions as a result of actors sensing, making and reacting to the changes in regulations, market and technologies (drivers). Additionally, despite the importance of value-creating networks for the provision of environmental technologies in certain industries [17], a gap in the knowledge exists regarding why and how eco-innovation in value-creating networks evolves. This is partly because most of the contributions about value-creating networks have been theoretical so far or applied to fields such as electronics or e-commerce [18]. Thus, we address the following research question:

How do eco-innovation drivers shape processes in value-creating networks?

Value-creating networks are particularly relevant in the maritime sector, where ship building, ship maintenance and ship repair become modular and allow for the supply of parts and equipment by networks of suppliers rather than by a single shipyard, as was in the past [17,19,20]. As a result of this modular approach to ship building, the supplier network became entangled with service sourcing and now participates in new product designs, many of which focus on eco-innovation [21,22].

The focus on eco-innovation in the maritime industry came about in recent years as the industry experienced rapid changes that sought to address many of the environmental impacts associated with maritime transportation and ships [23,24]. Air pollution from shipping is a well-documented subject, with pollutants, such as SO_X and NO_X, directly related to cardio-pulmonary diseases, premature deaths and acid rain in coastal areas [25–27]. In response, the International Maritime Organization (IMO) created Sulphur Emission Control Areas (SECAs) in the English Channel, the North Sea, the Baltic Sea and along the North American coasts. Additionally, in 2013, the Energy Efficient Design Index (EEDI) and the Ship Energy Efficiency Management Plan were highlighted by the IMO as tools for reducing the greenhouse emissions of ships. Furthermore, the EU introduced the Monitoring, Reporting and Verification (MRV) regulation 2015/757 on 1 July 2015. This regulation obligates shipping firms operating in European waters to release information about their greenhouse gas emissions [28]. As result of the above-mentioned changes, the maritime industry increasingly adopted environmental technologies and less polluting fuels; e.g., biofuels, liquefied natural gas [24,29,30]. Today, maritime suppliers have the potential to collaborate to deliver joint services in providing a "green" retrofit to vessels in operation; such a service implies the installation of energy-efficient and pollution control technology on board older vessels [22].

The contribution of this paper is three-fold. Firstly, we contribute to the emerging literature on eco-innovation by shedding light on the phenomenon by applying the concept of value creation and a process perspective. We theorize about the eco-innovation process and its drivers in value-creating networks as an evolving process of actors' practices shaped by regulatory, market and technology drivers. Secondly, we contribute to a better understanding about how a network of firms shapes the value proposition by offering a green retrofit service for old ships. We also identify a period of exploitation, characterized by efforts to commercialize the green retrofit package. The type of activities during this period demonstrate a stronger focus on defining the other elements of the business model besides the value proposition. Thirdly, we develop a knowledge framework to organize the impact of drivers, such as regulation, market and technology, in collaborative eco-innovation processes.

2. Literature Review

Organizations seek to integrate sustainability principles into their innovation processes, yet face some barriers that prevent this integration, for example lack of resources or knowledge [6,31,32].

Therein, collaboration with external actors, such as universities, suppliers customers or even competitors, becomes more common in order to overcome these barriers [33]. These collaborative, open-innovation settings receive attention in eco-innovation research [34,35]. A new area of research in this domain is that the open-innovation processes for eco-innovation shall not exclusively be focused on the development phase of the technology, but also account for value creation and capture aspects of the business model to commercialize eco-innovation [36]. The reason is that technological changes and societal trends such as "dematerialization", "decoupling" or "circular economy" suggest that companies must implement innovative, sustainable business models in order to capture value in an otherwise competitive environment [37]. As a result, more research pays attention to issues such as how eco-innovations can be part of business ecosystems involving multiple actors and creating value jointly with end-users [38].

The purpose of this section is to set an analytical framework to understand how these new forms of open-innovation manifest in the eco-innovation process. We sound the call for a better understanding of how companies adapt different models of eco-innovation in their innovation process rather than merely sketch what drives them to adopt eco-innovations [1,9,39]. We emphasize a value-creating network; this kind of network is especially relevant in these settings of open-innovation, as stated above, that require a stronger focus on the business model aspects of the eco-innovation [14,40]. We highlight the role of drivers of eco-innovation and illustrate the situation in the shipping industry, claiming how these drivers might motivate some types of eco-innovation (Section 2.1). The final section joins the value-creating network theory with the innovation process literature, including suggestions for analyzing the empirical materials (Section 2.2).

2.1. Eco-Innovation and Drivers in a Maritime Context

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 [41] 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. Papers using the concept "eco-innovation" address the design of more environmentally-friendly solutions, but also the evolutionary diffusion of these technologies [42].

In a highly cited review article [43], the authors compiled 16 different definitions of eco-innovation. From the various definitions, an overall agreement is that eco-innovation is one particular type of innovation, which is beneficial to the environment: "any form of innovation" [44], "innovation processes towards sustainable development" [45] and "innovations that benefit the environment and lead to sustainability" [46]. Several goals are linked to eco-innovation. One of these goals is to use natural resources in a more effective way: "The efficient use of resources", "minimization of the use of natural resources per unit of output" and "reduction of energy use". A second goal is cleaning up already existing environmental problems [47]. A third goal relates to a broadly-defined reduction of environmental impacts: "specified sustainability targets" [45] and "reduction of environmental impact, intended or not" [48].

The extant research therefore has implications in the way we use the concept in this paper. The most important implication is that the social aspects of the innovation, while important in the sustainability discourse [49], are not a priority from an eco-innovation perspective. The focus of eco-innovation is instead on the environmental and economic realm of the innovation. Considering environmental and economic goals, Machiba [50] 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 trending toward radical changes in existing technologies and seeking systemic solutions. Incremental innovation refers to slight, continuous changes or improvements in the existing technological systems [43]. Radical innovations are discontinuous changes of technology, which seek to replace already existing technology [51]. This paper addresses one particular type of eco-innovation: retrofitting of old vessels with end-of-pipe technologies or components that improve the overall energy efficiency of the vessel (Figure 1).

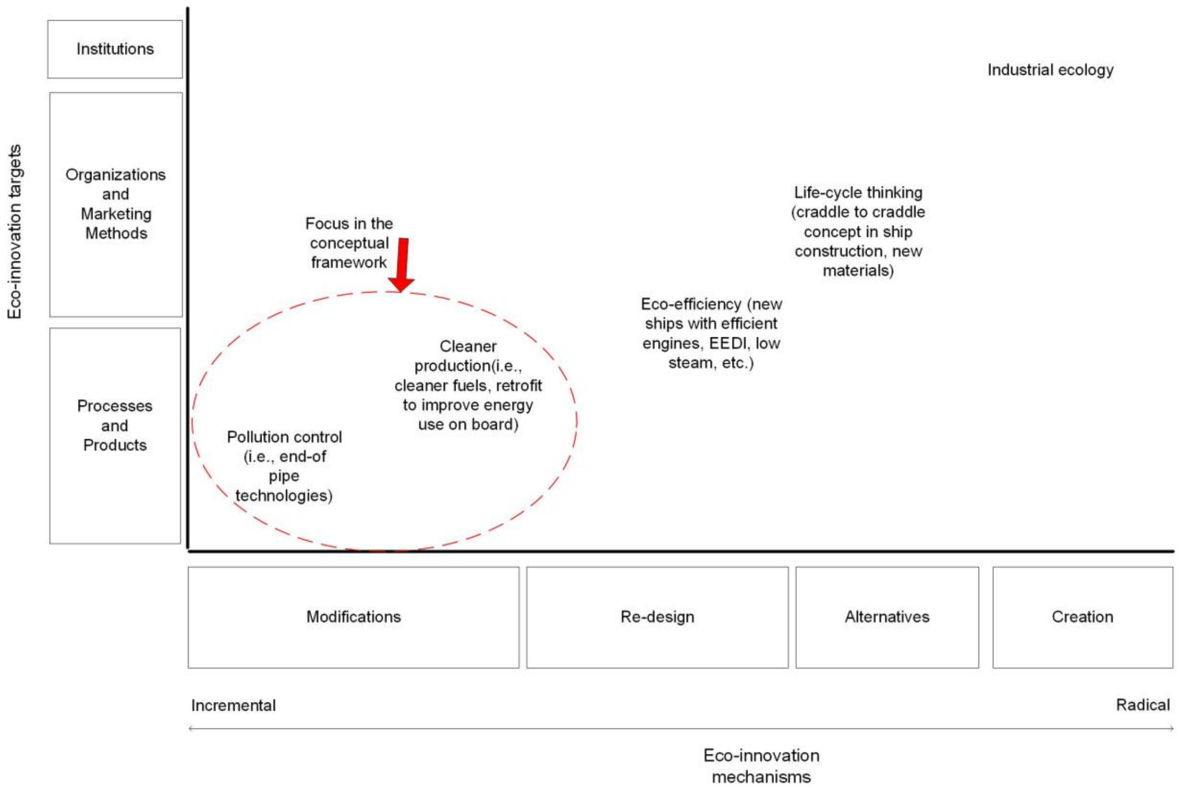

Figure 1. Eco-innovation in supply networks: understanding how to co-create value though eco-innovation in the maritime industry. Adapted from Machiba [50]. EEDI, Energy Efficient Design Index.

In the maritime context, eco-innovation applied to technologically-advanced products with a multi-tier supply chain, such as the green retrofitting of vessels, can be customized. Incumbent players, such as the IMO, categorize technologies tackling the environmental impact of ships into two large groups: energy-efficient technologies and pollution control technologies [52]. Det Norske Veritas-Germanischer Lloyd (DNV-GL), an authoritative ship classification society, refers to energy-efficient technologies as those bringing improvements in the consumption of fuel: hull shape optimization, shaft generators and speed reduction [53]. The literature highlights how air pollution control regulations impact operational costs for shipping firms and thus become a demand factor for energy-efficient technologies [29,54]. Pollution control technologies can reduce pollution at the source; this includes low sulfur heavy fuel oil, distillate fuels and waste heat energy recovery. Alternatively, end-of-pipe technologies clean the exhaust gases or the ballast water before releasing them into the air or sea, i.e., SO_x scrubber, ballast water treatment systems.

Research on pollution control technology often analyzes the effect of regulations in the diffusion of these technologies [27,55,56]. 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 [57]. Cleff and Rennings [58] 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 [45].

Furthermore, previous studies discuss how technological and market drivers increasingly challenge manufacturing industries to adopt environmental technologies [8]. Market pull is comprised of factors such as customer demand for greener products or production processes, a firm's image linked to environmental protection, improved competition by the reduction of costs (i.e., a product eco-innovation could entail less use of materials and energy along the production process) and the creation of new markets [58]. 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 [59].

Technological push refers to the supply side embedded knowledge in the form of machines, human capital and organizations [60]. Technological push has two main effects: first, it reduces manufacturing costs in the production processes, and second, it commercializes a greener product [45]. Technological push becomes a driver for eco-innovation through improvements in the product's quality and in the production process by reducing material and energy costs [45]. The adoption of efficient technologies brings challenges to a firm as increased investments; however, they result in improved eco-efficiency (i.e., energy and material) [61].

2.2. Eco-Innovation Process in Value-Creating Networks

The idea to analyze innovation as a process rather than a causal mechanism has antecedents in the works by Van de Ven and others [62,63]. From this perspective, rather than outputs, innovations are seen as ideas to further develop, test and identify proper manufacturing techniques; identify additional suppliers; increase commercialization channels; and facilitate customer implementation [64]. Garud et al. [64] define the innovation process as a sequence of events unfolding over time and characterized by a long-period of "gestation" of ideas, followed by the so-called development journey of the initial idea, which implies several possible testing possibilities and failures. Possibly, the development phase yields some successful prototypes, which face the challenge of implementation [64]. Rather than a temporal heuristic framing of the innovation development stages, a process perspective calls for interpreting the agency of actors, the transformation of resources into outputs and exchanges with other actors. For this reason, an innovation process perspective is of great value to understand value-creating networks.

2.2.1. Value-Creating Networks

Customized solutions, for example in the form of eco-innovations, are often produced through a tier-structured, multi-level supply network [21]. The joint effort to deliver complex solutions is often organized in the form of supplier-networks that deliver added value to the customer. A widely-accepted definition of "supply" implies that actors collaborate in networks or other forms of relationships with the clear objective to fulfil the demands of an end-user [65]. In supply networks, value is the relationship between market offering to price, i.e., the expected value proposition [66]. The resulting ratio will have significance according to the end-user's perception [15]. For suppliers, value is associated with the wealth generated. Therein, when suppliers collaborate in 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 [67]. Value-creating networks are characterized as a "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" [68].

Innovations are required to provide some form of value propositions for the customer in order to be marketable [69]. Value proposition promises economic, social and environmental benefits or a combination thereof. Furthermore, they may not only exclusively address benefits for the customer, but can include value-creating features through connection with other actors and/or by acquiring resources in a profitable manner [70].

In networks of suppliers, value creation is developing capabilities beyond the firm to improve the value proposition embedded in the supplier's service and product. Single-supplying firms look into collaborative relationships with other suppliers [71]. Furthermore, since the end-user is an important actor to define the value proposition, eco-innovation processes in value-creating networks intermingle with those of value co-creation. This means that the network shall facilitate a series of interactions between suppliers and end-users [72]. These interactions or encounters can be of different types, such as emotion, cognition, behavior or action. In these types of encounters, suppliers and end-users deploy agency as stories, customer promises, trials or proficiency presentations [72]. For this reason, it is not feasible to create value for the end-user as single companies [72]; the quality of the competencies of the partners influences the process of co-creating value. The combined competencies 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 [15].

2.2.2. Different Perspectives on Eco-Innovation Processes in Networks

We identified few previous studies dealing with all of the issues of (a) eco-innovation processes involving, (b) multiple organizations/stakeholders and (c) addressing the aspects of value creation in the network. We consider that those articles listed in Table 1 addressed all three issues. In four articles from Table 1, the focus is one particular arena of the eco-innovation process, which involves resource exchange, actions and learning among stakeholders: the fuzzy front-end of eco-innovation [3] or demonstration and pilot projects [4,73,74]. We decided to focus on the other four articles that have a more longitudinal character for the eco-innovation and the network collaboration [12–14,75].

Table 1. Research about eco-innovation processes in networks.

Ref.	Scope	Theoretical Approach(es)	Main Insights about the Eco-Innovation Process
[13]	Analysis of a network evolution for developing an energy-efficient house concept	Technology embedding and network evolution	• The actors' interactions within the network influence how the technologies are embedded in the development, production and use phase of the innovation process • Resource integration among different partners
[14]	Implementation of green ICT innovation through a value network	Practice-based approach	• Innovation process is inherently linked to the actors' practices • Focus on the co-creation practices (actions, actors, resources), rather than just the innovation output
[12]	Renovation of old buildings through multiple suppliers	Stakeholder constellations	Stakeholder relations have implications on how the network evolves, which at the same time set the direction of the eco-innovation process
[75]	Renovation of old buildings through multiple suppliers	Multi-stakeholder innovation processes	• The innovation process is not linear; external shocks likely to influence the innovation journeys • The process in the network is influenced by goals' evolution and trust. • Over time, some setbacks are likely to arise

Table 1. *Cont.*

Ref.	Scope	Theoretical Approach(es)	Main Insights about the Eco-Innovation Process
[4]	Maritime green demonstration projects	Multi-stakeholder innovation processes	• Considers multi-stakeholder eco-innovation as a process with initiation, development and implementation phases • The demonstration projects are key to facilitate the learning process among the stakeholders
[3]	Co-creation in the fuzzy front end process of eco-innovation	Fuzzy front-end Stakeholder theory	The earlier phases of any eco-innovation process are complex, and specific tools exists to facilitate the integration of multiple stakeholder perspectives
[74]	Review article about the demonstration phase of innovation, with a focus on sustainable bio-economy	Demonstration projects	Demonstration projects as tools for firms to reduce uncertainty, trial new technologies closer to the potential market
[73]	Review article about demonstration projects for cleaner technologies	Demonstration projects	The article addresses factors that contribute to the success of demonstration projects

The concept of a value-creating network as we introduced in Section 2.2.1 is not homogenously used in all articles. Furthermore, there is not a common definition of process in all of these studies. In [12] and [75], the authors use the concept of stakeholder constellations to explain the eco-innovation process and the changes of the configuration of the value network over time. The focus is on the journey approach to the innovation process, which implies how technologies are developed and implemented by the network, while interactions among stakeholders are considered part of the process. The value creation aspect is inherently linked to the stakeholder configuration over time and roles assigned to different actors. In [13] and [14], the eco-innovation process is equated to the actors' agency and the network evolution. Eco-innovation practice [14] is used to disentangle the innovation process. Eco-innovation practices are "systematic actions carried-out by actors using resources in their value search" [14]. The practices integrate resources as new solutions, information and infrastructure to create environmental value by actors in networks [14]. The idea from this perspective is that eco-innovation does not result from the sole effort of one company, but instead, different actors combine resources in ad hoc constellations. The practices manifest in actions performed by actors in the context of projects; through the interaction, the actors jointly finish projects [14].

2.2.3. Eco-Innovation Process: Actors' Practice Influencing Network Evolution

The customer/end-user also induces the type of competencies required in the value network, as the needs of the end-user will shape the competence requirements of the firms in the network [15]. The process of value creation between suppliers, but also with the insights from end-users, leads 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 [66]. Value co-creation focuses on this process when end-users/consumers jointly create value along with suppliers, but it also involves the end-user jointly defining the problem and solutions. Stakeholder constellation theories inform about the dynamic nature of the end-user roles. Mosgaard and her team [75] present the case of the value network for renovating buildings (in this example, a hotel) with efficient technologies. At the outset of the project, the hotel owner has a high degree of ownership of the project and decides about technological pathways in relation to the renovation project. The owner acts as manager of a renovation project rather than as the end-user. Over time, when an engineering consultant is hired, the consultant acquires more power, and thus, the end-user becomes a conventional stakeholder, reducing the influence of the hotel owner in the decisions pertaining to the technological solutions. The consultant therefore also manages the value network, which is in charge of the renovation initiative [12,75].

Stakeholder constellation evolution is also manifested in the upstream (suppliers) and downstream (end-users, customer base) structure of the value network. Given that each actor puts forward its own resources, ideas and goals, integrating new actors or leaving some of them behind has consequences on the eco-innovation process and the value proposition of the network. Since networks are dynamic, the value-creating process implies that suppliers might leave or enter the network over time. Meanwhile, the customer base of the network might expand [13]. The reason why some partners leave the network has to do with how well these partners fulfil the technological requirements from the customer [13]. Therein, the aspect of value proposition comes once more into play, as the supplier might not fit with the overall value proposition of the network as a whole; it is likely that a new supplier conveying a better fit is sought.

During the innovation process, each stakeholder puts forward their existing technologies in the network setting [13,75]. As a result, the process of value creation implies that actors in the network select technologies over time, but also discard some of the technological solutions. This means that the eco-innovation process involves rejection of some actors in the final network/technological solution [13,75]. As a result, the interaction among these actors is often complex and leads to a continuous redefinition of goals over time [75]. An issue faced in this process of value-creation is possible setbacks, for instance, due to the lack of proper information exchange among partners. This leads to proposals of technologies not considered appropriate in the final value proposition of the network. In addition, the technical aspects of combining different technologies add to the challenge of making different solutions work together [75]. Conflicts arise in the network over time due to partners' differing goals for and expectations from the project [13]. A manager shall coordinate the relations among network members to deal with potential conflicts, but also facilitate the access to a knowledge network [12].

In the conventional approach of the business model theory, the definition of value is perceived as something static, which depends on the customer/end-user assessment [76]. In a value network, one key characteristic is that multiple actors put forward different resources. The combination of these different resources leads a focal technology to assume new values and functions over time [13]. Instead of a fixed, static characteristic, the value changes. One example illustrates this aspect: the case of the "leaf-house", a value network to develop an eco-efficient building. Seen as an end product/service, the leaf-house acquires different functions and values over time depending on the types of resources integrated and the actors involved [13]. Therefore, value creation in the network is closely linked to how goals evolve during the eco-innovation process: "In this case, the goals of the process have shifted from just ensuring heat supply to gaining a modern, efficient, and long-term energy system" [75]. The implication is that the end-user has a strong steering in the goal setting, given that the value network does not necessarily start with one specific goal in consideration, but evolves over time [75].

In this perspective, extant research about eco-innovation processes in collaborative networks highlights how the different actors relate to each other. Therefore, facilitating the eco-innovation process equals managing the relationships among partners in the network. What the literature review also highlights is that the analysis of eco-innovation drivers in the innovation process has not received a systematic analysis. Technological evolution aspects have been slightly addressed in the paper by [13]; the insights brought forward by our review indicate that each actor brings different technological value propositions to the network. As such, technology push (by each individual actor) is a key factor for the selection of the value proposition within the value network, but also an issue of potential conflict. Other research sporadically touches upon the influence of market changes as disrupting the dynamics in the value-creating networks [4,13]. The influence of regulations in the value-creating network is not addressed in the reviewed research.

3. Method

3.1. Empirical Setting and Case Selection

Partnerships between shipping companies and Danish suppliers have been highlighted by previous research. Maritime suppliers from the region of Northern Denmark contribute significantly in terms of maritime service and equipment supply for Danish shipping companies [77–79]. In this line of ecological modernization of the Danish fleet, the maritime suppliers in Northern Denmark have initiated collaborative development projects of maritime environmental technology involving different types of actors and with different levels of structuration [12,35]. These networks of maritime suppliers can provide a rich insight into the eco-innovation processes and its drivers. Hence, we considered the empirical setting adequate to study value-creation in these networks. To select the case study, we set the following criteria:

1. The network shall involve actors of the region's maritime sector.
2. The network must seek to develop green products or services.
3. The network should involve several actors working together in the development of the product or service.

In the following case study, we guide ourselves by this criteria as we focus on one eco-innovation initiative: the green ship, built by a network of firms from, a coastal municipality in Northern Denmark, which joined to develop the service as a one-stop retrofit solution of old vessels with green technologies.

3.2. Data Collection and Analysis

The authors relied on three qualitative methods: document review, interviews and observation (Figure 1). The document review allowed a better understanding of the macro issues surrounding the shipping sector in regards to the implementation of the SECA in the North Sea and the Baltic (European Commission's reports, directives, green papers; IMO's conventions and environmental committee internal communications; classification societies' safety regulation databases, commercial documentation from environmental technology suppliers; European and Danish branch organizations (position paper, commissioned studies)), in particular the perspectives of key stakeholders on the drivers and barriers for innovative air pollution control and eco-efficient technologies. The information gathered through the document review was subsequently useful to locate key informants and prepare the interview guides with experts. The authors had access to documentation related to the network, such as meeting-minutes, power-point presentations, formal contracts and lists of attendees to the different meetings (Figure 2).

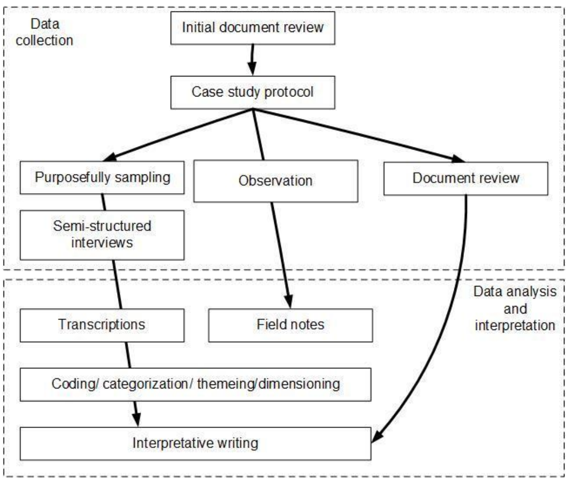

Figure 2. Summary of the methodological approach to collect and analyze the empirical materials.

To complement the document review, we carried out in-depth interviews with actors in the maritime network and with external experts acquainted with the shipping industry eco-innovation drivers (Appendix A, Table A1). We followed a combination of judgmental and snow-ball sampling strategies to select the interviewees. Both are examples of non-probability sampling, which seeks to select a representative sample of the total population. The term representative is the result of an expert assessment of to what degree the selected interviewees will provide comprehensive information about the case study [80,81].

The first set of interviews (1–11) had the purpose of gathering specific information about the network processes and activities. We carried out these interviews with the key actors involved in the network "Green ship". The first interviewee was one of the coordinators of the network who worked on this project for two years. This person suggested additional interview subjects and facilitated the network's documentation. This allowed us to prepare a list of potential interviewees and ensured a balance between different types of stakeholders and actors involved over the period of five years in the network (Appendix A, Table A1). This included, for example, an "end-user", which was a shipping company participating in the network. We also carried-out contextual interviews (12–17) with experts and ship owners to gather information about the regulatory push and market-pull drivers forcing the maritime industry to develop certain types of environmental technologies. We emailed the interview guides to the interviewees in advance. We used a semi-structured interview for the network actors with three themes: the network, the internal process in the participant's firms and the external process of collaboration. An advantage of semi-structured interview guides is that they allow flexibility for the interviewer to cover in-depth issues that require particular attention [82]. For this reason, the interview guide with network partners is a simplified version of the interview guide used during the actual interviews. Here, we present the topics we covered; however, over the course of the meetings, we had the opportunity to question interviewees about specific environmental technologies (Appendix B). The semi-structured interview guide for the experts addressed how shipping companies expect to comply with forthcoming air pollution regulations and other drivers (besides the regulation) pushing the maritime industry to develop environmental technologies. The interviews were audio-recorded and transcribed verbatim. In Appendix B, we also present the semi-structured interview guide, but over the course of the interviews, we had the opportunity to question interviewees about specific environmental regulations or technologies.

Direct observation allowed us to understand the discourses surrounding the implementation of SO_x limits in the SECA. The first author of this paper was also the research fellow at 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 first author to participate in meetings, seminars, conferences and networking (Appendix A, Table A2). After each event, the main author created narrative memos, including the most important issues at stake, and then, these memos were used along the interview transcripts as explained below.

The transcripts and analytical memos were stored in a file in the QSR-NVivo software. The use of NVivo also facilitated the creation and administration of codes, which were later used to analyze the empirical materials [83,84]. We followed an inductive method of organizing first order concepts and higher order themes that lead to general categories following Gioia [85] (Appendix C, Figure A1).

3.3. The Case Study

The network green ship was developed during the period between 2009 and 2016. In the case study, we analyze how actors shaped the green retrofit network's value proposition by the processes of collaboration and selection of technology. We highlight three phases in this process: exploration of the technological opportunity, testing the value proposition of the network and exploitation of the technological opportunity (Table 1). In the first phase, the actors in the network made sense of the external environment and how it drives the demand for environmental technologies

(Section 4.1). Afterwards, the partners engaged in a process to establish common goals (Section 4.2). During the final phase, the actors tested the original value proposition through joint pilot projects to learn and commercialize the networks' retrofit service (Section 4.3). While the network was mostly composed of maritime service and equipment suppliers, other types of actors were also involved in one way or another in the network, including university researchers and a maritime equipment branch organization.

4. Innovation for the Green-Retrofit of Ships in a Value-Creating Network: A Process Perspective

4.1. Stage 1: Making Sense of the Market Trends and Future Regulatory Changes

The maritime supply industry in a Northern Danish municipality has origins in the closure of the former Danyard in 1999. Due to a series of financial drawbacks, the shipyard went bankrupt. New firms emerged in a new industrial park established in the former shipyard. Over the years, these firms developed their own competencies and managed to establish an important contribution to the economy in the municipality (maritime business advisors, Interview 2). The late 2000s were challenging in the municipality due to the closure of one of the largest employers, the MAN engine factory, in 2007. The suppliers, with their competencies and high-end technologies, needed to search for new markets for their technology. The suppliers received support from the Business Council (maritime business advisors, Interviews 2 and 5).

At the same time, the European Union (EU) and the International Maritime Organization (IMO) introduced air pollution regulations to control the emissions of SO_x, NO_x and CO_2 (Figure 3). In particular, the creation of a Sulphur Emissions Control Area (SECA) in Northern European waters gave birth to the different technological means of compliance with the requirements of 0.1% of sulfur content in marine fuels from the 1 January 2015 legislation [86]. Low sulfur fuels, such as marine gas oil (MGO) or marine diesel oil (MDO), are included as a primary means of compliance, along with alternative means like the use of exhaust gas cleaning systems [86]. Some ship owners consider "environmental regulation and environmental technology as an extra cost" (ship owner, Interview 15). Other ship owners consider environmental technological upgrades as a way to be ahead of possible regulations for certain environmental aspects. As a leading European ship owner representative puts it:

> "For all business, an important aspect is future risks and costs. Likely, more regulations will appear, we expect more regulations in such areas as greenhouse gases and the transfer of invasive species in ballast water. It is our strategy to look at very early stages and try to tackle the problems associated with these regulations from there on" (ship owner, Interview 17).

A number of voluntary initiatives started to emerge in the late 2000s as a complement to these regulations in order to incorporate cleaner technologies "beyond" the requirements by IMO. Those initiatives are driven by the awareness of suppliers of new environmental trends in the market:

> "In the future, when someone wants to charter a ship, that customer will be looking at that number [energy efficiency of the ship] if it is a green ship. It will be a decision of the ship owner to own or charter a green ship" (supplier, Interview 8).

The suppliers tried to foresee the upcoming regulatory changes and the implication for environmental technology requirements on board ships. Meanwhile, the suppliers speculated about the market trends, considering if a market demand existed for more environmentally-friendly technology than required by the foreseen regulatory changes.

Besides the ship owners and the suppliers, those external changes also have gained the awareness of other actors having interest to develop the local maritime industry. In particular, the Business Council, along with the municipality, organized a maritime business workshop held in November 2009. The purpose of this workshop was to create a strategy for further developing the local maritime service industry. The workshop organizers invited experts to inform the actors about the new air pollution regulations and included the possibility of transforming the changes into environmental technologies to address the perceived new markets. At the same time, the speakers also introduced some of the concerns ship owners had about increasing operational costs (consultant, Interview 3). Thus, the workshop addressed advances in environmental technology, regulatory changes and customer demands.

The actors who attended the workshop proposed some ideas of potential areas of growth, such as state-of-the art environmental technologies, and brought up the idea of creating a network (maritime business advisors, Interview 2). The initial idea of the network was to find new markets for the suppliers' competencies and high-end technologies.

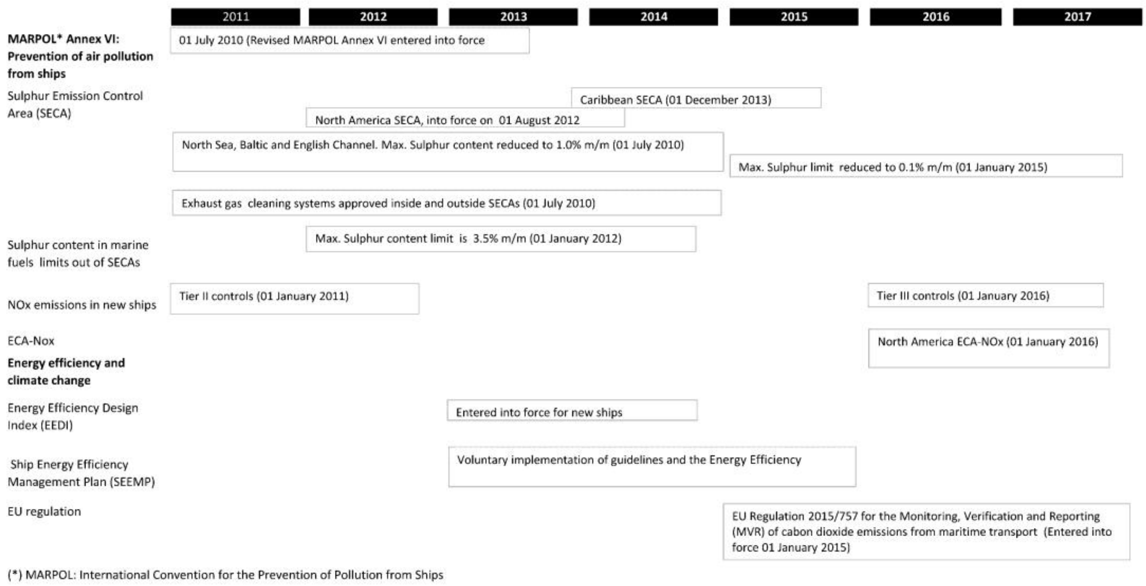

Figure 3. Air pollution from ships, selected regulatory developments regarding SO_x, NO_x and CO_2 emissions.

4.2. Stage 2: Towards a Common Understanding of the Network's Objectives

At the outset of the creation of the network, the members agreed on the network's objective. The Business Council followed up on the ideas and organized a set of meetings with the maritime business advisors in 2010 and 2011, encouraging the firms with interest to participate in a network. The participant firms expressed three major drivers for joining the network and engaging in these joint offerings: (i) acquaintance of the market potential, (ii) opportunity for developing new products and (iii) testing already developed products in real conditions. As summarized by some interviewees

> "We have been in contact with ship owners, so we get a lot of feedback from them about what they need in the future" (supplier, Interview 8).

> "I know that my company will not make money on this particular project, that is for sure, but we can take the learning from this project and bring it to other large-shipping customers (supplier, Interview 9).

> We expect that our NO_x reducing-system is operational. So we could say, this network and its testing ship is a good place to install our prototype" (supplier, Interview 11).

Ultimately, the agreed-upon idea was to offer the retrofitting service of older vessels with state-of-the-art environmental technology. The end-user partner, a ferry company partly owned by the municipality, pushed the idea to focus on renewing older vessels with more efficient technology:

> "We considered if installing the cleaner technologies on board a new ferry will not make any sense, we are a small company, part of the municipality, and we could not invest that much in a new vessel. We proposed renewing our older vessel" (shipping firm, Interview 7).

Thus, the network provided a platform for interaction between the suppliers and the end-users to discuss the changes in the external environment. In particular, the end-user played a crucial role and had the power to influence the network's objects. Moreover, the idea of offering a retrofit service draws on the suppliers' technologies. Combining the technologies and offering them as a service creates additional value for the end-user. In this stage, the objectives of the network and the roles of the actors have been clarified.

Once the partners agreed to focus on retrofitting old vessels, the partners had to negotiate and agree on the services offered in the "green retrofitting package". The partners agreed on incremental improvements in the ship's overall performance rather than on radical change: "insulation improvements, efficient pumps, exhaust gas equipment, efficient heating, improved ventilation, reducing the energy consumption from the propulsion system" (external expert, meeting minutes, 12 August 2010). The partners considered commercializing green retrofit as a service that provides end-users with cost reductions:

> "We should not bind ourselves into a green ship concept, we should prepare a broad catalogue as possible ... the problem with the maritime sector is that customers will not purchase a service if it is not required by the regulations. We must first invest, test the solutions and then convince the customers that this is a service worth the investment even if it is not required by the regulations" (Danish maritime participant, meeting minutes, 12 August 2010).

Thus, the actors discussed the three different drivers: regulatory changes, technological advances and market demand and tried to balance the effect of those drivers in the set objects of the network.

4.3. Stage 3: Developing the Eco-Innovation's Value Proposition and Commercializing the Environmental Technologies

Once the network decided on its objectives, the next step was to develop the eco-innovation's value propositions and to organize this value proposition into concrete product/service offerings. In particular, the network participants had to agree upon the environmental and economic value of the eco-innovation.

The Business Council took the leading role in this process and collected and summarized a catalogue of environmental technologies that individual firms prepared. In the follow-up meetings, the partners discussed the catalogue and scoped the value proposition in two specific areas of energy efficiency improvements: (1) energy efficiency on board through lighting, ventilation/heating and (2) energy efficiency by improving the propulsion system. Partners proposed projects and prepared a business case to use during the commercialization phase. In Table 2, we summarize these projects in terms of type(s) of partners involved, the project's contribution to test the "fit" of certain technology, the partner within the value network/final package and the (main) achievement of the project.

As seen from Table 2, these joint-projects shaped the value proposition and provided learning in three areas: the end-user's role in shaping value proposition, the financial feasibility of the value proposition and the complementary knowledge gained among partners.

The projects indicated how a better "package" of services could convince end-users about the potential benefits of the green retrofit:

> "Installing two silencers, it is nice to have, but it is not a priority to have. That was also the problem for many of the other ideas. The supplier could eventually provide the LED lights without costs but will ultimately request a fee for the labor-costs, yet external funding sources will not cover such costs" (advisor, Interview 3).

The joint projects yielded additional learning outputs to the partners from the perspective of further commercialization of the joint-services:

> "When offering green retrofitting packages, lifetime-calculations of the ship should be contrasted against payback time. $1\frac{1}{2}$–2 years of finance packages are good, but it's harder with longer repayment periods" (advisor, meeting minutes, 7 May 2015).

Actors in the network realized the logic that these modules shall be combined with each other to create the green retrofit concept. However, during the eco-innovation process, this association did not automatically translate into selecting all of the proposed individual modules as part of the final green retrofit package solution:

> "You are not bringing new technology, monitoring, but on heating, driving systems, LED lighting there is no nothing new in there. If you put everything together you can say, there is a possibility to get something" (network facilitator, Interview 1).

During the eco-innovation process, regulatory and cultural/cognitive constraints arose, which lead to this situation. On the regulatory side, the shipping industry has high safety standards, which had to be considered by the network. For example, the commercialization of environmental technologies for heating, ventilation and air conditioning is constrained by the classification societies and IMO safety requirements:

> "Regarding the HVAC. They want to implement ammonia as cooling system inside compressors. The Danish Maritime authority, the class Bureau Veritas were also involved because they must approved the technology. However, they cannot approve it without the project description, with the drawing of the piping and everything else. All the documentation must be in place before issuing the green light for that" (network facilitator, Interview 1).

The cultural/cognitive practices of the end-user also played a role in the selection of some technologies and modules over others:

> "Then we were talking about ammonia as refrigerant for the heat pumps. There are a lot of new things about this technology. The shipping firm's intendent is very open-minded, but about this proposal he used to say: "ammonia, no ammonia" (supplier, Interview 8).

The intertwined character of regulatory/cultural constraints had an effect on the integration of modular technologies that were supposed to work together as a "package". To illustrate, the energy monitoring system is an example of a technology with high interdependence with other parts of the retrofit service. The idea was for this system to work as plug and play and be useful to track the changes in energy consumption on board once all other modules were installed. Issues with the HVAC or other technologies (due to price or incompatibility with the ship's structure) prevented the modular-connection concept in the retrofit from working smoothly:

> "So we would like to have data, running all the type to verify all the calculations we made, of course we will do the monitoring and of course that will be part of the solution" (shipping firm, Interview 6).

An overall agreement was that the experience gained through these projects also strengthened the relations among the suppliers:

> "It is better to earn 20% on a joint solution than 100% of nothing, if individual partners spot a niche that can help a shipping customer save money, other companies in the network can be invited to collaborate" (advisor, meeting minutes, 7 May 2015).

In parallel to the activities carried-out as part of the test projects, the market demand for green retrofit showed a better picture. All of these perceptions pushed the partners for a more active utilization of their joint-service. In Denmark, maritime stakeholders created a retrofit partnership:

> "Ship owners/charterers often require retrofit solutions. In the last few years many important shipping companies joined working groups and networks which are developing retrofitting solutions and energy efficiency" (advisor, meeting minutes 7 May 2015).

To commercialize the green retrofitting package, the network began to cooperate closely within another network named Frederikshavn Maritime Network (FMN). FMN is a formal network of maritime suppliers with international reach. This approach to FMN included the coordination and promotional resources available from FMN for the benefit of the green retrofit network. As the facilitator, FMN coordinated the meetings after 2015, and companies belonging to FMN hosted these meetings. The FMN's website also hosted an updated retrofit catalogue from the partners of the green retrofit network.

In order to identify customers, the network partners considered several possibilities. First, each partner became an ambassador of the green retrofit package among its current customers:

> "We would like to do more to promote the common; we do not know each other's services and skills well enough. The items are not visible enough–the product portfolio has become more complex–give the customer good experiences–attract ships"

> "We must remember to communicate with other domestic firms about each other's products/services and opportunities, and remember to update those who travel a lot" (supplier, meeting minutes 24 August 2015).

The promotion of the network's green retrofit packages was also carried out through public activities: participating with a stand in large shipping trade-fairs (Hamburg Maritime Fair, Danish Maritime Days) and press releases about the network's firms' achievements regarding green retrofitting projects. The idea was to ensure that the maritime sector better knows the value proposition of the network (Interview 11). Finally, the firms also directly contacted previous and existing customers, who they knew may be interested in performing green retrofitting projects on their own ships.

Table 2. Projects developed by the network towards the eco-innovation's value proposition.

Project	Actors Involved	Contribution to the Value Proposition of Green Retrofit	Achievements	Learning in the network	Period
Noise reduction systems	Supplier of noise reduction equipment	Improve the experience sailing in the ship; reduce the noise and vibration feeling on board the ship	• Ship owner/supplier aware of the technology. • Initial design, but not installation	• Partners in the network require resources for installing technologies, even if it is for demonstration purposes • Technologies already proven have challenges to obtain financing from external innovation development funding pools	2011
Propellers	• Marine engine manufacturer • End-user • Metal works supplier • Shipyard	Upgrading the propeller systems reduces 17% fuel costs	Initial design, but not installation	Ship age influences the investment decisions by the end-user; in particular with the type of investments, which might imply larger resources	2011–2012
Emission monitoring/NO_x emissions cleaning	• Technological Institute • Exhaust gas cleaning equipment supplier	Comply with MARPOL Annex VI requirements on NO_x emissions	• Joint project idea document for submission to external funding source • Dimensioning of NO_x emission treatment unit according to Tier-III parameters	• Awareness on how the different technologies can "fit" together with relatively new equipment as NO_x reduction technology • Costs of NO_x reduction technology can be relatively high for small ships; therefore, the value proposition of this technology can apply for large ships	2010–2011
Car-deck illumination	• Electrical installations supplier • Ship owner	• Energy efficiency improvements • Reduction of fuel consumption	• Prototypes installed by the supplier • Installation by the ship owner	• Funding of certain type of pilot project does not fit the "innovation" impact by funding organizations • The ship owner closely collaborates with the supplier in the design of the lighting system	2011–2015
Heating, ventilation and air conditioning	• Refrigeration equipment suppliers • Ship owner • Maritime Business Centre	Improve energy efficiency	• Project idea, applications submitted for funding • The technology, due to safety issues, is still not fully accepted by authorities; the partners promote the safety aspects of the technology	• The ship owner and the supplier closely collaborate in the design of the heating, ventilation and air conditioning system	2014–2015
Energy monitoring system	• IT supplier • Electrical installation supplier • Technological Institute • Maritime Business Centre	The energy use on board monitoring system is the "heart" of the retrofit service, as it seeks to enhance awareness about energy use on board	Funding granted for a technology development project	• Ship owner closely collaborated with the other supplier in the development of the technology • Maritime business center and Technological Institute developed the project idea and got external funding	2012–2015

5. Discussion

In this case study, we seek an explanation to the research question: How do eco-innovation drivers shape processes in value-creating networks?

At the outset of this paper, we defined the context of eco-innovations as those incremental improvements to existing assets (i.e., ships, facilities) with end-of-pipe technologies and cleaner processes with the purpose to retrofit them and improve their overall environmental performance. This type of improvement falls into the modifications realm of the eco-innovation framework [50]. The case study, however, highlights how actors in the network can further develop the retrofit concept into a slightly more radical eco-innovation with a greater stake in eco-efficiency (Figure 1). The eco-efficiency idea manifested in the network's attempted goal to offer shipping firms' customers a service of "one-stop" green retrofit in a Danish harbor. The service idea was characterized by each individual supplier contributing one component to improve the ratio of energy use per unit of fuel in the old ship. The partners in the network, in collaboration with the end-user, tried to align the different technological concepts into this green retrofit value proposition. This case fits well into similar situations in the context of eco-innovation, but studied under different theoretical scopes as business ecosystems [87], stakeholder constellations [12] or value-creating networks [13,14]. In this study, we elaborated an analytical framework based on the last, as this accounted for a process perspective, which highlights the interactions and practices by the actors involved in the eco-innovation development over time.

As highlighted in our literature review section, an eco-innovation process deals with aspects of network dynamics, i.e., how actors interact among them, but also how changes in the environment impact these relations. Taking a longitudinal perspective in the analysis of the value-creating network and its eco-innovation process also allowed us to unveil how the interaction of regulations and technological advantages create a window of opportunity for eco-innovations. Sulfur regulations on marine fuels, as the regulatory driver in this case study, have generated much research in terms of to what extent they push the development of cleaner technologies [7,30,88]. These drivers are often assumed independent in the literature, but our case study shows that they interact and, as such, have some consequences in the type of expected eco-innovation. The current market situation of the shipping business provides challenges to environmental technologies. In particular, ship owners will not have enough motivation to install environmental technologies, if the law does not require this. The shipping firm in our case study, which is a representative of the overall shipping business globally, is primarily interested in reducing operational costs. A large share of these costs is associated with fuel consumption. Retrofitting the vessel to gain efficiency is thus one aspect in which market drivers (high fuel prices) interact with another driver (technology push). Besides the market pull and technology push drivers, new regulations from IMO and the EU set strict guidelines on SO_x, NO_x or the type of marine fuel to be used on board. Several suppliers are in the business of energy efficiency improvements, and this is shown in the type of value proposition offered by the network partners.

A direct consequence of these drivers into the eco-innovation process was that the value proposition has been developed gradually, in line with previous findings [38,89], and that the network had a tendency to try and discard different combinations of technologies. Each partner tried to span the boundaries of each organization's original business model in order to create a joint value proposition: green retrofit. As seen from this case's quotes from the marine equipment suppliers, their individual business models were quite narrow to sell given equipment/services and expect a payment in exchange. For this reason, the network coordination tried to collect quotes from the different participants in order to prepare a budget, which was used in project applications or in communication with the end-user. While extant research has sketched the importance of completing this transition from an individualized value creation/capture, complex projects like ship retrofits pose particular constraints. Although the focus of this research was not to analyze these constraints in detail, in Section 4.3, we pinpointed some institutional constraints faced by the network as regulatory or cultural. Previous research highlights these constraints in the context of complex projects and relates them to the issue of path dependency, which means that a business ecosystem finds it difficult to reach a proposition that challenges the existing regime, including market structures, infrastructure or contracts among actors [90]. While this narrative could also be meaningful to explain why many of the green retrofit package's different combinations of technologies were discarded over time, we perceive that issues of actors' practices [14] are more meaningful to explain institutional constraints in the context of value networks. We explained these practices as actors' performances, actions and resource exchanges over time.

The case study findings allow us to propose a framework whose purpose is to help networks of firms direct their eco-innovation processes when influenced by regulatory, market or technological evolution. The framework suggests that supply networks can deliver products and service eco-innovations 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 competencies and collaboration for maritime eco-innovations (Figure 4).

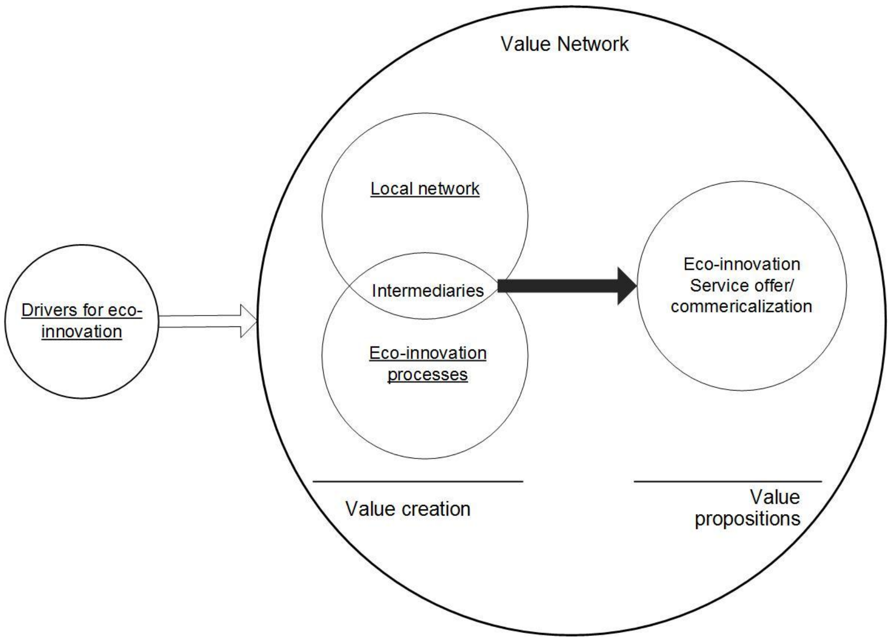

Figure 4. Conceptual framework: explaining value creation through eco-innovation.

The first part of the framework deals with end-user involvement in the value creation process. End-users influence the type of competencies and outcomes developed within the value network [15,68]. In the context of this case study, the end-user was a shipping company, which either owned or managed a fleet of ships, and demanded eco-innovations characterized by incremental modifications of existing technologies. The model proposes three interacting 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 internal business aspects.

The second element in the conceptual framework is value creation. The suppliers' interest is to develop new products and services with the primary purpose of creating new markets and thus generating growth in the regional maritime cluster in Northern Jutland. A close collaboration between end-users and suppliers can lead to co-creation, which implies value created by co-production with suppliers, end-users or partners (Normann and Ramirez, 1993, in [91] (p. 10)). 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. Local networks with a goal of developing maritime eco-innovations can be a platform for staging this collaboration.

According to the framework, it is possible to understand the development of eco-innovations by analyzing the processes within the networks or other forms of supplier and end-user collaboration. At this point, processes can have two meanings: the functioning of the network and the innovation process. The first meaning deals with the roles of actors in the network and the activities and 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 framework as a circle beneath "local network". Local suppliers created a network that brought together companies with experience in the sector and mature technologies with potential energy efficiency benefits for ships. As a result, the network sought to develop customized solutions to the end-user by combining different individual technologies. Developing combined product/service solutions as incremental environmental technologies for the maritime industry is not an activity that may generate the same type of revenues and return on investments as, for example, developing navigation instrumentation or propulsion equipment [92]. However, with better knowledge about the market developments, the perception about the demand for certain types of products became clearer. In other sectors, as in energy-renovation projects in the construction sector, this type of combination of energy-efficient technologies establishes a specialized service industry [12].

Innovation intermediaries represent a link between the overall network partners and the innovation processes. Actors such as the Business Council and other external actors' knowledge of the regulatory changes and the market trends triggered the perception of a market opportunity based on environmental technology. 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 who play several functions. These functions range from brokering to networking, but also increasing the absorptive capacity among cluster firms involved in the retrofit network.

The third element in the framework is how the created value as products or services can be transformed into value propositions for further commercialization to a larger group of users. The value proposition was introduced as the "promise" of what can be delivered to end-users and was in direct relation with the competencies of actors. From this perspective, value propositions are also one of the key elements included in the concept of the business model, along with the supply chain, customer interface and the financial model. 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; though the actors in the green ship network started to do so when the data collection was over, it sets the direction of action in such cases.

6. Conclusions

With insights from the literature on supply chain management, we present an analytical model to understand the drivers and processes of value creation in supply networks. The model explains that suppliers and other actors perceive drivers such as regulations, market and technologies as sources of opportunities to enter new markets. As a result, these drivers, mediated by the actors' decisions, trigger activities in order to exploit the possible opportunities behind the new regulations, technologies and market trends. The insights from the case study are translated into a framework, which presents three overall propositions about how collaborative eco-innovation networks can deal with external changes/drivers:

- Four interacting drivers motivate 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 internal business aspects

- Value creation manifests as a process of actors' practices in a context of network evolution, which shall be properly managed by innovation intermediaries in order to provide a strategic direction of the eco-innovation goals, but also deal with potential institutional constraints
- The created value in the form of ecosystem of products/services is transformed into a value proposition for further commercialization to a larger group of users.

Our framework can be generalized according to the empirical generalization approach; 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 [93]; this could be the case of other industries with similar modular production and service structures as the maritime industry. In our research design, we followed a longitudinal approach to the analysis of the value-creating network with an overview of the network over the last five years. However, issues such as regulatory changes and market trends seem to develop over the years. While we attempted to keep track of these changes, it is possible that emerging regulations, i.e., the ballast water convention, will influence the value proposition of the network. Our focus was therefore strictly on air pollution-related technologies.

Our study has two theoretical implications. First, we expand on the literature on eco-innovation processes, which so far has received scant attention, as we highlighted in our literature review section. As a result, while it is well known that eco-innovation can be developed in networks, we explicitly examined, through a longitudinal case study, the influence of eco-innovation drivers (regulatory, market and technology push) on the network dynamics and actors' practices. The novelty is combining the practice approach to the network dynamics approach in the understanding of these drivers influencing the eco-innovation process. Second, we also evidenced that the aspects of business models as value creation and capture of eco-innovation become more important in the literature, usually under a business ecosystem lens. Yet, no research so far has analyzed these aspects under the scope of value-creating networks. We identified differences between both lenses, in particular the lack of attention of the business ecosystem lens to the issues of processes, practices and stakeholder constellations. We consider, however, that both frameworks have the potential for cross-pollination and move forward the debate on how to create and capture value for eco-innovations in networks.

The study also has implications for practitioners. Managers involved in the design and coordination of eco-innovation collaborative settings shall consider the type of network the organization plans to develop. Value-creating networks differentiate from other networks because of the involvement of the end-user in the innovation process, but also in that partners must be clear about the strategy to develop a joint-value proposition as a result of the innovation process. Managers must therefore set clear mechanisms to guide the eco-innovation process in the value network. One mechanism is creating a platform so that all partners collaboratively build the objectives of the network. Another mechanism is to clearly set parameters to choose the modules that will be part of the final value proposition. A third mechanism is to integrate some kind of scenario analysis methodology to account for the effect of drivers as regulations, market pull or technology push over the eco-innovation process. While the scenario planning was not the focus of this research, other papers involved in business ecosystems have reached similar conclusions [87]. Managers from organizations who plan to engage in networked collaboration for eco-innovation must balance the costs and benefits of such initiatives. Particularly, they must consider the complexity of arguing on the value proposition due to the involvement of multiple stakeholders and their idiosyncratic perception of eco-innovation drivers. A balance should be made whether the joint-network business model leaves room for the individual interests or not.

Further research could address more in-depth the different types of challenges faced in value-creating networks, which we touched upon in this research, yet these become key to unfolding barriers for more sustainable business models for eco-innovations. For example, other longitudinal case studies could be valuable to uncover joint value creation along the innovation process for eco-innovations in other sectors. In addition, we suggest putting more attention on the aspect of the steering of value-creating networks. Critical case studies comparing successful and unsuccessful eco-innovation processes in value-creating networks could complement our research findings.

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Author Contributions: Roberto Rivas Hermann designed the research and carried-out the data collection. Roberto Rivas Hermann and Karin Wigger analyzed the data. Roberto Rivas Hermann and Karin Wigger contributed equally to the writing of the paper.

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Appendix A.

Table A1. Interviews in relation to the eco-innovation initiatives by maritime suppliers in Northern Jutland.

Stakeholder	Interview	Purpose
Maritime business consultants	1	Network facilitator in 2013
	2	Network facilitator in 2009 and 2010
	3	Network facilitator 2012–2013
	4	Network facilitator 2014–2015
	5	Network facilitator in 2011
Shipping firm involved in the network	6	Participant in the network, technical manager of the shipping firm
	7	Participant in the network, director of the shipping firm 2014–2015
Maritime suppliers involved in the network	8	Supplier involved in the test-projects
	9	Supplier involved in the test projects
	10	Supplier involved in all phases of the network
	11	Supplier who initiated the network
Experts in air pollution regulation European Commission and European Parliament	12	Expert shipping environmental regulations Directorate-General for Maritime Affairs and Fisheries, Brussels
	13	Expert shipping environmental regulations Directorate-General for Environment, Brussels
	14	Member of the European Parliament from the Finnish delegation, Brussels
Ship owners	15	Representative of European national ship owners associations, Brussels
	16	Drivers and barriers for the implementation of cleaner technologies; senior adviser in environmental regulations, Ship owners Association Copenhagen
	17	Scandinavian large shipping firm, legal department executive, Oslo

Table A2. Observation: sources of data. MARCOD, Maritime Centre for Operations and Development.

Event	Date	Role
MARCOD and Interreg IV-A Project Maritime Competence and Innovation Skagerrak and Kattegat 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, Middelfart, Denmark	January 2013	Participant
Maritime Business Opportunities	March 2014	Participant
Danish Maritime Days	October 2014	Participant
Maritime Business Opportunities	March 2015	Participant
Frederikshavn retrofit network	May 2015	Participant
Meeting(s) with MARCOD staff to present results/feedback	2014/2015	Presenter

Appendix B. Interview guides

Interview guide with network partners

Theme 1. The network

Can you describe the project-contacts and actors?

Theme 2. Internal process

How has the internal process in your organization been (regarding the projects in the network)?

- Motivations for entering in the project
- Responsible persons
- Department within your organization
- Resources to join the network
- Regulations influence
- Market influence

Theme 3. External processes

Did other organizations (out of the involved companies) take part in the network?

- Who contacted them?
- What each partner do?

Could you explain your experience collaborating with external partners?

- Barriers and drivers in collaborating
- Agreements/contracts
- Resources/learning

Contextual interview guide with ship owners and experts

Air pollution regulation and your organization

1. What is your organization position concerning the MARPOL Annex VI new amendments?
2. Have there been disagreements in the way the new regulation is put in place? Which? By whom?
3. How do the Danish authorities intend to apply this regulation in the practice?

4. Is your organization working to comply with this regulation?
5. How have you considered the issue of competence-building and new technologies associated?

Other factors pulling/pushing environmental concerns

6. Which other environmental regulations are source of interest/concern for your organization?

What are your organization's perspectives on market based instruments?

Appendix C. Data Analysis

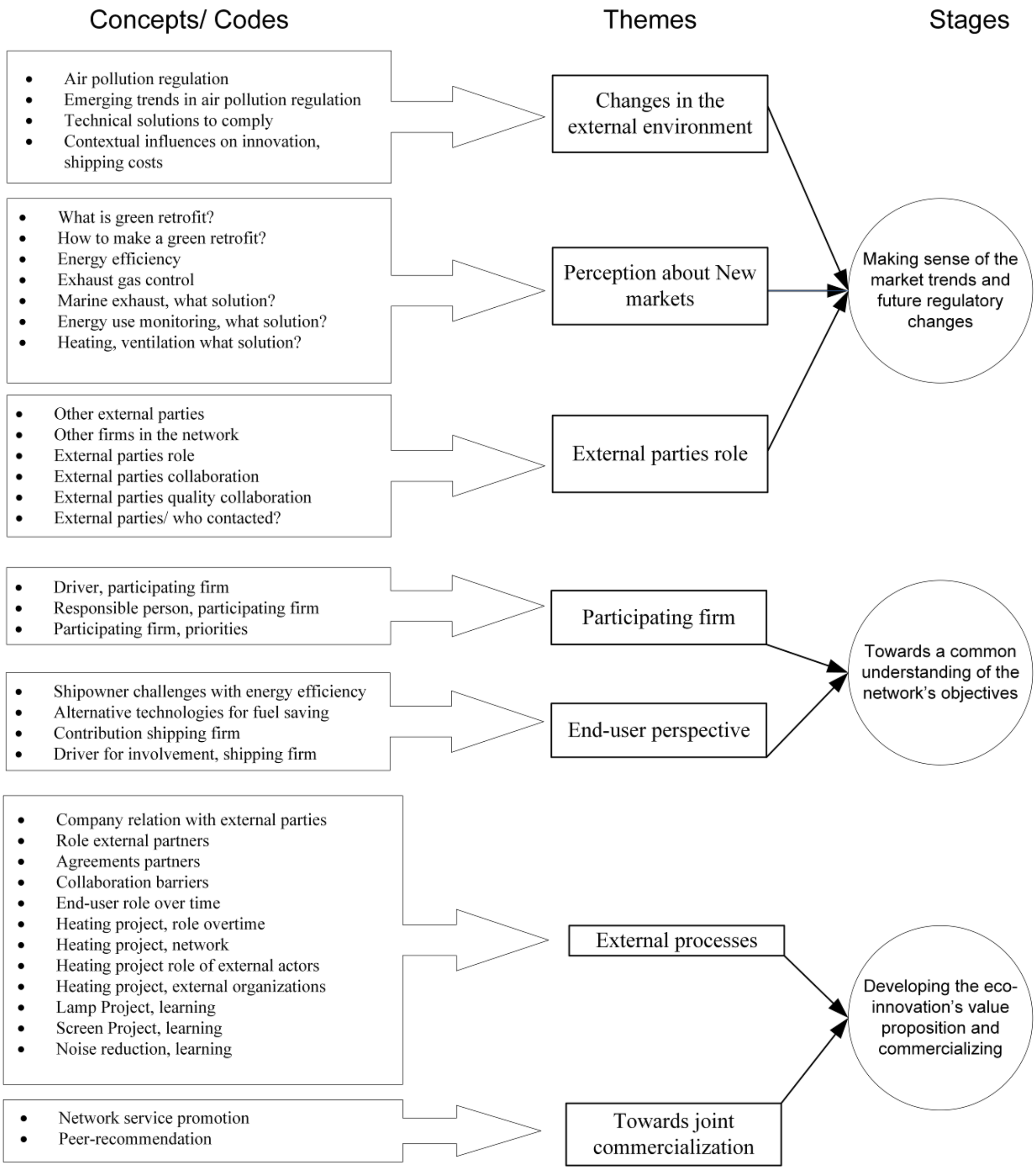

Figure A1. Data structure.

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