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Exploring the Role of Industrial Symbiosis in Advancing the Green Transition

A Case Study of Maritime Clusters in Western Norway

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Abstract

Introduction: While industrial symbiosis is gaining international recognition, research in a Norwegian and maritime context remains limited. This thesis addresses this literature gap by exploring the role of industrial symbiosis in advancing the green transition within maritime clusters in Western Norway. The study investigates industrial symbiosis practices within maritime clusters, examines the dynamics of cooperation and competition, and identifies key drivers and barriers to industrial symbiosis implementation. Moreover, it provides insights and recommendations to support Norwegian maritime clusters in their green transition.

Methodology: The study utilised an exploratory, qualitative case study approach to explore two cases: Grøn Region Vestland and Symbiose Fjordane. Semi-structured interviews were conducted with 15 participants from clusters and facilitating organisations. An inductive approach was employed, providing flexibility and enabling an exploration of the dynamics of industrial symbiosis.

Findings: The findings reveal familiarity with industrial symbiosis and strong commitment among maritime clusters to adapt to this circular strategy, although its implementation is in the early stages. The study uncovers that sectorial boundaries should not confine industrial symbiosis. It emphasises the importance of cooperation, enabled by geographic proximity, facilitation, knowledge sharing, and the balance of cooperation and competition through co-opetition. The study also identifies a complex interplay of factors impacting industrial symbiosis in maritime clusters, often acting simultaneously as drivers and barriers. The study presents insights suggesting that maritime clusters can benefit from being a first mover and succeed with industrial symbiosis by building a collaborative culture. Additionally, it suggests recommendations for maritime clusters to engage with policymakers, expand their network of cooperators and leverage their unique competitive advantages.

Discussion: We underscore industrial symbiosis as a viable strategy for Norwegian maritime clusters to adapt to an evolving business landscape. While the associated economic risks should be considered, it may offer an advantageous investment opportunity. This research contributes to the growing literature on industrial symbiosis and provides a roadmap for industry actors.

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Throughout the studies at NHH, Lise has developed a deep interest in sustainability, particularly within the field of circular economy, an interest that was further promoted through participating in the course Sustainable Business Models (BUS446). Elida finds topics related to innovation and organisation interesting, substantiated by the participation in the course Managing Change and Innovation (STR460). Our research has allowed us to explore the circularity, in the form of industrial symbiosis, in Norwegian maritime clusters, which further sparked our interest in this subject.

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1. Introduction

1.1 Background and Context

Linear economic thinking has dominated since the beginning of the third industrial revolution, leading to growth and wealth in many parts of the world (Jørgensen & Pedersen, 2018). However, the linear economy also contributes to current sustainability issues by utilising resources in an unsustainable manner and generating substantial amounts of waste. In response to these issues, the circular economy concept has gained significant attention in recent years (Barona et al., 2023). The circular economy introduces a favourable alternative, with its potential to balance environmental and economic objectives. By reducing resource usage, the circular economy can stimulate economic growth in a sustainable manner (Baldassarre et al., 2019). The negative externalities resulting from the linear economy have played a significant role in introducing the EU's strategy for sustainable growth, which includes the objective of achieving climate neutrality by 2050. Introduced in 2019, this strategy is known as the European Green Deal, with the circular economy action plan as a central component (European Council, n.d.; European Commission, n.d.). This strategy aligns with the goals of the Paris Agreement, which 196 parties, including Norway, have agreed upon. These parties are committed to limiting the rise in Earth's temperature to 2 degrees Celsius, with an even more ambitious target of 1,5 degrees Celsius (UNFCCC, n.d.). As the world strives for a sustainable future in alignment with these climate goals, the maritime sector plays a substantial role due to its influence on global trade and its potential for sustainable transformation (Morante, 2022).

The maritime sector is responsible for approximately 2,8% of global greenhouse gas emissions (GHG), mostly due to its reliance on carbon-intensive fuels and the extensive scale of its operations (Morante, 2022). Tasked with the responsibility to significantly reduce these emissions, the sector faces the dual challenge of mitigating its environmental impact while seizing new opportunities. Achieving this reduction will necessitate a global collaborative effort. In response, the International Maritime Organization (IMO) adopted a revised strategy in 2023 to reduce greenhouse gas emissions from international shipping. The strategy sets an ambitious goal to reduce emissions by at least 40% by 2023 (relative to 2008 levels), with the overall target of reaching net-zero emissions by 2050 (IMO, 2023). With a rich maritime heritage spanning over 150 years, Norway is a leading force in promoting green technology within the maritime sector (Nærings- og fiskeridepartementet, 2021; Kvamstad-Lervold, 2019). The maritime sector is one of the most comprehensive sectors in Norway, encompassing a complete set of industry actors that covers the entire value chain. As the fourth leading maritime nation globally, the maritime sector holds significant importance for the Norwegian economy, contributing to value creation and job opportunities. The green transition presents an additional market opportunity for Norway. It serves as a catalyst for enhancing value creation and job opportunities (Kvamstad-Lervold et al., 2019). In particular, Western Norway, with its strategic position where "sea meets land", holds a robust position within the maritime sector (Grøn Region Vestland, 2024, p. 20). This advantageous positioning and a strong commitment to green technology, position Norway as a key player in driving sustainable practices within the maritime sector.

While significantly contributing to Norway's economy, the maritime sector is also a major source of emissions and waste (Grøn Region Vestland, 2024). These challenges can be mitigated by adopting green technological developments (Morante, 2022). Industrial symbiosis holds the potential to create new business opportunities and contribute to reducing the sector's environmental footprint by using such technology. It has gained prominence over the past years and plays a central role in the green transition (Teräs & Mikkola, n.d.) by harnessing waste streams and turning them into valuable resources for other processes or industries (Bocken et al., 2014; Chertow, 2000). It serves as a pathway to transition from the linear economy towards circular business models (Baldassarre et al., 2019). Additionally, the complexity and extent of current climate issues, coupled with a rising need for long-term sustainable solutions, necessitates collaborative organisational approaches (Jørgensen & Pedersen, 2018; Kamm et al., 2016). According to the Ellen MacArthur Foundation (2013), networking and shared value creation are vital in organising a sustainable future. Thus, a determining factor for industrial symbiosis is collaboration (Teh et al., 2014), which may arise in various forms and can include different stakeholders from the private and public sectors (Boons et al., 2016), for instance, through cooperative networks known as clusters. Given the importance of collaboration in achieving climate goals, clusters can play an important role in the green transition (Derlukiewicz et al., 2020). In clusters, firms can collectively generate and sustain a competitive advantage while creating a competitive environment that drives innovation (Porter, 1998a; 1998b). This simultaneous presence of competitive and cooperative logic has been labelled as "co-opetition" by Brandenburger and Nalebuff (1996).

1.2 Clarification of Terminology

To ensure a consistent and common comprehension of terminology throughout the thesis, a clarification of the understanding we employ is necessary. Primarily, our thesis is contextualised within the green transition and the maritime sector. Moving forward, we build the thesis on three main theoretical concepts: circular economy, industrial symbiosis and clusters.

The Green Transition: Although it lacks a precise definition, “the green transition” is widely used to describe the shift towards more sustainable practices within various industries. This shift is typically characterised by reducing dependence on fossil fuels, improving the efficiency of resource use and limiting overconsumption (Finnish Ministry of the Environment, n.d.). It is reasonable to emphasise that the green transition does not represent a singular process but rather processes within various sectors aiming to achieve sustainable development (OECD, 2021, referred in Cedergren et al., 2022). Within the scope of this study, the term is used to encompass the diverse array of sustainable practices within the maritime sector.

The Maritime Sector: The study defines the term in accordance with SINTEF (Kvamstad-Lervold et al., 2019). The maritime sector encompasses “organisations that design, develop, build, supply, maintain, modify, own, operate and trade ships, equipment and specialised services for all types of ships and other floating units” (Reve & Sasson, 2012, referred in Kvamstad-Lervold et al., 2019, p. 4). Given the broad definition of the maritime sector, there is significant overlap with other industries, including offshore operations, carbon capture and storage (CCS), offshore and land-based aquaculture, offshore wind, and sea-based mineral extraction (Kvamstad-Lervold et al., 2019). This broad perspective allows for a comprehensive exploration of symbiotic relationships across diverse maritime activities.

Circular Economy: In the context of this thesis, the term “circular economy” is used as defined by the Ellen MacArthur Foundation (2013). This definition provides a framework for understanding how the circular economy is applied in our study. Particularly, the definition suggests the “elimination of waste through (…) business models” (Ellen MacArthur Foundation, 2013, p. 7), which can be directly aligned with the sustainable business model archetype of creating value from "waste", as suggested by Bocken et al. (2014). An example of this business model archetype is the concept of industrial symbiosis.

Industrial Symbiosis: We have adopted the definition by Chertow (2000), due to its wide recognition (Lombardi & Laybourn, 2012). Industrial symbiosis is the collaborative exchange of resources among separate entities leveraging geographical proximity and synergistic opportunities (Chertow, 2000). Moreover, industrial symbiosis can be viewed from an industrial ecology perspective or a circular economy perspective (Baldassarre et al., 2019). Following Baldassarre et al. (2019) and Bocken et al. (2016), our research investigates industrial symbiosis in the context of circular economy as an example of a business model for circularity.

Clusters: Industrial symbiosis engages diverse organisations within a network (Lombardi & Laybourn, 2012), and according to Porter (1998a, p. 242): "A cluster is a form of network that occurs within a geographic location" characterised by its proximity and interconnection (Martin & Sunley, 2003). Hubs can be referred to as next-generation clusters (Lange et al., 2010) and are characterised as "Networks driven by practitioners, shaped around … interlinked problems, shared interests, and shared principles (…). Operating in a local or regional setting" (Kamm et al., 2016, p. 38). Eco-industrial parks are organisations located in a defined area that exchange resources, information, and services (Chertow, 2000). This study adopts the term "cluster" as a collective reference to cooperative efforts such as clusters, hubs, and industrial parks, which are all located within geographic proximity and are interconnected. Here, the cluster represents the collaborative framework, while industrial symbiosis may serve as the mechanism facilitating the green transition. This understanding creates a link between the concepts of clusters and industrial symbiosis.

1.3 Research Question and Research Objectives

Today, we find extensive literature on industrial symbiosis and clusters. However, according to Baldassarre et al. (2019), further research on industrial symbiosis should focus on how new clusters can intentionally be designed for an industrial symbiosis purpose. We find that the Norwegian context for industrial symbiosis is highly unexplored. Simultaneously, Liao et al. (2021), propose that there exists limited research on the maritime sector and its inter-industry relations. The combination of these research gaps forms the focal point of our study. We are studying clusters within two cases, Grøn Region Vestland and Symbiose Fjordane. These projects aim to incorporate industrial symbiosis in businesses, thus creating a new green business environment in Western Norway (Hub for Ocean, n.d.; Grøn Region Vestland, 2024). By exploring the dynamics of collaborative relationships and resource-sharing within maritime clusters, this study seeks to explore the role of industrial symbiosis in promoting a sustainable future for the Norwegian maritime sector. This has resulted in the following research question:

How can industrial symbiosis contribute to the green transition in Norwegian maritime clusters?

The primary objective of this study is to explore and understand the significance of industrial symbiosis in fostering the green transition within maritime clusters. The division into specific research objectives (RO) allows for a focused exploration of the sub-topics that have been introduced. Each research objective builds on the previous one, ensuring a structured approach to answering the research question. Specifically, the research aims to:

RO1: Examine the practices of industrial symbiosis within clusters that engage in maritime activities.

RO2: Explore the dynamics of cooperation and competition within maritime clusters, investigating how knowledge is shared and exchanged to foster industrial symbiosis.

RO3: Identify the drivers and barriers associated with implementing industrial symbiosis.

RO4: Provide insights and recommendations for Norwegian maritime clusters to succeed in the green transition by implementing industrial symbiosis.

The research objectives address the challenges and opportunities the maritime sector faces in the green transition. By investigating industrial symbiosis, our aim is to support industry actors in reducing their emissions and waste streams. The study intends to fill a gap in the existing literature and contribute to an improved understanding of industrial symbiosis dynamics in Norwegian maritime clusters.

1.4 Scope of Thesis and Delimitations

To enhance feasibility, we must define a reasonable scope and establish clear delimitations for the thesis (Saunders et al., 2019). While numerous aspects of industrial symbiosis offer interesting research opportunities due to its increased popularity in recent years (Teräs & Mikkola, n.d.), this study will concentrate on understanding the dynamics of industrial symbiosis within clusters that engage in maritime activities. The maritime sector is specifically chosen due to its considerable emissions and challenging path towards decarbonisation (Morante, 2022; IMO, 2023). Our approach aims to provide a comprehensive analysis of the role of industrial symbiosis in driving the green transition within the Norwegian maritime sector.

Studying industrial symbiosis requires a geographical focus (Teh et al., 2014; Chertow, 2000), particularly when examining clusters, which are inherently characterised by their geographic proximity (Porter, 1998a; 1998b). In particular, we have narrowed our focus to Western Norway due to the region's pivotal role in the global effort for a green maritime transition and strong position within maritime activities (Grøn Region Vestland, 2024). While acknowledging potential national variations in culture, regulations, support programmes, and institutions, the narrow geographical scope enhances the relevance and applicability of our findings within this context. Co-locating businesses might be beneficial since it promotes collective learning processes through recurring opportunities for formal and informal exchanges (Maskell & Malmberg, 1999). In the extension of this, Ehrenfeld and Gertler (1997, referred in Domenech Aparisi, 2010) emphasise that short mental distance is an underlying factor in the emergence of industrial symbiosis.

The research adopts a thematic focus by narrowing the scope to industrial symbiosis practices within maritime clusters. The rationale behind this delimitation is dual. Firstly, Saunders et al. (2019) stress the importance of being capable of undertaking the project. Due to time constraints, we find it necessary to narrow our research to one sector. This delimitation will ensure the focus on sector-specific implications or opportunities regarding industrial symbiosis. Secondly, the research is confined to two cases, Grøn Region Vestland and Symbiose Fjordane, to ensure an in-depth exploration (Yin, 2018, referred in Saunders et al., 2019) of two cases within a specific region. This approach allows for a detailed analysis of the challenges and opportunities within the cases.

Finally, methodological delimitations and other implications that are associated with our chosen research design, will be thoroughly discussed in Chapter 4. Moreover, Chapter 6 discusses the study's limitations, proposing possible constraints that arise from the methodological choices. Additionally, this chapter suggests potential areas for further research that extend beyond the scope of these delimitations, thereby suggesting paths for additional exploration and understanding.

1.5 Thesis Structure

The thesis unfolds across seven consecutive chapters. Chapter 2 establishes the theoretical foundation by delving into the literature on circular economy, industrial symbiosis, and clusters, including each concept's definition and key characteristics. Chapter 3 narrows the focus to the maritime sector, reviewing literature specific to this context. Firstly, it explores circular economy initiatives within the maritime sector, including the drivers and barriers to its implementation. Subsequently, it follows examples of industrial symbiosis in maritime activities, and lastly, maritime clusters and their efforts in the green transition. Chapter 4 introduces the methodology used in the study. It elaborates on our methodological choices and describes the data collection and analysis. This chapter also addresses data quality issues and ethical considerations, ensuring transparency in our research process. Chapter 5 presents the findings from the interviews with members of Norwegian maritime clusters. Here, we systematically present and analyse the findings concerning each research objective. This chapter ends with the presentation of a conceptual framework. Chapter 6 discusses the theoretical and practical implications of our findings, limitations in the study, and suggests pathways for future research. Lastly, in chapter 7, the study concludes with a summary of key findings.

2. Circular Economy, Industrial Symbiosis and Clusters

In this chapter, we will present literature concerning our research objectives. The theoretical emphasis will be on the circular economy, industrial symbiosis and clusters. Firstly, we present the circular economy theory as our conceptual perspective on industrial symbiosis. Subsequently, the main section of the chapter is dedicated to industrial symbiosis, as this is the overarching theme in our research question. Lastly, we explore competition and cooperation in the context of clusters.

2.1 Circular Economy

This section explores the circular economy, a concept central to sustainable industrial practices. We explore the definition, underlying principles and associated business models, with an emphasis on its role in shifting industries from linear models to circular, resource-efficient systems.

2.1.1 Definition

The concept of the circular economy is influenced by the work of Boulding (1966, referred in Geissdoerfer et al., 2020), who suggests that for a balanced coexistence of the economy and the environment, the earth should be viewed as a closed-loop system with limited capacity. However, the concept's interpretation can vary significantly among stakeholders, leading to potential confusion or misrepresentation (Kirchherr et al., 2017). This variability in understanding and application makes it challenging to establish a universally accepted definition for the circular economy. Lieder and Rashid (2016, p. 37) further emphasise the existence of "(…) various possibilities for defining [circular economy]". Kirchherr et al. (2017) underscore that the definition introduced by the Ellen MacArthur Foundation (2013), a leading authority on the subject of circular economy, is the most widely adopted. The Ellen MacArthur Foundation suggests the following definition:

> A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of

> materials, products, systems, and, within this, business models. (Ellen MacArthur Foundation, 2013, p. 7)

2.1.2 The Principles of the Circular Economy

Today, the linear economy conflicts with various environmental, social and economic challenges (Papamichael et al., 2023). As environmental challenges increase, there is a growing recognition that traditional linear systems are unsustainable (Bocken & Short, 2021). The linear economy is perceived by McDonough and Braungart (2002) as a cradle-to-grave model, which is characterised by the logic of "take-make-use-dispose" (Bocken et al., 2016, p. 308) where resources are extracted, produced, consumed and in the end disposed. In opposition, the circular economy constructs circular value chains through a cradle-to-cradle flow of resources (McDonough & Braungart, 2002), promoting sustainable practices by efficiently using resources, minimising waste and reducing environmental harm (Barros et al., 2021). The concept is based on the idea of the economy being restorative and regenerative (Baldassarre et al., 2019; Ellen MacArthur Foundation, 2013), meaning that economic activities should reinforce instead of breaking down environmental and social resources (Jørgensen & Pedersen, 2018). Moreover, circular economic models can be built upon three strategies: slowing, closing and narrowing resource loops (Bocken et al., 2016). *Slowing resource loops* is about ensuring longer lives of products by designing for longevity. Secondly, *closing resource loops* involves ensuring a continuous flow of resources from post-use to the production of new products, ensuring the reuse of materials through recycling. Lastly, *narrowing resource loops* focuses on resource efficiency, aiming to use fewer resources per produced unit. In essence, these strategies seek to create an economic ecosystem where resources are utilised efficiently, products are designed for longevity, and waste is minimised. The slowing, closing and narrowing of resource loops can be achieved through "long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (Geissdoerfer et al., 2017, p. 759).

2.1.3 Circular Business Models

A business model serves as a conceptual tool for understanding how a firm does business (Osterwalder et al., 2005). According to Osterwalder and Pigneur (2010, referred in Osterwalder & Pigneur, 2011, p. 62), a business model "describes the rationale of how an organization creates, delivers and captures value". In this regard, the business model is comprised of several elements (Bocken et al., 2014). Firstly, the value proposition involves understanding what the customer values. Additionally, value delivery encompasses the essential resources, activities and partners necessary for the company to fulfil the requirements of the value proposition. Lastly, value capture involves determining how to generate revenues by providing users and customers with goods, services, or information. Having a precise and effective business model is crucial for a business's success, according to Barona et al. (2023). Sustainable business models integrate principles and goals prioritising environmental and social considerations, thereby expanding the scope of value creation, delivery and capture processes beyond traditional business models (Lüdeke-Freund et al., 2019). Schaltegger et al. (2016) provide the following definition of a sustainable business model:

> A business model for sustainability helps describing, analyzing, managing, and communicating (i) a company's sustainable value proposition to its customers, and all other stakeholders, (ii) how it creates and delivers this value, (iii) and how it captures economic value while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries. (Schaltegger et al., 2016, p. 6)

In alignment with the presented circular economy definition introduced by the Ellen MacArthur Foundation (2013), business models outline the strategies and practices companies can adopt to achieve the circular economy's restorative and regenerative goals, including reuse and waste elimination. The subcategory of sustainable business models, circular business models, aims to "drive the sustainability of a business network through the circular strategies" (Baldassarre et al., 2019, p. 448). Circular business models provide a narrower environmental and economic focus. The models facilitate economically viable approaches to continually reusing products and materials, prioritising the use of renewable resources whenever feasible (Bocken et al., 2016). Bocken et al. (2014) propose a categorisation of sustainable business model archetypes that organisations can adopt to integrate sustainability into their business practices. These archetypes provide a framework for understanding and implementing sustainable business models. They are designed to offer a common language and guidance for organisations aiming to develop and integrate sustainability into their overall business strategy. In the next section we will explore the concept of industrial symbiosis, recognised as a business model archetype for closing resource loops.

2.2 Industrial Symbiosis

In this section we present theory on industrial symbiosis. As the concept has its origin in industrial ecology, we introduce the section by presenting this term. In the extension of this, we will introduce the definition of industrial symbiosis, followed by a presentation of benefits, drivers and barriers to the concept. Moreover, we will present industrial symbiosis facilitation, before we conclude by building a bridge between the circular economy concept and industrial symbiosis.

2.2.1 Industrial Ecology

The term industrial ecology appeared in the early 1990s as a response to the concern on industrial activities' environmental influence (Frosch & Gallopoulos, 1989, referred in Baldassarre et al., 2019). Following this, industrial ecology evolves around the idea that science, social sciences and engineering play a role in managing industrial systems in order to accomplish sustainable development (Yu & Zhang, 2021). In 1997 John Ehrenfeld published an article on industrial ecology, and summarised the article as follows:

> Industrial ecology is a new system for describing and designing sustainable economies. Arising out of an ecological metaphor, it offers guidelines to designers of products and the institutional structures in which production and consumption occur, as well as frameworks for the analysis of complex material and energy flows across economies. (Ehrenfeld, 1997, p. 87)

Today, industrial ecology has found its way into various fields such as academia, environmental policy and industrial development. The concept is also inherently connected to business strategy (Ehrenfeld, 2004). According to Chertow (2000, p. 315) industrial ecology operates at three levels: "facility/firm", "inter-firm" and "regional/global" level. Industrial ecology at facility/firm level is related to how an individual business can become more sustainable, exemplified by activities such as green accounting and pollution prevention. Furthermore, the inter-firm level is connected to industrial sector initiatives as a whole, whereas industrial symbiosis is included. Industrial ecology at regional/global level refers to for instance materials and energy flow studies (Chertow, 2000). In the extension of this, Chertow (2000) finds that researchers assume that a shift towards more sustainable activities will begin at a local (regional) level. Finally, industrial ecology seeks to enhance the efficiency of exchanges within and among systems, and industrial symbiosis highlights collaborative efforts between businesses to encourage practices aligned with ecological concepts (Leigh & Li, 2015; Chertow, 2000).

2.2.2 Definition of Industrial Symbiosis

A frequently cited definition of industrial symbiosis was introduced in 2000 by Chertow (Lombardi & Laybourn, 2012), and the concept is defined as follows: "(…) industrial symbiosis engages traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity" (Chertow, 2000, p. 314). By engaging in such collaboration, the objective for companies is to create greater advantages than would be possible to develop and attain independently. Chertow (2007) introduced the "3-2 heuristic" to separate industrial symbiosis from other exchange processes. For an exchange process to be called a basic type of industrial symbiosis, this heuristic emphasises that "(…) at least three different entities must be involved in exchanging at least two different resources (…)" (Chertow, 2007, p. 12). A prevalent approach to achieve industrial symbiosis is by establishing eco-industrial parks, which are organisations located in a distinct area with the opportunity to exchange water, energy and other materials, as well as intangible products like information and services (Chertow, 2000). However, industrial symbiosis is not limited to only occur within such parks. Lombardi and Laybourn (2012) have further developed Chertow's (2000) definition. After their extensive literature review, a suggested updated definition reads as follows:

> [Industrial symbiosis] engages diverse organizations in a network to foster eco-innovation and long-term culture change. Creating and sharing knowledge through the network yields mutually profitable transactions for novel sourcing of required inputs, value-added destinations for non-product outputs, and improved business and technical processes. (Lombardi & Laybourn, 2012, pp. 31-32)

The proposed definition has dismissed the importance of geographical location and included a broader spectrum of entities involved in a potential resource exchange. Following this update, a more flexible view on industrial symbiosis is therefore introduced (Turken & Geda, 2020).

Illustrated by the above, the literature does not give one definition that is fully recognised as the true definition of industrial symbiosis, as highlighted in Boons et al. (2016). This has led to a need of finding a common understanding of the concept, including a framework that can be applied to analyse different examples of industrial symbiosis (Boons et al., 2016). The authors, with Chertow as a contributing author, have published an article with the aim to develop such framework, which will be revisited in subsection 2.2.6. Based on the definition concern raised earlier, the authors have not attempted to develop a new universal definition of industrial symbiosis or relied on an older definition. Nevertheless, the authors refer to industrial symbiosis as a process, where the goal is to bind flows between industry actors through "(1) use of secondary material, water and energy resources and/or (2) utility and service sharing, such as collective use of infrastructure or environmentally related services across a network" (Boons et al., 2016, p. 941).

2.2.3 Benefits of Industrial Symbiosis

Jørgensen and Pedersen (2018) argue that it is important for an organisation to shift from a one-dimensional to a three-dimensional bottom-line focus to encourage sustainable activities. This implies that the focus should extend beyond the economic perspective and consider the environmental and social implications of business activities. According to Domenech Aparisi (2010) the benefits of industrial symbiosis can be divided into economic, environmental and social benefits, thus a parallel to the triple bottom line from Jørgensen and Pedersen (2018). Firstly, companies engaging in industrial symbiosis may experience *economic benefits,* which can unfold as a motivational factor for engagement. Economic benefits are often linked to cost efficiency measures, waste management and income from by-products and waste streams (Domenech Aparisi, 2010). This corresponds to the benefits emphasised by the project Scaling European Resources with industrial symbiosis (Scaler). Economic benefits can be achieved through reduction of raw material cost, diminution of waste disposal cost, increased income generated from by-products and/or waste sales and expansion of market reach (Scaler Project, n.d.). Additionally, if a company reduces its reliance on non-renewable resources, this can lead to a decrease of production costs (Van Berkel, 2006). Van Berkel (2006) further explains that another benefit is that risk profiles can improve, for example due to regulatory compliance. Moreover, industrial symbiosis fosters *environmental benefits,* predominantly attributed to the reduction of resource utilisation (Domenech Aparisi, 2010). The engagement in a comprehensive industrial symbiosis can lead to (1) more recycled water and energy, (2) material and energy recovery, (3) reduction of sourced raw materials and overexploitation of resources, (4) less waste ending up as landfill, and (5) reduction of GHG emissions through for instance use of alternative fuels (Scaler Project, n.d.; Bossilkov et al., 2005). The *social benefits* that stem from industrial symbiosis, from a community perspective, are connected to the creation and retention of jobs. Moreover, the social benefits also relate to the improvement of the environment around a local population to be cleaner and safer, thus implying better local ecosystems (Domenech Aparisi, 2010). Ecosystems with less pressure on local resources, more opportunities for employment and improved regional economy are also enhanced as social benefits by Scaler Project (n.d.). In extension, outcomes connected to conservation of, for instance, heritage and landscape, general health and safety, and hazard control may arise from industrial symbiosis (CTTÉI, 2013).

2.2.4 Drivers Fostering Industrial Symbiosis

Teh et al. (2014) introduce twelve determinant factors that can influence the development of industrial symbiosis and affect the success of it, whereas each of these factors plays a different role in the development of the industrial symbiosis. The drivers are as follows: institution, laws and regulations, finance, research and development, technology, market, collaboration, information, geographical proximity, awareness and capacity building, environmental issues, and industry structure. In addition to these twelve factors, Ehrenfeld and Gertler (1997, referred in Domenech Aparisi, 2010) emphasise that short mental distance should be an underlying factor in the emergence of industrial symbiosis.

The institutional, regulatory and financial drivers are inherently connected to the role of governing bodies in industrial symbiosis. Firstly, *institution* is tied to the role of the government in fostering industrial symbiosis (Teh et al., 2014). Although the governmental actor may not initiate the symbiosis, it does play an important role in promoting the concept. It is necessary with a commitment from the governmental actor to coordinate and communicate different types of needed support for the emergence of industrial symbiosis (UNIDO, 2011, referred in Teh et al., 2014). This can be related to financial support programmes, education, and training, as well as policymaking, laws and regulation (Almasi et al., 2011, referred in Teh et al., 2014; van Beers et al., 2007). Secondly, *laws and regulations* may affect industrial symbiosis because taxes, fees, and levies can steer businesses in a certain direction (Teh et al., 2014). Furthermore, the authors emphasise that subsidiaries for activities using non-renewable resources should be removed as it can lead to less initiative-taking when it comes to reuse, recycling and sharing of resources (Kalundborg Symbiosis Institute, 2011, referred in Teh et al., 2014). Domenech Aparisi (2010) argues that a regulatory framework, for instance regarding pollution control can build incentives for by-product exchanges. Moreover, the *financial* factor addresses that achieving industrial symbiosis often necessitates new investments. This financial commitment can be substantial, especially for small and medium-sized businesses (UNIDO, 2011, referred in Teh et al., 2014). Teh et al. (2014) highlight subsidisation and/or low interest loans with long payback time, which can be favourable for small businesses to afford new and necessary equipment. Subsequently, providing financial support for research and development will reinforce further development of industrial symbiosis (Teh et al., 2014).

Moreover, the drivers of research and development, technology, and market are connected in the sense that research and development can lead to new technological solutions, which in turn can mature and create new markets. In terms of *research and development*, the goal should be to bring new technologies for commercial and sustainable use (Teh et al., 2014). Technologies that require low capital investments, little maintaining costs and are simple to use and implement into the business, can create an increased awareness of industrial symbiosis from a business perspective. Following this, research and innovation creates technological breakthroughs which in turn can unfold as the groundwork for creating new synergies and more general sustainable products (Teh et al., 2014). Therefore, *technology* is further disclosed as a critical factor for achieving industrial symbiosis. For instance, new and updated environment technologies are vital when it comes to the exchange or conversion of by-products (Teh et al., 2014). An additional factor that substantiates industrial symbiosis is the *market* for green products. A stronger awareness and demand for greener products for private consumption and procurement (public and private) works as a pull factor for developing industrial symbiosis. Due to this, public and private actors that may need to buy greener products will create a larger market for such products (Teh et al., 2014).

Collaboration, as a driving factor, may be related to other drivers such as short mental distance, and the efficient exchange of information. *Collaboration* is an essential component in the development of industrial symbiosis as companies need to share utility and exchange by-products (Teh et al., 2014). In general, it is important that industries, for instance through platforms, institutions, or alternative arenas, are exposed to the concept of industrial symbiosis and build a common understanding of today's environmental issues. In the extension of this, continuous stakeholder discussion and/or public dialogue to promote industrial symbiosis is important. This can increase participation from businesses within several industries and rise their willingness to partake in synergies. However, it is important to note that creating robust social cohesion between, and among industries, require time (Teh et al., 2014). *Short mental distance* means that there should be a close alignment in understanding and perspectives among actors, as this ensures that goals and visions are harmonised which in turn can make the communication and interaction easier between the actors (Ehrenfeld & Gertler, 1997, referred in Domenech Aparisi, 2010). Another factor in fostering industrial symbiosis is *information*. It is necessary for a business to possess comprehensive information about their activities, like for instance the raw material input and waste output, to be able to identify symbiotic opportunities. Sharing information between industries can contribute to more well-informed decisions and effective synergies because access to information can reinforce connections (Teh et al., 2014). According to Domenech Aparisi (2010) trust between partners within a network may lead to a reduction of transaction risks and promote a readiness for collaboration. In addition to building trust by sharing information, it is also important to remove unnecessary confidentiality between collaborators (Teh et al., 2014).

Following this, *geographical* proximity, or the distance between collaborators, can influence the efficiency of resource exchanges (Almasi et al., 2011, referred in Teh et al., 2014). The arguments concerning why distance is important is (1) shorter distances lead to lower transportation costs, substantiated by Neves et al. (2020), (2) achieving energy synergies is more challenging due to energy degradation, and (3) pipeline infrastructure for longer distances is costly (Almasi et al., 2011, referred in Teh et al., 2014). However, transporting goods (physical by-products) over a longer distance can be considered if the material is deemed highly valuable (Teh et al., 2014). Furthermore, Domenech Aparisi (2010) indicates that geographical proximity is important, as longer distances may discourage the creation of symbiotic links. However, determining which businesses fall within geographical proximity can be challenging. According to the National Industrial Symbiosis Programme (NISP), half of the successful synergies between industrial actors occurred within a radius of approximately 33 kilometres from the origin of the resource, and three-quarters took place within approximately 63 kilometres radius (Jensen et al., 2011). Nevertheless, Neves et al. (2020) find examples of symbioses that has emerged although the businesses are located far from each other, while Lombardi and Laybourn (2012) dismiss the importance of geographical location.

Awareness and capacity building, environmental issues and industry structure are additional factors presented by Teh et al. (2014) that foster ideal involvement in industrial symbiosis. *Awareness and capacity building* is connected to an increasing awareness level both for local businesses and local communities, thus enhancing the significance of resource conservation and more general environmental issues. According to the authors, the higher the level of awareness, the higher the motivation will be towards integrating ideas within industrial symbiosis into the business activities. Showcasing economic and environmental benefits with industrial symbiosis by raising awareness, can enhance a business' interest in the exchange of materials (Teh et al., 2014). Creating awareness can connect to another determinant factor which is *environmental issues.* This driver refers to the negative impact the industry has on the environment today, and industrial symbiosis is perceived as a measure to cope with certain environmental issues, like for instance resource scarcity (Teh et al., 2014). Following this, it is possible to draw a line between capacity building and *industry structure.* Industry structure relates to how a variety of industries in an industrial park affects the synergies that can arise, in both quantity and complexity. In industrial parks some industries unfold as anchor tenants. These are industries that typically possess substantial capital and considerable large material streams. Subsequently, having such anchor tenants present sets a good foundation for creating synergies with other industries (Teh et al., 2014).

2.2.5 Barriers to Industrial Symbiosis

Yang et al. (2022b), present eight recurring barriers to the emergence of industrial symbiosis. Some of the drives presented in subsection 2.2.4 may unfold as barriers. The barriers are as follows: governmental, economic, technological, informational, organisational, cognitive, motivational, and safety barriers.

According to Yang et al. (2022b) *governmental barriers* to the development of industrial symbiosis are connected to regulations and policies. There are several reasons why these may unfold as barriers, but the overarching issues can be connected to complexity in regulations. Heeres et al. (2004) highlight the overwhelming amount of environmental laws and regulations, and van Beers et al. (2007) emphasise that there is often an uncertainty about regulatory frameworks. Furthermore, some policies may limit the emergence of industrial symbiosis as they do not harmonise with industrial innovation (Chiu & Yong , 2004). Moreover, it is important to review the *economic barriers* to industrial symbiosis (Yang et al., 2022b), and the economic perspective is fundamental to consider (Yeo et al., 2019), as companies aim to be profitable (Yang et al., 2022b). A reason why economy may unfold as a barrier is because an exchange of material, which is fundamental in industrial symbiosis, may not be economically responsible or even introduce an economical risk for the business (Heeres et al., 2004). Bossilkov et al. (2005, p. 52), highlight “dependence on by-product supply” as a barrier which in turn may unfold as an economic risk in reference to Heeres et al. (2004). Finally, an investment related to industrial symbiosis must be economically viable and should be considered competitive compared to other investment opportunities (Bossilkov et al., 2005). Following this, *technological barriers* are also evident in relation to industrial symbiosis (Yang et al., 2022b). To be able to engage in industrial symbiosis, there must exist a form of technology that enable the conversion of by-products (Bossilkov et al., 2005) because capture, recovery and reuse of such products is a necessity in a symbiosis (van Beers et al., 2007; Chertow, 2000). Moreover, van Beers et al. (2007) highlight that the technological barriers to engage in industrial symbiosis mainly implies a lack of suitable technology needed to leverage the potential of symbiotic exchanges.

Yang et al. (2022b) further highlight *informational barriers*. In the establishment of exchange initiatives, Heeres et al. (2004) underline that there exist such barriers. More specifically, it is important that the relevant people possess necessary information at the right time, which can be challenging. This is due to the importance of being able to identify symbiotic opportunities in the sense of material flows (Yeo et al., 2019). Bossilkov et al. (2005, p. 52) substantiate further by explaining that “lack of awareness on potential use of by-products” is a barrier to industrial symbiosis, which must be seen in the context of informational barriers. Moreover, Yang et al. (2022b) point out that *organisational barriers*, such as organisational culture can hinder the emergence of industrial symbiosis, while Heeres et al. (2004) highlight that the corporate organisational structure may lead to difficulties in engaging in industrial symbiosis initiatives. Bossilkov et al. (2005, p. 52) identify some specific challenges such as “lack of time”, “lack of internal support and commitment” and “reluctance of companies to become involved in activities different to their core business”, whereas especially the last two can be imposed due to a specific culture within the organisation. Moreover, *cognitive barriers* can impose a challenge to the emergence of industrial symbiosis (Yang et al., 2022b). Ehrenfeld and Gertler (1997) highlight that there might be cognitive barriers related to industrial symbiosis as a concept. This is grounded in the idea that waste has traditionally not been perceived as valuable for businesses. It was for a long time a challenge to integrate the aspect of waste in their strategic process, but this is changing. Nevertheless, Bossilkov et al. (2005) state that companies can experience complications with working outside their core businesses. In the extension of this, *motivational barriers* may hinder the establishment of successful symbiotic exchange (Yang et al., 2022b). Therefore, companies, public actors and other relevant actors must demonstrate a willingness to collaborate. Following this, the lack of trust may hinder the establishment of necessary relationships in symbiotic exchanges (Gibbs, 2003). Lastly, *safety barriers* must be taken into consideration if businesses engage in the exchange of by-products (Yang et al., 2022b). It is important to thoroughly assess the appropriate use of by-products, and the potential harm it may impose for instance in relation to environmental and health concerns (Chertow, 2007).

2.2.6 Industrial Symbiosis Facilitation

Boons et al. (2016) propose a framework including seven examples of industrial symbiosis dynamics. The dynamics are categorised based on the initiator for the industrial symbiosis and motivation behind the choice to seek symbiotic linkages. The authors present three possible initiators: industrial, third-party, or governmental actors. Self-organisation and organisational boundary change are initiated by industrial actors, brokerage facilitation, collective learning facilitation, and pilot facilitation and dissemination are facilitated by a third-party, while the dynamics initiated by governmental actors are government planning, and eco-cluster development. Eco-cluster development can also be initiated by industrial actors. While Boons et al. (2016) state that the findings are not empirically tested yet, it serves as an illustration, based on case studies, of seven pathways on how the process of industrial symbiosis may unfold.

Self-organisation takes form when an industrial actor is self-motivated and incentivised by the economic and/or environmental benefits from the engagement in industrial symbiosis, and independently develops a connection with other actors. The strategy is to search for other actors that are appropriate and can contribute towards the achievement of their goals. Based on this, the initial actor is the industrial actor itself. Due to the autonomous development of linkages, it is not given that one actor knows of all the other actors in the network. It is noteworthy that although the outcome often is a symbiotic network, this is not always the underlying motivation for the initiator. A case of self-organising industrial symbiosis can be when a large industrial actor gathers smaller actors to develop and maintain a symbiotic network. *Organisational boundary change* is characterised by symbiotic networks evolvement due to a change in the company's organisational boundaries, like for instance outsourcing. In short, this dynamic occurs when a company reorganise itself and potentially leads to new networks within the company itself and with other companies. Behind this dynamic, eco-efficiency and business strategy resides as the motivation (Boons et al., 2016).

Brokerage facilitation is when a public or private third-party organisation's task is to enhance the visibility of a market for companies to engage in industrial symbiosis. For instance, the NISP in the United Kingdom, and the United States Business Council for Sustainable Development, search for industrial symbiosis opportunities between actors. Moreover, *collective learning facilitation* is different from the above-mentioned because the third-party organisation aims to develop knowledge and share experiences to foster collaborative learning, encouraging the develop of structured and advanced symbiotic networks. Facilitators in this regard has a larger focus on developing and exchange of experimental knowledge. To exemplify this dynamic, NISP focused on facilitating for a communication area for industrial actors. They saw that as the learning progressed, more strategic and objective-oriented processes occurred, like for instance related to new symbiosis projects relevant for the actors. Based on the examples, it is possible to engage in both types of facilitation. *Pilot facilitation and dissemination* is another example of a dynamic with a third-party organisation as an initial actor. Here, the initiator acquires insight and knowledge on existing industrial symbiosis cases in a non-local context. The objective is to develop a conceptual model and test it on a local cluster, followed by an evaluation to extract best practices most suitable for the specific area. This process may lead to a dissemination of the industrial symbiosis concept among clusters (Boons et al., 2016). On a final note, Schlüter et al. (2022) emphasise the necessity of a third-party facilitator role when companies seek to engage in resource exchange.

The industrial symbiosis initiated by the government is referred to as *government planning*. This dynamic occurs when the government plans for location based eco-industrial development. In this regard, strategies and actions plans are established and applied using incentives and enforcements. Typically, these measures will be observed, so it is possible to re-evaluate and change strategies as needed. The motivation resides in the government's intention to implement industrial symbiosis efforts into national and/or local policies based on principals from existing cases rather than being rooted in business opportunities. The last dynamic, *eco-clusters*, is a result of local actors such as government, businesses and interest organisations gathering with the objective to foster technological innovation as well as economic growth. Industrial symbiosis is a central strategy to reach the development goals which is a part of a broader agenda. The initiator can be both governmental and industrial actors, and the symbiotic linkage occurs between various stakeholders through participation (Boons et al., 2016).

2.2.7 Circular Economy Perspective on Industrial Symbiosis

Industrial symbiosis has gained prominence as an example of a business model in the context of circular economy practices (Baldassarre et al., 2019). Industrial ecology principles, and particularly industrial symbiosis, is viewed as an approach that can contribute to business model innovation for sustainability (Bocken et al., 2014; Short et al., 2014). According to the sustainable business model archetypes established by Bocken et al. (2014), industrial symbiosis is an example of the archetype create value from "waste", where "the concept of "waste" is eliminated by turning waste streams into useful and valuable input to other production and making better use of under-utilised capacity" (Bocken et al. 2014, p. 49). Rather than reducing waste to a minimum, this archetype aims to identify and create new value from what is perceived as waste. Industrial symbiosis is an example of how businesses can create value from what was once considered waste, aligning with the principles of circular business models.

Rounding off our perspectives on industrial symbiosis, we draw upon a descriptive framework developed by Baldassarre et al. (2019). This framework rests on three pillars of a circular business: technical innovation, collaboration and sustainable business model innovation. In the context of industrial symbiosis, the first pillar involves a technical innovation focused on facilitating the exchange of waste, resources and energy across diverse production processes (Bocken et al., 2014). The second pillar focuses on identifying the stakeholders who need to cooperate to ensure a successful implementation and operation of the industrial symbiosis (Short et al., 2014). The third pillar is about defining a precise value proposition focused on eliminating the concept of waste. This involves specifying value creation and delivery activities, establishing cross-industry partnerships to eliminate life cycle waste and formulating value capture mechanisms that transform waste into value while conserving virgin materials and energy (Bocken et al., 2014). Concluding this section, these three pillars build a bridge between the concepts of circular economy and industrial symbiosis, as well as collaboration.

2.3 Clusters

At the end of this chapter, we delve into the dynamics of clusters and co-opetition in today's competitive and innovation-driven business environment. Initially we explore the concept of clusters as geographically proximate and interconnected companies. Moreover, the section investigates the paradoxical strategy of co-opetition within clusters, where firms balance cooperative and competitive forces.

2.3.1 Definition and Characteristics

According to Porter (1998a), "Cluster theory bridges network theory and competition" (p. 242). The emergence of a cluster signifies a company's shift from operating independently to becoming part of a network of interconnected companies (Staber, 2001, referred in Fundeanu & Badele, 2014). Dyer and Singh (1998) underscore that a firm's vital resources may span beyond its boundaries, embedded in routines and processes interconnected across multiple organisations. In today's knowledge-based economy, clusters are a key driver of a country's competitiveness (Turkina & Van Assche, 2018). Furthermore, a growing body of empirical literature underscores the positive influence of clusters on regional and industry performance, including innovation, job creation, patenting and the establishment of new businesses (Delgado et al., 2014; Fundeanu & Badele, 2014).

The cluster concept can be associated to the competitive advantage theory described by Porter (1990) through the "diamond of national advantage". The effect of the local business environment on competition can be graphically illustrated in a diamond consisting of four interrelated attributes. These are (1) factor conditions, (2) demand conditions, (3) related and supporting industries and (4) firm strategy, structure and rivalry. The theory describes how these four factors "combine to produce a dynamic, stimulating and intensely competitive business environment" (Porter, 1998b, p. 90). The co-location of organisations in a cluster amplifies the pressure to innovate and thereby enhancing competitiveness and productivity.

Porter (1998a) defines the concept of clusters as: “geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (for example, universities, standards agencies, and trade associations) in particular fields that compete but also cooperate” (pp. 213-214). In this definition, two essential elements emerge: geographic proximity and interconnection (Martin & Sunley, 2003).

Firstly, clusters are geographically proximate groups of companies. Porter (1998b) underscores the significance of geographic proximity among firms and institutions, suggesting that proximity fosters improved coordination and trust. Co-location of companies can provide an environment of increased collaboration, competition and exchange of ideas, leading to improved innovation and competitive success. Furthermore, the co-location of similar and related companies can be seen as advantageous, as it can stimulate collective learning processes through frequent opportunities for formal and informal exchanges (Maskell & Malmberg, 1999). However, some studies indicate that geographical proximity is not a sufficient condition for firms to benefit from localised knowledge spillovers (Boschma, 2005). Knowledge spillovers often stem from intentional and selective network linkages rather than unplanned interactions between co-located entities (Cantwell & Mudambi, 2011).

The second key characteristic refers to the interconnection of companies, where clusters are constituted of interconnected companies linked by shared characteristics and mutual dependencies. According to Porter (1998a), most of these connections are based on social relationships or networks, yielding benefits for the involved firms by promoting trust and enhancing the flow of information (Porter, 1998b). This idea aligns with Boschma (2005), who proposes that other dimensions of proximity, such as cognitive, social, organisational, and institutional, explain the creation of inter-organisational network linkages alongside geography. These dimensions facilitate effective communication, by fostering trust-based relationships, enabling coordination and providing a favourable environment for collaboration. While physical closeness can facilitate collaboration and knowledge transfer, it is not the sole determinant of successful interactions within a cluster. A cluster’s strength should also be attributed to the multiple linkages and synergies that participating businesses benefit from, including improved efficiency and flexibility (Porter, 1998b).

2.3.2 Co-opetition

In today's complex business environment, there has been an increased interest in the paradox of co-opetition. The early work by Brandenburger and Nalebuff (1996) marked the starting point of academic research on the concept, where companies engage in collaboration and rivalry. According to the theory, companies not engaging in co-opetition may miss out on promising opportunities (Brandenburger & Nalebuff, 2021). The primary rationale behind co-opetition lies in benefits such as cost savings, skill exchange and risk mitigation. Co-opetition is portrayed as an adaptable and context-dependent strategy, requiring strategic decision-making to navigate changing surroundings. The concept focuses on how businesses can build lasting relationships by utilising each other's advantages while remaining competitive. It serves as a risk management strategy, enabling firms to diversify risks by balancing cooperation and rivalry (Brandenburger & Nalebuff, 2021).

Co-opetition raises strategic questions concerning changes in the competitive dynamics in industries caused by cooperation (Brandenburger & Nalebuff, 2021). The authors suggest four categories of strategic questions related to the competitive dynamics within industries. Firstly, when neither party has a unique competitive advantage at risk, co-opetition might result in the pooling of resources, which creates additional value. However, this scenario raises concerns about sharing the newly created value. Furthermore, a situation where both parties possess a competitive advantage may enable them to outperform common rivals. This strategic problem revolves around the risk of losing exclusivity and, thus, the value of the competitive advantages of each party. Thirdly, when one party has a solid competitive advantage, sharing it could heighten its dominant position. Even so, less powerful parties are willing to cooperate. If the cooperation is thought to give one party an unfair advantage or hinder competition, the dominant party may face regulatory reaction to anti-competitive practices. Lastly, co-opetition may lead to concerns with collective action, where one party shares its unique competitive advantage, resulting in a loss for both parties. The sharing party could be losing its competitive advantages or proprietary knowledge, potentially diminishing its position in the market, while the receiving party may become overly dependent on the other's expertise. Brandenburger and Nalebuff (2021) acknowledge that balancing rivalry and cooperation can be challenging as it requires mental flexibility. However, for organisations that develop flexibility and consider risks and rewards, co-opetition can be beneficial.

The interplay between competition and cooperation is further supported by the work of Porter (1998a; 1998b) in the context of clusters, defining clusters as companies that "compete but also cooperate" (Porter, 1998a, pp. 213-214). Rival companies compete for customers while simultaneously, collaboration occurs among companies in related industries and local institutions. The advantages of this competitive collaboration extend beyond the individual firms involved and are realised through inter-firm connections. According to Porter (1998b), clusters impact competition in three key dimensions. Firstly, by enhancing the productivity of companies through improved efficiency in sourcing inputs, accessing information, technology and institutions, coordinating with related companies and measuring improvement. Secondly, they act as catalysts for innovation by offering better market insights, facilitating early learning about technology trends, enabling rapid experimentation with local partners and creating a competitive environment that drives innovation. Lastly, they foster the establishment of new businesses, contributing to the overall expansion and robustness of the cluster. This environment enables each cluster member to benefit from the advantages of scale without compromising their inherent flexibility (Porter, 1998b).

Further research has found benefits of co-opetition in relation to innovation as a source of competitive advantage (Corbo et al., 2023). Innovation is generally recognised as a key source of competitive advantage, as it relies on developing and integrating new information (Bouncken et al., 2018b, referred in Corbo et al., 2023). However, businesses may lack the resources or capabilities to pursue innovation successfully. This can be solved by sourcing the necessary knowledge to innovate from outside the firm through various collaborative efforts, such as clusters (Xu et al., 2023). Such collaborations often occur between competing firms by balancing cooperative and competitive forces. Thus, co-opetition strategies are more encouraging to innovation than just cooperative or competitive strategies (Corbo et al., 2023). Co-opetition facilitates knowledge exchange, enables joint development of technologies, and offers the sharing of risks and costs connected to innovation (Ritala et al., 2016, referred in Corbo et al., 2023). Evidence against this suggests that co-opetition may cause knowledge leaks that could limit or prevent each partner's potential to innovate (Rouyre & Fernandez, 2019). To avoid unintended knowledge spillovers and define knowledge-sharing boundaries, companies can rely on formal (i.e. intellectual property rights, licensing or patenting) and informal (i.e. trust, relational or individual capabilities) mechanisms when engaging in innovation-related co-opetition.

2.4 Summary of Theory

This chapter has presented the theoretical foundation of the study, focusing on the concepts of circular economy, industrial symbiosis, and clusters. The study adopts the Ellen MacArthur Foundation's (2013) definition of the circular economy, which suggests that it is a restorative or regenerative industrial system that aims to eliminate waste through superior design and business models. The core principle of the circular economy is shifting from a linear economy to circular value chains through a cradle-to-cradle resource flow (McDonough & Braungart, 2002). We further introduced the concept of sustainable business models, as suggested by Schaltegger et al. (2016), with circular business models being a subtype (Baldassarre et al., 2019). Bocken et al. (2016) present three strategies for circular business models: slowing, closing, and narrowing resource loops. Industrial symbiosis can be perceived from two perspectives: circular economy or industrial ecology (Baldassarre et al., 2019), and we have adopted the former in the study. Thus, industrial symbiosis is considered a circular business model strategy for closing resource loops (Bocken et al., 2016) by creating value from "waste" (Bocken et al., 2014). Industrial symbiosis involves "traditionally separate entities" collectively seeking competitive advantage through the physical exchange of resources (Chertow, 2000, p. 314). Chertow (2007) further introduce the "3-2 heuristic", which offers guidance for industrial symbiosis. Domenech Aparisi (2010) suggests that industrial symbiosis can yield economic, environmental and social benefits, while Teh et al. (2014) and Yang et al. (2022b) have contributed with an understanding of the drivers that encourage involvement in industrial symbiosis and barriers that could hinder its implementation. Moreover, the framework proposed by Boons et al. (2016) has been incorporated to provide an understanding of the facilitation dynamics of industrial symbiosis. Finally, the study adopts Porter's (1998a) cluster definition, where clusters are geographically concentrated, interconnected firms that compete and cooperate. The concept of co-opetition was introduced by Brandenburger and Nalebuff (1996) and supported by Porter (1998a; 1998b) in a cluster context. It refers to a paradoxical strategy where firms collaborate and compete. Co-opetition can lead to benefits such as cost savings, skill exchange, and risk mitigation (Brandenburger & Nalebuff, 2021) and can facilitate innovation (Corbo et al., 2023). However, it also raises strategic questions about the risk of losing competitive advantages (Brandenburger & Nalebuff, 2021) and the possibility of knowledge leaks (Rouyre & Fernandez, 2019).

3. Green Transitioning in the Maritime Sector

The chapter serves as a literature review to map current initiatives related to the circular economy, industrial symbiosis and cluster cooperation within the maritime sector. Initially, we explore the sector's efforts towards a circular economy, including drivers and barriers for circularity. Moreover, we look at how industrial symbiosis unfolds in the maritime sector, and lastly, how cooperation matters for green transitioning in maritime clusters. The concepts presented in Chapter 2 are contextualised to the maritime sector through literature and practical examples. This demonstrates these concepts' relevance and applicability within the maritime context.

3.1 Circular Economy in the Maritime Sector

The maritime sector is facing increasing sustainability pressures, and in response to policy demands, the sector has committed to ambitious emission reduction targets (IMO, 2023). However, within the maritime sector, understanding of the circular economy concept is often limited, with a tendency to focus solely on the recycling stage (Okumus et al., 2023b). For example, while ship recycling is widespread in the maritime sector, current practices in recycling yards often hinder the sector's potential. As recycling represents the lowest level in the circular economy's end-of-life hierarchy (Ellen MacArthur Foundation, 2013), it often leads to diminished quality and shortened usable life cycles. Remanufacturing is, in contrast, often referred to as the ultimate form of recycling (Okumus et al., 2023a), contributing to all three dimensions of sustainability (Jørgensen & Pedersen, 2018). While in recycling processes, large amounts of energy and labour are lost (Ellen MacArthur Foundation, 2013), remanufacturing conserves materials and energy, thereby reducing waste production (Karvonen et al., 2015). The recycling stage can be postponed by implementing reuse and remanufacturing practices, thereby extending the lifespan of equipment or assets. This contributes to energy conservation, resource efficiency, and reduced costs and emissions (Okumus et al., 2023a). However, implementing circular economy principles, such as reuse and remanufacturing, is far behind, and low utilisation of such practices might result from the identified barriers presented in subsection 3.1.2.

3.1.1 Drivers Fostering Circular Economy in the Maritime Sector

Adopting circular economy principles in the maritime sector has the potential to transform the linear resource management model, benefiting the environment, economy and stakeholders (Barona et al., 2023). A study by Barona et al. (2023) identifies six central drivers for adopting circular economy approaches in maritime ports, and we propose that these insights could be transferable for fostering circularity practices in the broader maritime sector (Kvamstad-Lervold et al., 2019). Firstly, establishing a *circular economy action plan and environmental plan* can enhance the attractiveness to consumers by informing their customers about environmental efforts. Maritime actors should set a circular vision and root it in the environmental plan. Secondly, deciding on *circular business models to implement for business sustainability* is a significant driver. Innovative circular business models can help maritime actors meet changing customer demands and expectations and reduce CO_2 emissions, thus maintaining competitiveness. With innovation and a shift towards more circular business models, they can avoid being outperformed by competitors who are better positioned to meet customer needs. The third driver is the application of *disruptive technology*. Technological innovations, including digital, physical, and biological technologies, can enable the implementation of circular business models and assist in closing the material loops. Furthermore, *incentive mechanisms* provided by governments and authorities can help achieve environmental priorities by motivating stakeholders towards more sustainable practices such as decarbonisation, air quality improvements and pollution reduction. The fifth driver is enhancing *partnership and collaboration.* Collaborative efforts can significantly contribute to creating effective circular models and policies. Government alliances, supported by stakeholders willing to collaborate, share knowledge and advocate for a global transition to a circular economy, are of great importance. Lastly, *measurement tools* that support the transition to a circular economy should be implemented to assess environmental and circular economic impacts. Utilising globally recognised sustainability tools like Life Cycle Analysis (LCA), Circulytics, and Circular Transition Indicators (CTI) can support the transition to circular business models across various operations (Barona et al., 2023).

3.1.2 Barriers to Circular Economy in the Maritime Sector

The maritime sector falls behind in adopting circular economy approaches (Okumus et al., 2023b) and there is a need to close resource loops to minimise waste and enhance revenue streams. Okumus et al. (2023a) identify five main barriers to implementing circular economy practices in the maritime sector. Firstly, there is a *low level of awareness* and understanding of the circular economy concept, with a lack of technical expertise hindering the effective implementation of circular practices. Awareness of the circular economy is considered vital to fostering stakeholder interest, strengthening company culture around environmental ethics and mobilising necessary resources for circular initiatives (Okumus et al., 2023a; Barona et al., 2023). Secondly, *regulatory and certification barriers* pose significant obstacles (Okumus et al., 2023a). The maritime sector is heavily regulated, and current regulations and certification procedures often do not favour remanufactured or reused items (Milios, 2019). Moreover, the *long lifespan of maritime vessels* complicates the transition to a circular model. A unique aspect of the maritime sector is that the lifespan of the vessels, where the average economic lifetime of 30 years, is longer compared to other transport modes (Okumus et al., 2023a). Vessels frequently outlast the regulations they were initially designed to adhere to, which can result in components becoming outdated or failing to meet current standards. This issue is further compounded by *geographical barriers and asset tracking issues*, given that production and demolition sites are often vastly separated, and the reverse supply chain is insufficiently developed to uphold circular principles. Additionally, tracking assets, which involves monitoring and managing the various components, equipment and materials onboard vessels throughout their lifecycle, is complicated due to the industry's lack of standardisation, diverse materials and long lifespan of vessels (Okumus et al., 2023a; Milos, 2019). Moreover, the extensive supply chain complicates recycling efforts and communication. Lastly, *perception and industry acceptance* of circular practices are significant barriers. Industry actors may show concern about the reliability and performance of remanufactured or reused items. These challenges highlight the complexity of implementing circularity in the maritime sector and underscore the need for collective efforts to overcome barriers and transition towards more sustainable practices (Okumus et al., 2023a).

3.2 Industrial Symbiosis in the Maritime Sector

Industrial symbiosis will emerge more frequently when organisations and governments see the full economic and environmental benefits of circular economy approaches in the sector (Barona et al., 2023). Although examples of industrial symbiosis are emerging more often (Ceylani et al., 2022), it can also indicate that industrial symbiosis is not yet widely prevalent.

Moreover, Castellet-Viciano et al. (2022) substantiate this by highlighting that substantial progress is still required before industrial symbiosis becomes a widespread practice. Given our literature search in this specific context, we find it reasonable to assume that this also applies to the maritime sector.

3.2.1 Examples of Industrial Symbiosis Rooted in the Maritime Sector

As the full prevalence of industrial symbiosis is not yet achieved, Ceylani et al. (2022) highlight that there is minimal literature on symbiosis concerning ships. This may be explained by the barriers mentioned in subsection 3.1.2. However, symbiosis involving ports are more common in the maritime sector. Following this, a study on international ports and the contribution to industrial ecology development by Cerceau et al. (2014) find that ports can impact the surrounding environment negatively and positively, and the most prominent challenge in seaports is waste management (Cerceau et al., 2014). To integrate improved waste management, it is necessary with new forms of collaboration between stakeholders. Cooperation between ports and port firms should be considered as a requirement for industrial symbiosis despite the competitive environment between ports (van Klink, 1998, referred in Cerceau et al., 2014). For port cities, it is important to reduce the pressure on local environment and society, and implementation of industrial symbiosis as a new collaboration form can be a way to mitigate this pressure. Barona et al. (2023) present several examples of industrial symbioses in Europe, where the most relevant examples in the context of the maritime sector are the examples including ports. Therefore, the ports of Rotterdam and Amsterdam are highlighted as examples of industrial symbiosis initiatives. The port of Rotterdam takes waste heat from nearby industries to heat private accommodation and other buildings, while the port of Amsterdam uses residual heat from plants to keep greenhouses warm. These are examples where ports are located in industrial areas and create benefits for entities nearby by implementing industrial symbiosis efforts (Barona et al., 2023).

Moreover, other examples of industrial symbiosis initiatives in the maritime sector relates to activities on ships and in fish-farming facilities. Firstly, an example is through using waste generated on ships. Such waste can be collected in ports, implying that other maritime actors can partake in symbiosis at ports (Ceylani et al., 2022). This is rooted in the sustainable business model archetype described by Bocken et al. (2014), create value from "waste". However, in this case, it is difficult to identify what type of waste that can be utilised, and for whom participation in such symbiosis initiatives will be valuable for. Another challenge is that symbioses require a consistent supply of materials, while for instance, in maritime transportation waste may be delivered more sporadic and at intervals. Nevertheless, industrial symbiosis is anticipated to drive the green transition in ports worldwide (Ceylani et al., 2022). Our broad definition of the maritime sector (Kvamstad-Lervold et al., 2019), allows for additional examples of how industrial symbiosis unfolds from a maritime perspective, for instance in the context of aquaculture. Looking at an example from Norway related to fish farming, by-products from seafood production can be repurposed for various uses, such as animal feed, cultivation of feed ingredients, and gas production. Another type of waste, fish sludge, may be used in biogas production and in the recovery of phosphorous and nitrogen from sludge (NORCE Klima og miljø, 2023). In the extension of this, Martin and Carlsson (2018) exemplifies this with how Renahav, a Swedish production company, uses fish sludge as an input in their production of biogas. NORCE Klima og miljø (2023) also convey that fish sludge from salmon farming can be used as input in the production of fertiliser and bio charcoal.

3.3 Maritime Clusters

While there does not appear to be an academic consensus on the definition of a “maritime cluster”, two commonly accepted criteria are typically considered: industrial relevance and proximity (Yang et al., 2022a). Industrial relevance suggests that maritime clusters include interconnected units, such as firms, institutes and organisations specialising in maritime-related activities, while proximity requires that these components are narrowed to a specific region: regional, national or global. We adopt the definition by Doloreux (2017, p. 216): “Maritime clusters are defined based on the geographical concentration of maritime industries within a regional community and the presence of a network of firms and institutions that support the development of the industry”. According to Zhang and Lam (2017), maritime clusters encompass various linked industries in the maritime sector, highlighting that the essence of a maritime cluster lies in the interconnection among a diverse range of industries, which is crucial for the cluster to achieve competitiveness and sustainability. Moreover, maritime clusters play an important role in fostering the growth of national or regional economies, offering support for innovation and technological advancements (Doloreux, 2017).

As a result, maritime cluster policy initiatives and programmes have expanded across various contexts.

3.3.1 Green Transitioning in Maritime Clusters

The ongoing evolution of maritime clusters presents promising opportunities for green transitioning (Liao et al., 2021), and industrial symbiosis theory has been used to describe the relationship between maritime actors (Zhang & Lam, 2017; Liao et al., 2021). Like clusters in other industries, maritime clusters typically demonstrate resource aggregation and sharing, fostering stronger inter-industry relationships within the cluster (Liao et al., 2021). Ports are critical components of maritime clusters, closely linked with various maritime activities. Liao et al. (2021) found that the level of corporate cooperation, open market, and supporting policies can influence the symbiotic relationship between ports and other industries within a maritime cluster. Furthermore, Liao et al. (2021) emphasise that industrial interaction and support from local institutions are needed for upgrading clusters. This collaborative strategy could potentially provide a solution to the challenges posed by resource scarcity, thereby accelerating the green transition within maritime clusters.

In the context of fostering circularity, Dahl et al. (2018) underscore the importance of developing a robust culture of collaboration among cluster members. Such a culture can facilitate project implementations by lowering the barrier to creating collective solutions to challenges and assisting industry actors to adapt to a circular economic mindset. Thus, fostering increased interaction and cooperation among cluster members should be prioritised, as this lays the foundation for the implementation of circular and sustainable practises. However, some researchers argue that inter-industry interaction within maritime clusters is often limited (Liao et al., 2021). For instance, a study of the Irish Maritime and Energy Resource Cluster revealed weak inter-industry relations despite sharing several related inputs and outputs (Morrissey & Cummins, 2016, referred in Liao et al., 2021). Similarly, Pardali et al. (2016, referred in Liao et al., 2021) found a limited overlap between shipping and port-related activities in Piraeus' (Greece) maritime activities, resulting in loosely defined and unstable sectoral relationships.

3.4 Summary of Theory

This chapter has built upon Chapter 2 by reviewing the concepts of circular economy, industrial symbiosis, and clusters within a maritime context. It has offered a literature review that underscores the relevance and applicability of these concepts to the maritime sector and the associated challenges, including practical examples that demonstrate the potential for green transitioning within the maritime sector. In the context of the circular economy, the maritime sector's sustainability pressures, the limited understanding of the circular economy concept, and the tendency to focus on the recycling stage were highlighted (IMO, 2023; Okumus et al., 2023b). The superior sustainability benefits of remanufacturing over recycling were emphasised (Okumus et al., 2023a; Ellen MacArthur Foundation). However, it was also acknowledged that the maritime sector falls behind in implementing these circular economy practices, possibly due to barriers identified by Okumus et al. (2023a). Barona et al. (2023) present drivers that could promote circular economic approaches in maritime activities. The section on industrial symbiosis within the maritime context examined the emergence of symbiotic practises in the sector (Barona et al., 2023; Ceylani et al., 2022) and its limited prevalence (Castellet-Viciano et al., 2022). Examples of industrial symbiosis initiatives in the maritime sector include those involving ports (Cerceau et al., 2014; Barona et al., 2023), potential waste utilisation from ships (Ceylani et al., 2022), and practices from the aquaculture industry (NORCE Klima og miljø, 2023; Martin & Carlsson, 2018). Finally, the chapter presented the definition of a maritime cluster (Doloreux, 2017). Liao et al. (2021) emphasise the need for a robust collaborative strategy through industrial interaction and support from local institutions to accelerate the green transition, which may assist the industry actors in adapting to a circular mindset (Dahl et al., 2018). The section also pointed out the limitations of inter-industry interaction within maritime clusters, which may result in unstable sectoral relations (Liao et al., 2021).

4. Methodology

This chapter presents the research design for the thesis. The textbook, Research Methods for Business Students by Saunders et al. (2019), will be the primary literature grounding our methodological choices, supplemented by other literature. Initially, we introduce our research approach, purpose and method, followed by an explanation of the chosen research strategy and a presentation of the cases, Grøn Region Vestland and Symbiose Fjordane. Following this, we present a description of the data collection and data analysis, and lastly, follows a section discussing the data quality. At the end of the chapter, we address the ethical considerations in the thesis.

4.1 Research Approach

An inductive research approach is particularly suitable for exploring industrial symbiosis within the context of the Norwegian maritime sector as we seek to provide new insights into the existing literature on a concept with limited research. Inductive research aims to generate new insights and elaborate on theoretical perspectives present in existing literature, without relying on a predetermined theoretical position. However, it allows using existing theory to formulate the research question and identify concepts to explore during the research process (Saunders et al., 2019). In alignment with the inductive approach, our work was initiated by a thorough familiarisation of theory related to circular economy, industrial symbiosis, and clusters, all of which were investigated as individually important components of the research question. An inductive approach allows meanings to emerge from data as they are collected to identify patterns and relationships that can be used to construct new theory or contribute to existing one (Saunders et al., 2019). We collected data through interviews, using an interview guide including questions designed to understand each participant's knowledge of and involvement in industrial symbiosis practices, with an emphasis on gaining insights into their unique perspectives. For example, we asked participants about their experiences with collaboration and competition within clusters, their perceptions of the drivers and barriers to implementing industrial symbiosis and their suggestions for promoting the green transition in the maritime sector. This data was subsequently used to identify key themes and patterns. We identified common themes across participants' responses and coded them to create structures to answer the research question. We constructed a conceptual framework from these insights to classify and comprehend the data (Saunders et al., 2019). According to Saunders et al.

(2019), the inductive approach is particularly suited to case studies, where a small selection of participants is investigated, allowing for a detailed exploration of the specific context of the studied subjects. In contrast, the deductive approach is often limited by a highly structured research design. By choosing the less structured inductive approach, it allowed for flexibility and alternative explanations, enabling us to gain a deep understanding of the dynamics of industrial symbiosis within clusters. The inductive approach is often used in qualitative research, where the focus is on understanding the individuals' unique feelings, perspectives, and experiences (Saunders et al., 2019).

4.2 Research Purpose

The exploratory purpose is chosen due to its dynamic and investigative nature (Saunders et al., 2019), aligning with our inductive approach by allowing contributions from participants to impact the course of our research. Exploratory studies are flexible and adaptable to unforeseen changes during the research process. While they may commence with a broad focus, the scope of the study may become narrower as the research progresses (Saunders et al., 2019). This is beneficial due to the iterative process when conducting case study research (Yin, 2014), enabling us to respond and adapt to new insights from data. The exploratory purpose is further appropriate for the study as it allows us to better understand the practices, challenges, and opportunities associated with industrial symbiosis. We used open-ended questions to be able to generate insights into the research question. Our research question, formulated with the interrogative word "how", reflects this exploratory purpose. A common method for conducting exploratory research is through expert interviews (Saunders et al., 2019), where the researcher needs to rely on the quality of the participants' contributions. Such interviews are likely to be somewhat unstructured due to their exploratory nature, which is why we have collected data through semi-structured interviews (refer to subsection 4.6.2).

4.3 Research Method

Given the exploratory purpose of the study, a qualitative research method is considered appropriate due to its flexibility and ability to generate rich and detailed data on complex phenomena. Qualitative research is characterised by its focus on analysing and understanding the depth of human behaviour and the relationships among individuals. This method is often associated with an interpretive philosophy, which requires researchers to interpret the subjective and socially constructed meanings of the phenomena under study. Qualitative research design collects non-numeric data, such as data gathered through interviews or observations. This contrasts with a quantitative research design, which involves collecting and analysing numeric data (Saunders et al., 2019). Qualitative data, given by words and opinions, as opposed to quantitative data, can hold several interpretations and tends to be more unclear (Saunders et al., 2019). In our research, we were aware of the potential for multiple interpretations inherent in qualitative data. To navigate this concern, we adopted a mono-method qualitative study approach, utilising a single data collection technique – semi-structured interviews. This method allowed us to explore the nuances of the participants' words to avoid potential misunderstandings. For example, when participants discussed barriers to implement industrial symbiosis, we used the advantage of semi-structured interviews to ask clarifying questions. This could assure us that our understanding of the challenges and how they impacted the organisation was accurate. Given our time and resource constraints, we could explore deeper into the participants' perspectives by focusing on a single qualitative method, enhancing the richness and depth of our findings.

4.4 Research Strategy

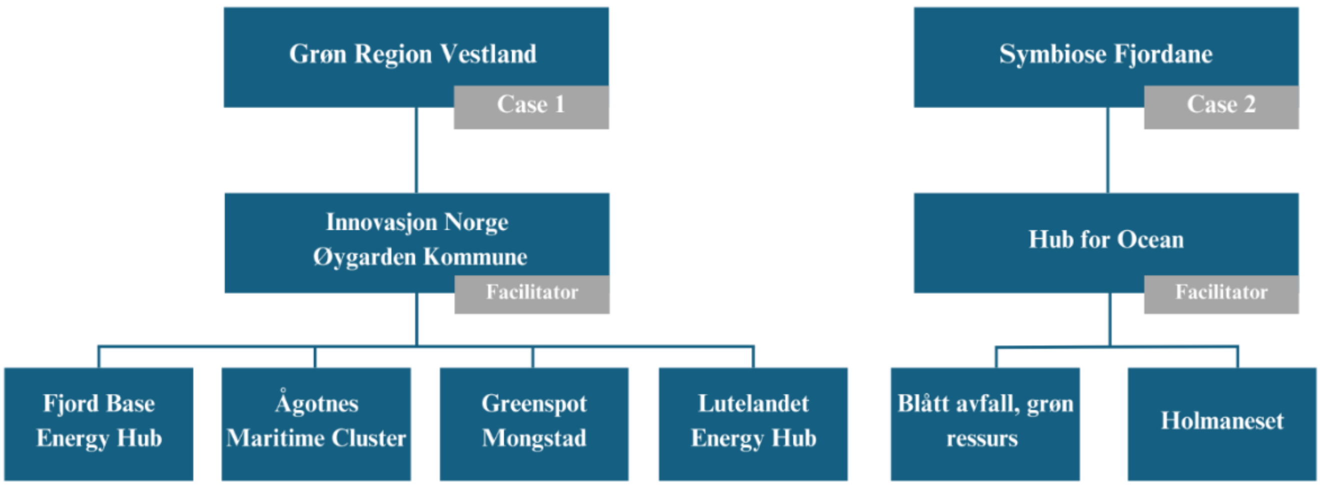
The research strategy is the plan to correctly answer the research question (Saunders et al., 2019). Case study research is a well-suited strategy to an inductive approach because it allows for an in-depth investigation of a situation (Saunders et al., 2019). Moreover, given that our research is exploratory, Yin (2014) illustrates that several strategies can be applied. To find the most appropriate strategy, a reasonable starting point is to evaluate the type of research question (Yin, 2014). Our research question is a "how" question, thus narrowing down potential strategies. "How" and "why" questions are connected to methods like "experiments", "history", and "case study" (Yin, 2014, p. 9). We have chosen a case study because it focuses on contemporary events (Yin, 2014), unlike the method of history. This aligns with our emphasis on the green transition, hereunder industrial symbiosis. Based on the above, conducting experiments could also serve as a potential strategy, but we did not consider this due to the requirement of control of behavioural events (Yin, 2014). A case study is also one of the most common techniques for gathering qualitative data (Saunders et al., 2019). Eisenhardt (1989) adds that a case study is considered appropriate when existing literature is deemed insufficient, which further supports our choice, pursuant to the identified research gap (refer to section 1.3). Yin (2014, p. 16) presents a definition of a case study: “A case study is an empirical inquiry that investigates a contemporary phenomenon (the “case”) in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident”. Yin (2014) explains that the aim is to study real-world cases, and understanding such cases may involve important contextual conditions such as geography, regulatory environment, and culture. We, therefore, aim to explore these cases in depth within their specific real-world context. The case study strategy aligns with our qualitative research methodology, allowing for data collection through semi-structured interviews, enabling us to capture the perspectives of various stakeholders engaging in maritime activities.

Multiple-case studies may be preferred over single-case studies (Yin, 2014; Meyer, 2001) as the latter can be viewed as vulnerable due to its uniqueness (Yin, 2014). Moreover, the findings from multiple-case designs are often considered more persuasive. Single-case studies can be useful if the researcher studies a highly unusual, extreme or critical case. However, this is different from the context of this study. On the other hand, multiple-case studies require more resources and time, which can be difficult to allocate properly (Yin, 2014). To overcome this challenge, given the time constraints of our study, we have conducted a cross-sectional study, thus a one-time data collection (Saunders et al., 2019) using mono-method data collection. By adhering to these choices, we conducted an embedded multiple-case study. Selecting the cases for a multiple-case study can be done using two options. This is known as the replication logic. A case should either predict similar results or contrasting outcomes that were expected (Yin, 2014). The former is known as literal replication, and the latter is called theoretical replication. In this study, the replication logic leans towards a literal replication. Considering our inductive approach with the aim to identify patterns, it was not reasonable to select cases that knowingly led to entirely different patterns, per Yin (2014). The rationale behind this anticipation was that the cases shared similar objectives concerning their industrial symbiosis initiatives.

4.5 Case Description

This embedded multiple-case study (Yin, 2014) explores the cases, Grøn Region Vestland and Symbiose Fjordane. By choosing two cases, we have applied a multiple-case approach while still being capable of exploring the cases in-depth by keeping the number of cases low (Yin, 2014; Meyer, 2001). Furthermore, the two cases were selected using a literal replication logic (Yin, 2014), explained by the facilitating projects' (cases) aim to promote industrial symbiosis in Western Norway, particularly within the maritime sector. These cases allow for a thorough examination (Saunders et al., 2019) of the facilitating organisations and the selected clusters with the potential for industrial symbioses. This aligns with an embedded case study because we can examine sub-units (Yin, 2014) within each of the cases, respectively the facilitating organisations and the clusters. In Figure 1, we have illustrated an overview of the cases. The structure is based on our understanding and was developed to create an overview of the participating organisations and clusters. However, we note that it is not an official organisational chart. In this section we will present the two cases and introduce each cluster under their respective facilitating project in order to ensure an understanding of the study's participants.

Figure 1 - Case Overview



4.5.1 Grøn Region Vestland

Grøn Region Vestland is a collaborative project between Innovation Norway and Vestland Fylkeskommune, intending to support the green transition in Western Norway. With an emphasis on industrial symbiosis, the initiative has identified more than 300 green innovation projects and 19 hubs with a particular potential for green industrial development and industrial symbiosis (Grøn Region Vestland, 2024). Grøn Region Vestland has defined four strategic goals: (1) Build world-leading green hubs through industrial symbiosis, (2) Undertake the position as the globally leading sea region, (3) Build innovative infrastructure, (4) Increase the pace through prioritisation and collaboration initiatives. The project emphasises SDG 17, “Partnerships for the goals”, as the green transition requires a collective effort, leveraging shared knowledge and resources, to position Western Norway as a leader in the green maritime sector (Sjursen & Helsengren, 2021).

4.5.1.1 Fjord Base Energy Hub

The Fjord Base in Florø, Norway’s largest supply base for offshore operations, aims to become a leader in offshore wind, maritime industry and aquaculture. Key actors include Fjord Base Group, HyFuel, Havlandet, Cargill, Slakteriet, Westcon, Aksello and Hub for Ocean. Major opportunities have been identified to create synergies, especially those connected to oxygen and energy. Key projects include HyFuel’s green hydrogen production for shipping, the construction of world’s first ship ammonia bunkering facility, land-based farming, including a fish farm slaughterhouse and offshore wind turbine assembly (Grøn Region Vestland, n.d.a).

4.5.1.2 Ågotnes Maritime Cluster

The Coast Center Base (CCB), located at Ågotnes, is a cluster of established companies providing services mainly to the petroleum industry and maritime sectors. Key actors include CCB, Bergen Havn, Equinor, Sotra Gruppen, TechnipFMC and Aker Solutions. The base centres around the maintenance of rigs, vessels and subsea equipment and offers storage, logistics and port services. Key projects include relocating Bergen Port to Ågotnes in 2027, with plans to establish one of the first emission-free ports in Europe. The cluster is also exploring local energy solutions like fjord-based heating and projects related to offshore wind and green shipping (Grøn Region Vestland, n.d.b).

4.5.1.3 Greenspot Mongstad

Greenspot Mongstad is a public-private project collaboration to create new, green value chains in the Mongstad industrial area. Key actors include Greenspot Mongstad, Asset Buyout Partners (ABP) and Equinor. The area hosts Equinor's refinery, an NGL processing plant, a crude oil terminal and the world's largest technology centre for CO_2 capture. Some potential projects include land-based fish farming and hydrogen production. Moreover, the waste from the potential land-based fish farming facilities can be used in their production of biogas (Grøn Region Vestland, n.d.c).

5.4.1.4 Lutelandet Energy Hub

Lutelandet Energy Hub, located at Lutelandet, aspires to take a leading position within new green value chains. Key projects include Htwo-Fuel's planned green hydrogen and ammonia facility for maritime transport and Bue Salmon's land-based fish farm, a facility that has the potential to utilise by-products like waste heat and oxygen from hydrogen production. Thus, key actors are Greenstat, Lutelandet Offshore, Blastr Green Steel and Bue Salmon (Grøn Region Vestland, n.d.d).

4.5.2 Symbiose Fjordane

Symbiose Fjordane is an innovative project facilitated by Hub for Ocean that aims to drive economic growth, innovation, job creation and develop a new green industry in Western Norway. Through the Symbiose Fjordane project, Hub for Ocean, in collaboration with member companies, other key industry actors, and partners in the public sector and research/university institutions, aims to establish robust partnerships and networks for developing industrial symbioses. Symbiose Fjordane is a regional co-creation platform where businesses meet in a dynamic ecosystem to share knowledge and resources, fostering new value chains for handling organic waste (Hub for Ocean, n.d.a).

4.5.2.1 Blått avfall, grøn ressurs

The collaborative initiative, Blått avfall, grøn ressurs, represents a step towards sustainable and circular use of resources in the aquaculture industry, turning "blue waste" into a "green resource". The initiative targets the creation of circular value chains for handling organic waste from the aquaculture industry. Managing fish sludge and other waste from fish farming is energy-intensive and involves transportation over long distances. Fish sludge and other waste contain phosphorus. Phosphorus is a limited resource globally that is crucial for all food production and supply security. As such, it is a resource that needs to be reused and recycled. This waste is also a good source of nitrogen, which can be used in agriculture (Hub for Ocean, n.d.b).

4.5.2.2 Holmaneset

The Holmaneset project, led by Fortescue, aims to pioneer Europe's green hydrogen and green ammonia production, building on Norway's hydropower resources, a skilled workforce and proximity to the European market. The project will use renewable energy to power a green hydrogen and ammonia process plant, with transmission infrastructure and port facilities for transporting green products to Norwegian and European markets. The production of green hydrogen and ammonia creates by-products, such as oxygen, heat, and water, which the project aims to recover and reuse in circular business development (Fortescue, n.d.). While Holmaneset is not presently a part of the Symbiose Fjordane initiative, it is recognised as a relevant future actor, according to a representative from the project. This is because Holmaneset has been identified as a significant entity that could contribute to regional synergies through the Hub for Ocean network.

4.5.3 Rationale for Case Selection and Research Strategy

This section has underpinned why we have chosen to explore these exact cases, considering our choice of research strategy. We have selected two similar cases, thus not choosing cases with substantially different contextual factors (Saunders et al., 2019). Furthermore, we have chosen to interview both facilitating organisations and cluster members in order to bring forth different perspectives on discussing the green transition, the circular economy, and industrial symbiosis in the context of Norwegian maritime clusters. Finally, Saunders et al. (2019) highlight that one feasible strategy for students is to examine two or three cases with the goal of literal replication, thus supporting the choices and overall procedure in our research strategy.

4.6 Data Collection

This section provides an explanation of the data collection. Firstly, we present our participant selection process, emphasising how participants were identified and selected. Subsequently, we describe our decision to conduct semi-structured interviews, followed by a presentation of the development of the interview guide. Lastly, we elaborate on the process of carrying out the interviews.

4.6.1 Participant Selection

To explore how industrial symbiosis affects the green transition in Norwegian maritime clusters, our population consists of companies involved in maritime activities practising industrial symbiosis within their cluster, to at least some extent. We were aware that the population was initially limited as industrial symbiosis is not yet a widespread concept (Castellet-Viciano et al., 2022). Therefore, we opted for non-probabilistic sampling, where the relationship between the selection technique and research design is essential (Saunders et al., 2019). Following the recommendations of Saunders et al. (2019), we conducted semi-structured interviews with a selection of 15 participants, exceeding the minimum suggested sample size of five. We opted for a purposive sampling technique, suitable for conducting a case study to select particularly informative cases (Saunders et al., 2019). Purposive samples are not considered statistically representative, however as qualitative research aims for in-depth understanding rather than generalisation (Saunders et al., 2019), our participant selection emphasised relevance and diversity over representativeness. Our purposive sample depended on the research question, and the cases were selected based on their involvement in industrial symbiosis. Thus, we targeted Grøn Region Vestland and Symbiose Fjordane, known for their efforts in promoting industrial symbiosis. This aligns with a homogeneous sampling technique focusing on a particular subgroup where the characteristics of the selected participants are similar (Saunders et al., 2019). Therefore, the participants were chosen based on specific shared characteristics in terms of their involvement in industrial symbiosis within maritime activities and geographic location in Western Norway. While the sample is considered homogeneous regarding their involvement in industrial symbiosis within the Norwegian maritime sector, the clusters within the selection had varied levels of experience concerning industrial symbiosis. This selection ensured that we captured a broad perspective from different stages of industrial symbiosis and the role this may play in the green transition. Moreover, it was crucial to identify employees within each cluster who were knowledgeable about industrial symbiosis, and we aimed to interview participants who were directly involved in these activities while also having management responsibilities. The participants either belonged to a facilitating organisation, the administration of the cluster or a company within the cluster. Our participant selection is illustrated in Table 1, presented in no particular order.

Table 1 - Participant Selection

Overview of the selection of participants, detailing their anonymous labels and gender.

Participant description	Description in text	Gender
Participant from Facilitating organisation 1	Facilitator 1	Female
Participant from Facilitating organisation 2	Facilitator 2	Female
Participant from Facilitating organisation 3	Facilitator 3	Male
Participant from Facilitating organisation 3	Facilitator 4	Female
Participant from Cluster 1	Manager 1 (C1)	Male
Participant from Cluster 2	Manager 2 (C2)	Female
Participant from Cluster 2	Manager 3 (C2)	Male
Participant from Cluster 2	Manager 4 (C2)	Male
Participant from Cluster 2	Manager 5 (C2)	Female
Participant from Cluster 3	Manager 6 (C3)	Male
Participant from Cluster 4	Manager 7 (C4)	Male
Participant from Cluster 5	Manager 8 (C5)	Male
Participant from Cluster 5	Manager 9 (C5)	Male
Participant from Cluster 6	Manager 10 (C6)	Male
Participant from Cluster 6	Manager 11 (C6)	Female

Note. In line with guidelines from the Norwegian Agency for Shared Services in Education and Research (Sikt), we assigned labels to each participant. This ensured personal anonymity while allowing us to differentiate between the participants.

4.6.2 Semi-Structured Interviews

As described by Saunders et al. (2019), a research interview is a purposeful conversation that requires the interviewer to ask concise and unambiguous questions and listen attentively to the responses in order to explore them further. Following our qualitative research methodology, we utilised semi-structured interviews, allowing flexibility by asking open-ended questions. Due to this, we could explore and clarify the responses that emerged during the interviews, providing a deeper understanding of the participants' perspectives and the reasoning behind them. Furthermore, while we planned central themes and questions for each interview, this format enabled us to adapt the content or sequence of questions based on the unique flow of each conversation. This aligns with our inductive approach, allowing the contributions from the participants to shape our research process (Saunders et al., 2019). Given the complex nature of industrial symbiosis, this was a suitable method. For example, during the interviews, we experienced that the participants frequently highlighted the role of collaboration in industrial symbiosis. As a result, we adjusted our interview guide to include more questions about this topic.

4.6.3 Interview Guide

In preparation for the semi-structured interviews, we developed an interview guide (refer to Appendix A) following the principles outlined by Saunders et al. (2019). This guide served as a tool to help participants understand the objectives of the research and the questions they would be asked. The interviews were tailored to the organisation of the participants. Therefore, certain questions were adapted based on which organisation the participant belonged to. The guide was sent to the participants before the interviews, allowing them to prepare in advance. Creating the interview guide required careful consideration of time management. Saunders et al. (2019) emphasise the importance of considering the time required to conduct an interview. Balancing the need for comprehensive data collection with respect for the participants' time was a challenge. Our solution was an interview guide with 20 questions distributed across the four research objectives. In alignment with the exploratory purpose, the interview guide aimed to formulate open-ended questions, which could be supplemented with probing questions during the interview. Such questions encouraged participants to respond freely, providing detailed and expansive responses. For instance, after asking an open-ended question like: "Can you describe your organisation's involvement in industrial symbiosis?" we used probing questions such as: "Can you give an example of a specific project or initiative?". Moreover, this enabled us to avoid leading questions, reducing the chance that the phrasing influenced their responses (Saunders et al., 2019). For example, instead of asking: "Don't you think industrial symbiosis is crucial for the green transition?" we asked: "What do you think are the most important measures your organisation needs to implement to succeed in the green transition?”.

4.6.4 Interview Conduction

The interviews were scheduled according to the availability of the participants and conducted online. Online interviews enabled us to record and transcribe automatically, ensuring our full attention to the conversation. Conducting semi-structured interviews on a digital platform can offer practical advantages associated with flexibility and access (Saunders et al., 2019). However, certain implications need to be considered. In qualitative research, establishing personal contact and trust is vital to ensure the participants are comfortable sharing their thoughts and ideas. According to Benjamin and Komlos (2021), in-person meetings offer a more convenient environment to establish contact. We encouraged the participants to turn on their cameras by doing so ourselves. This was to imitate a face-to-face discussion and get a sense of personal contact, although we did not physically meet. The interviews had a duration varying from 30 to 60 minutes. The variation in duration was due to the nature of semi-structured interviews, indicating that it was difficult to set a specific time frame because we could not foresee how the interviews would unfold (Saunders et al., 2019). The use of open-ended questions relies on the unique responses of the participants, and participants may provide detailed answers when appropriate, and more brief answers elsewhere. We avoided interruption and unnecessary probing questions to ensure a free answer flow. This sometimes led to questions being answered without being asked. Overall, this resulted in some interviews being short while others lasting significantly longer. Furthermore, we agreed upon the roles to undertake during the interviews. One researcher was assigned the task of notetaking and observation, while the other was focused on dialogue with the participant. This splitting of responsibilities aimed to enhance the quality of our data collection.

The interviews consisted of two phases: an introductory and a thesis-specific phase. As per (Tjora, 2012) each interview was initiated with a brief, informal conversation to establish a relationship and to ensure that the technology was working properly. This was followed up by assuring that the participants understood and agreed upon the information in the participation information sheet and consent form. In the introductory phase, we asked general questions related to the company’s activities and the specific role of the participant. Subsequently followed questions in direct relation to our research objectives. Our key focus during the interviews was to let each participant delve into topics they considered relevant within the scope of the research objectives. We acknowledged that the participants had various levels of knowledge and involvement about industrial symbiosis. Thus, we told the participants to focus on the questions they had prerequisites to answer. Our follow-up questions targeted further exploration of significant subareas relevant to the specific company or seeking clarification when the participant’s meaning or rationale was unclear.

4.7 Data Analysis

The nature of data, quantitative or qualitative, determines how the data should be analysed. However, there is not a specific correct or incorrect technique concerning qualitative data analysis. The data collection and the data analysis are interrelated and interactive, meaning that the data can be analysed after and during the collection (Saunders et al., 2019), and this constituted as a part of our data analysis technique. In the following we will present how we have analysed the data through the data transcription and template analysis.

4.7.1 Data Transcription

The optimal approach to secure a complete capture of the data was to videorecord and transcribe the extensive interviews by using the inherent function of Microsoft Teams. By videorecording the interviews, we were able to observe non-verbal gestures such as body language and facial expressions which may be of significance in drawing conclusions (Saunders et al., 2019). The transcription process started with cross-checking the transcripts with the video recordings and analysing the transcripts individually after the interviews. Secondly, we discussed our findings with each other to secure a common understanding of the participants’ meanings. To avoid any misunderstandings, we also discussed intonation, punctuation, irony, unfamiliar words and non-verbal gestures. Finally, we strived to complete the process while the data was recent before proceeding with the remaining interviews, in accordance with Saunders et al. (2019).

4.7.2 Template Analysis

Template analysis is a technique to analyse qualitative data closely related to thematic analysis (Saunders et al., 2019). The primary objective of thematic analysis is to identify themes or patterns within the data, allowing for a systematic and flexible approach to data analysis (Braun & Clarke, 2006, referred in Saunders et al., 2019). The importance of familiarisation of data is fundamental in both techniques (Saunders et al., 2019), like for instance through a data transcription process. As the interviews were held jointly, all the raw data was shared between the two researchers. The transcription process ensured a more in-depth familiarisation, facilitating a sufficient preparation for the coding. Furthermore, both template analysis and thematic analysis can be applied regardless of the research approach, i.e. inductive or deductive approach. However, the data coding appears somewhat different in the two techniques based on their respective approach (Saunders et al., 2019).

Both thematic and template analysis draw from two sources of codes: data-driven and theory-driven codes (Saunders et al., 2019). Template analysis begins with theory-driven codes ("a priori codes") and supplements them with data-driven codes, specifically terms used by participants ("in vivo codes"). Given the exploratory nature of our study, template analysis proved advantageous as it allowed us to utilise both theory-driven and data-driven codes and provided the added benefit of continuous data analysis. Unlike thematic analysis, where all the data is coded before searching for patterns, template analysis allows for ongoing examination of patterns and themes (Saunders et al., 2019). By applying the principles of template analysis, we began coding parts of the data before developing a list of codes. This initial coding template, as per King and Brookes (2017, referred in Saunders et al., 2019), allowed for an adaptable organisation and reorganisation of codes until the identification of themes, representing the key ideas and relationships in the data, was feasible. This flexibility implies that the template can be modified as data collection progresses, if necessary, through adding, removing or merging codes. The choice between thematic and template analysis is largely based on preference (Saunders et al., 2019). We opted for template analysis as it enabled early data analysis, which was beneficial given our data collection through interviews that spanned over several weeks.

4.8 Data Quality

In this section we evaluate our data collection method by assessing the quality of our research (Saunders et al., 2019). There are distinctive data quality issues that appear when collecting data qualitatively instead of quantitatively, and vice versa. Reliability, internal and external validity are widespread measurements to evaluate data quality. Reliability concerns the research's consistency and ability to be replicated. Validity refers to the discussion around appropriate data collection methods and their ability to study what is planned. Internal validity is related to which extent the findings are assigned to interventions and rather than a result of fault(s) in the research design. External validity refers to the study's generalisability (Saunders et al., 2019). However, Saunders et al. (2019) highlight the debate concerning the assessment of qualitative data adhering to reliability and validity. Therefore, we have decided to utilise the four criteria parallel to reliability and validity introduced by Lincoln and Guba (1985, referred in Saunders et al., 2019). The alternative criteria to ensure trustworthiness from Lincoln and Guba (1985) are credibility, transferability, dependability and confirmability. The introduced terminology follows the nature of qualitative research, hereunder data that is more connected to human experience (Stahl & King, 2020). We adhered to these criteria because reliability and validity, if applied rigorously and conventionally, can lead to difficulties for qualitative studies to prove high data quality (Saunders et al., 2019).

4.8.1 Credibility

Credibility is the parallel criterion to internal validity, and it can be seen as the confidence that the research findings convey the truth (Lincoln & Guba, 1985; Megheirkouni & Moir, 2023), thus "how congruent the findings are with reality" (Stahl & King, 2020, p. 26). Yin (2014) highlights that internal validity is related to establishing casual relationships, and threats are often linked to spurious effects. However, this is more related to explanatory case studies, and not exploratory case studies. Saunders et al. (2019) highlight that credibility is often highly present in semi-structured and in-depth interviews. In the extension of this, triangulation is a widely recognised method to foster credibility (Saunders et al., 2019; Megheirkouni & Moir, 2023; Stahl & King, 2020). Data triangulation is about using multiple data sources or collection methods in a research study (Saunders et al., 2019; Yin, 2014). We collected primary data through interviews and engaged with secondary data sources such as presentations and reports. This approach broadened our understanding of the overall cases and helped us establish findings (Stahl & King, 2020). Additionally, we individually interpreted and analysed the data. This allowed us to draw conclusions based on our understanding of the themes before collectively discussing the findings, thereby enhancing the credibility of our data interpretation. This concept is known as investigator triangulation (Stahl & King, 2020). Furthermore, semi-structured interviews offered the opportunity to enhance credibility through persistent observation which involves evaluating factors in the interview setting, such as language connotations, body language, facial expressions and reactions (Megheirkouni & Moir, 2023). Another strategy to enhance credibility, is known as referential adequacy (Megheirkouni & Moir, 2023). This is connected to the fact that the researcher can verify findings and interpretations with the raw data material. By videorecording the interviews, as well as taking notes, we could go back to the raw material if uncertainty appeared at any time in the process.

4.8.2 Transferability

The parallel criterion to external validity is transferability (Lincoln & Guba, 1985), and Saunders et al. (2019) describe external validity as the generalisability of the findings in the research. Stahl and King (2020) note that ensuring transferability in qualitive studies can be complicated, given that qualitative studies do not typically aim for replicability. More conventional research might have higher expectations of demonstrating external validity, for instance, through statistically significant findings (Lincoln & Guba, 1985). The generalisability of qualitative research has been questioned due to the small sample sizes (Yin, 2014), which is also the case in this study. In the extension of this, Mitchell (1983, referred in Meyer, 2001) emphasises that case studies are not grounded in statistical inference, which applies for this study due to its small sample size. Therefore, we are not able to draw conclusions based on statistical evidence. The choice to introduce two case studies, thus a multiple-case study (Yin, 2014), instead of adhering to a single-case study (Yin, 2014) does not necessarily support the transferability concern (Meyer, 2001). Nonetheless, Buchanan (2012, referred in Saunders et al., 2019) suggests that findings from qualitative research can potentially be transferred to other settings, and according to Yin (2014) using replication logic in multiple cases is a way to deal with the generalisability challenge (refer to section 4.4). Leonard-Barton (1990, referred in Meyer, 2001) emphasises that a multi case approach is about replicating findings from one case to another, therefore choosing two cases instead of one case has a transferability potential. Lincoln and Guba (1985) recommend that researchers provide sufficient data for readers to make their own transferability judgements to facilitate transferability. This includes details about the research questions, design, context, findings and interpretations (Saunders et al., 2019). In developing this methodology chapter, we have meticulously presented and justified our choices, enhancing the reader's ability to assess the potential for transferability to other settings (Lincoln & Guba, 1985; Meyer, 2001).

4.8.3 Dependability

Dependability is the parallel criterion to reliability (Lincoln & Guba, 1985). It refers to "the stability of findings over time" (Megheirkouni & Moir, 2023, p. 859), in the form of decreasing errors and biases in the study (Yin, 2014). If a study is reliable, repetition of the findings should be possible for other researchers, given that the same research design was followed. Nevertheless, repeating the same process does not necessarily result in the same findings due to uncontrollable factors that can potentially interfere with, or in other ways, influence the research setting (Megheirkouni & Moir, 2023). Yin (2014) highlights that in a case study, researchers have to be aware of their prejudices, and that the researchers' interpretation and understanding of data can impact the results. Potential threats to reliability (dependability in this context) are researcher and participant errors and biases (Saunders et al., 2019; Yin, 2014). To minimise researcher bias, we strived to remain open to all evidence. Yin (2014) challenges researchers to test how open they are to contrary evidence, and we have therefore structured our research objectives so there is no "right" or "wrong" answer, thus we do not aim to enhance or undermine certain data. More specifically, we used neutral language and open-ended questions in our interview guide to avoid leading participants towards particular responses. Furthermore, to reduce researcher errors we suggested to schedule the interviews in the morning, to ensure focus and minimise the likelihood of errors stemming from tiredness. To mitigate participant biases and errors, we conducted interviews at times chosen by the participants and provided them with the interview questions in advance. This allowed participants to prepare their responses and potentially reducing the likelihood of factually incorrect statements and could serve as a stress-reducing factor. Furthermore, all interviews were conducted digitally with the intend to lower the participation threshold and ensure a comfortable environment for the participants, which could encourage more open and honest responses.

4.8.4 Confirmability

The parallel criterion for objectivity is confirmability (Lincoln & Guba, 1985). Confirmability pertains to the researcher's concern for objectivity, thus the ability to demonstrate that the study's findings are shaped by the experiences and ideas of the participants, rather than the biases of the researcher (Shenton, 2004). However, researcher bias is present in human-developed studies as it is challenging to achieve complete objectivity (Patton, 1990, referred in Shenton, 2004). One key approach we have taken to enhance confirmability is through triangulation, as discussed in subsection 4.8.1. Triangulation occurs when using multiple data sources or methods to cross-verify findings, which can help reduce researcher bias (Shenton, 2004). For instance, we have verified interview data with information from publications on websites, reports, and presentations. Furthermore, this chapter has provided a detailed account of the methodological choices made in our study. It outlines the various steps in our method, such as data collection and analysis, thereby offering an "audit trail" (Lincoln & Guba, 1985), by giving the reader an overview over the methodological steps. This audit trail provides transparency about our research process, enabling readers to assess the trustworthiness of our data and the conclusions we draw from it (Shenton, 2004). For example, we clearly outline how we selected participants, developed our interview guide, conducted interviews, and analysed the data. We also explain how we addressed potential issues, such as managing researcher bias and ensuring participant confidentiality. By providing such details, we have aimed to demonstrate the transparency of our research process, thereby enhancing the confirmability of our study.

4.9 Ethical concerns

In conducting research, different ethical concerns will emerge, and ethical questions appear to be related to the people who are involved in the development of the work (Saunders et al., 2019). In our research, these ethical considerations primarily revolved around the participants and the collection of their information. One ethical concern that emerged concerns to consent (Saunders et al., 2019). To ensure informed consent, we first developed a participant information sheet, in accordance with Saunders et al. (2019) to give clear information about what the project entailed. Secondly, by signing the consent form, we asked the participants to give written consent before the interview. When collecting personal data for a research project, Sikt should be notified (refer to Appendix C for Sikt approval). The participation information sheet and consent form (refer to Appendix B) were developed using templates from Sikt. It was recommended to use these templates, thus we relied on those in the preparation of the forms, to be sure that we provided necessary information in the process. The forms were subsequently dispatched in advance to ensure that the participants had sufficient time to process the information and ask questions if needed. Other ethical considerations are confidentiality and anonymity. The participant information sheet guarantees anonymity when presenting the findings and in the discussion. This is to ensure that the reader cannot identify any participants. In the study, we have only presented the organisations on a general basis. However, it has also been important to ensure anonymity in the process of data collection. We have been careful to send e-mails individually, and not naming other organisations if there was a discussion of other participants' responses during interviews to ensure that the participants could not be identified by each other. To ensure the privacy and confidentiality of our participants, we have saved consent forms, video recordings and transcripts on password-based cloud storage (NHHs IT-solution), which will consequently be deleted after the study is completed.

4.10 Summary of Methodology

This chapter has presented our research design, an exploratory, mono-method qualitative case study (Saunders et al., 2019), following an embedded multiple-case design, where the cases have been selected based on literal replication (Yin, 2014; Meyer, 2001). Semi-structured interviews with 15 purposely selected participants from the two cases, Grøn Region Vestland and Symbiose Fjordane, formed the core of the data collection process. The participants either belonged to a facilitation organisation, the cluster administration or a firm within a specific cluster. The inductive research approach provided flexibility, allowing for themes and patterns to emerge from the data, which were used to construct a conceptual framework as illustrated in Figure 2 (Saunders et al., 2019). The collected data was transcribed and further analysed using the template analysis technique in accordance with the inductive approach, with the aim to code the data to be able to identify themes and patterns from the interviews (Saunders et al., 2019). Regarding data quality, the four criteria of credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985) were utilised to enhance the trustworthiness of the research, with methods including triangulation, managing researcher and participant errors and biases, and presenting an audit trail in accordance with Lincoln and Guba (1985). Finally, the ethical concerns have been addressed following Saunders et al. (2019). The ethical concerns in this study are primarily related to consent, confidentiality, and anonymity of the participants.

5. Findings and Analysis

In this chapter, we present and analyse the findings from the interviews with participants from Norwegian maritime clusters. Employing our theoretical framework, we aim to understand the role of industrial symbiosis in the green transition. This chapter is structured in alignment with the four research objectives detailed in section 1.3, all of which contribute towards answering our research question:

How can industrial symbiosis contribute to the green transition in Norwegian maritime clusters?

The first section provides an exploration of industrial symbiosis practices in the Norwegian maritime clusters, highlighting participants' understanding of the concept, reasons for engagement and identified industrial symbiosis initiatives. Following this, we present the identified dynamics of cooperation and competition within the maritime clusters and their implications for industrial symbiosis. Furthermore, we explore the drivers and barriers that influence the implementation of industrial symbiosis practices within maritime activities, and lastly, we propose insights and recommendations that can facilitate a successful implementation of industrial symbiosis. The chapter concludes with a conceptual framework that summarises key elements and how they relate, offering a comprehensive view of the industrial symbiosis landscape within Norwegian maritime clusters.

To substantiate and illustrate our findings, we have included direct quotes from the participants in this chapter. If certain parts of a quote do not contribute to illustrate the findings, they have been replaced with "(…)". Any necessary supplementary information is indicated with "[…]". It is important to note that the interviews were conducted in Norwegian, and the quotes have been translated into English. Superfluous filler words have been removed to ensure clarity and conciseness.

5.1 Practices of Industrial Symbiosis in Maritime Clusters

RO1: Examine the practices of industrial symbiosis within clusters that engage in maritime activities.

This section presents a status overview of industrial symbiosis practices in Western Norway based on insights from the participants. Firstly, we present the participants' understanding of the concept, followed by reasons to engage in industrial symbiosis. Subsequently, the findings on industrial symbiosis related to sectorial boundaries will be presented. The main part of the section showcases the findings related to industrial symbiosis initiatives, and we complete the section by presenting the findings regarding other circular activities.

5.1.1 Industrial Symbiosis as an Academic Concept

Our findings indicate that the participants were familiar with what industrial symbiosis entails in the context of their operations. This was an expected finding as all the clusters were categorised within projects promoting industrial symbiosis as a part of their green transitioning strategy. Facilitator 3 describes industrial symbiosis as "an academic concept (…) which raises the need to transfer this academic concept into business practices". Facilitator 3's statement highlights the challenge of translating the theoretical concept of industrial symbiosis into a practical business setting. This may explain why some participants showcased a somewhat limited understanding of the industrial symbiosis definition and perceived the term as somewhat vague and difficult to implement into practice. To exemplify this, Manager 2 (C2) explains that "I had to Google the term as it is not a term I use", and Manager 3 (C2) highlights that "industrial symbiosis, (…) is kind of a difficult term and maybe a bit of a high-flying term". In the extension of this, Managers 2 and 3 (C2), proposed a similar understanding of industrial symbiosis. Manager 2 (C2) describes it as "a collaboration between several businesses where maybe one's waste becomes another's product", while Manager 3 (C2) perceives it as a form of collaboration to optimise resources both individually and collectively, potentially transforming one company's waste into input for other companies:

> The way I perceive [industrial symbiosis] is that companies have a form of collaboration to utilise resources to optimise their own and collective operations. It could typically be that a product which might be a waste product in one company could be something used in the production of another company. (Manager 3 (C2))

Despite Cluster 2's involvement in the facilitating project, we did not identify industrial symbioses within the cluster. Furthermore, participants from the cluster, who were not currently engaged in industrial symbiosis practices nor had any concrete plans to do so, tended to equate symbiosis with general sustainability and collaboration efforts. This understanding does not fully align with Chertow's (2000) definition of industrial symbiosis. On the other hand, the remaining five clusters were engaged in current or planned industrial symbiosis initiatives, but not in complete alignment with Chertow's (2007) "3-2 heuristic". Nevertheless, participants from these clusters demonstrated a more profound understanding of the theoretical concept, as well as how to implement it into their operations. For example, Manager 6 (C3) provides a comprehensive description of industrial symbiosis:

> [Closing gaps in value chains] enable us to create this great symbiosis where nothing goes to waste, we use the waste from one company as raw material for the next [company]. (…) Symbiosis is indeed the nice term for the waste from one [company] becoming the raw material for the next. (Manager 6 (C3))

Cluster 3 is one of the clusters that has shown most progress in implementing symbiotic initiatives, and the understanding of industrial symbiosis demonstrated by Manager 6 (C3), aligns closely with academic perspectives. This may suggest a connection between a comprehensive understanding of the concept and successful implementation.

5.1.2 Objectives for Participating in Industrial Symbiosis

In the discussion of participants' understanding of industrial symbiosis as a concept, Manager 8 (C5) highlights that a business working with circularity, including industrial symbiosis as a circular business model (Baldassarre et al., 2019), typically have one out of three interests. It is noteworthy that if a business primarily has one interest, it does not automatically exclude another interest. Firstly, businesses may need resource access, and they typically aim to fulfil this in a cost-effective and environmentally responsible manner. A type of resource can be organic waste from fish farming or surplus energy from an incineration plant. Secondly, some businesses have resources needed by others, thereby establishing a market for surplus resources. Lastly, there are businesses whose business model focuses on connecting companies in need of resources and those that supply them. These three interests can be viewed in the light of the three pillars presented by Baldassarre et al. (2019): technical innovation, collaboration and sustainable business model innovation. The first group of businesses, seeking cost-effective and a more sustainable resource access, exemplifies the technical innovation pillar. They innovate by identifying alternative resources, such as organic waste from fish farming or surplus energy from an incineration plant to integrate into their production processes. The second group, which supplies surplus resources, can also contribute to the technical innovation by partaking in the exchange process. They also represent the collaboration pillar, by establishing a market for surplus resources, creating opportunities for collaboration with other businesses and stakeholders. The third group, connecting resource-demanding and resource-supplying companies, represents the sustainable business model innovation pillar. By facilitating the use of surplus resources from one source into another, they eliminate the concept of waste, transforming it into value, which captures the create value from "waste" sustainable business model archetype, turning waste into a resource (Bocken et al., 2014). Manager 8's (C5) company, which falls into the third category, has defined sustainability development as a business opportunity. All the aforementioned is inherently connected to developing more circular value chains. More particularly in the context of introducing industrial symbiosis as a circular business model (Baldassarre et al., 2019). Efforts to implement circular value chains was highlighted as important by Facilitator 4, and Facilitator 3 added that it is not possible to advance in the green transition unless new value chains are developed. Thus, creating synergies between the various businesses can generate more circular value chains, or in the words of Bocken et al. (2016), contribute to closing resource loops.

5.1.3 Industrial Symbiosis Blurring Sectorial Boundaries

As our findings highlight, industrial symbiosis can occur across different sectors and between industries within the same sector. The industrial symbiosis that appears between industries in the maritime sector (Zhang & Lam, 2017), will be returned to in subsection 5.1.4. This subsection presents the findings related to cross-sector industrial symbiosis initiatives. We experienced that some participants exemplified cross-sector symbiosis initiatives. For instance, Facilitator 4 emphasises that businesses operating in a certain sector may recognise how a given technology can be applied in other sectors as well. Furthermore, an example of cross-sector application of synergies is given by Manager 9 (C5): "I think that the aquaculture industry and municipalities can learn from each other. Much of what they are doing culminates down to the same sewage requirements so there are good opportunities to achieve synergies". This corresponds with an observation from Manager 8 (C5), stating that from a technical point of view, the solutions to issues regarding fish sludge also applies for sewage sludge. Moreover, Manager 8 (C5) states that it is not necessary to draw a distinction between the maritime sector and other land-based sectors. If there is a potential opportunity to establish symbiotic relationships between the maritime sector and another non-maritime land-based sector, symbiosis initiatives should be considered if waste generated from one sector is of value to the other. Hence, in such cases, industrial symbiosis does not occur exclusively between actors within the same sector.

5.1.4 Industrial Symbiosis Initiatives in Maritime Clusters

We found that most of the clusters were in an early stage of establishing industrial symbiosis initiatives. This is substantiated by Facilitator 1 who suggests that “There are very few of [the clusters] that are in a symbiosis today, a few have something. But they have a great potential”. Additionally, considering the “3-2 heuristic” (Chertow, 2007) as a foundational premise, our findings suggest that none of the clusters are currently engaged in symbioses in accordance with this heuristic, although they engage in activities that may include industrial symbiosis elements. This finding corresponds with the perception of Facilitator 1, who suggests that there exist few complete symbioses today, even on a global scale.

> If you look at the symbiosis that exists in the world today, where real industrial symbiosis occurs, it has taken them 50 years to build it. [Industrial symbiosis] requires a tremendous effort over a long period of time, and it requires willingness and that people do not give up. This is not a quick fix; it takes time, and it will be very demanding to put in place. (Facilitator 1)

Moreover, Facilitator 1 mentions that: “Industrial symbiosis in itself is not the goal, but it is the mindset around collaboration and reuse, and, through this, reduce the overall emissions”, which can be interpreted as even though the clusters may not represent a complete symbiosis, the journey towards a symbiosis is valuable because it can still lead to environmental benefits (Domenech Aparisi, 2010). In the extension of this, the industrial symbiosis initiatives we identified were mostly related to the production of hydrogen and/or ammonia, and land-based aquaculture.

5.1.4.1 Hydrogen and Ammonia Production

Hydrogen and ammonia are evolving as feasible alternative fuels for the maritime sector, according to some participants. This can connect to the fact that the maritime sector currently relies strongly on carbon-intensive fuels (Morante, 2022). For instance, in the production of hydrogen, it is possible to achieve symbiotic effects from the by-products in such production: "When producing hydrogen, you get two by-products. One is surplus heat, and the other one is oxygen, and a fish production facility has an enormous need for oxygen (…)" (Manager 7 (C4)). This type of symbiosis is also noted by Manager 1 (C1): "Production of hydrogen goes quite well together with land-based fish farming because you can utilise both by-products, heat and oxygen". When it comes to initiatives on ammonia, the manager mentions that they are suggested as a location in relation to an ammonia technology bunkering project. Manager 7 (C4) further notes that one should not "dispose oxygen from a hydrogen plant as a surplus resource and dispose it for no further use". This also shows the opportunity to use by-products from hydrogen production into a fish production facility, and the manager says that some of the most concrete plans for implementing symbioses are related to the production of ammonia and hydrogen and land-based salmon farming. Although the manager states that it is too early in the process to measure the effect of symbioses initiatives, the cluster had considered the impact of oxygen levels on fish farming facilities:

> We have done some analyses on how much oxygen [facilities] needs. It is of course something they know very well already, based on how much tonnes of fish that will be produced (…) and how much oxygen that goes along with the production. We know how much surplus oxygen we will have, and in that regard, we have made some calculations. (Manager 7 (C4))

Manager 11 (C6), who is working on a green ammonia and green hydrogen project, notes that while the production facility has not been built yet, a key focus of the project is identifying how the by-products can be utilised, thus identifying potential material flows, in accordance with Boons et al. (2016):

> In a production process [like hydrogen and ammonia] there will be by-products. There will become large amount of oxygen, something like for every kiloton of hydrogen we produce, we will produce 80 kilotons of oxygen. In addition to hot water. (…) I believe we [will] have around 10 times of the oxygen consumption in aquaculture facilities today. (Manager 11 (C6))

Manager 11 (C6) further explains how a circularity project in relation to the facility aims to map which local actors have the possibility and interests in utilising the by-products from the production. Furthermore, the logistics around the production should be organised as early as possible, because knowing which companies they want to collaborate with can ensure precautions in the technical planning. This corresponds with what Manager 8 (C5) highlights as important: “Every time something new is established, we should now look at: what can this be combined with?”. Thus, if there are prior ideas to establishments regarding the utilisation of by-products, this may simplify and encourage industrial symbiosis initiatives. Moreover, Facilitator 4 underscores the importance of hydrogen in the maritime sector:

> In relation to the hydrogen initiative, we continuously receive inquiries from actors that feel the need to partake in cluster collaboration to be able to keep up with the times and take part in the value chains that currently are being built to not fall out [remain competitive], lose market and to manage the transition process. (Facilitator 4)

Overall, given the participants’ focus on hydrogen and/or hydrogen production in the clusters, this can imply that hydrogen initiatives are currently among the most feasible solutions in terms of decarbonising the maritime sector. As seen, hydrogen is an alternative fuel, although not yet mature for maritime transport, and it can also be used in carbon capture and storage. Due to the lack of maturation in the hydrogen market, this indicate that the market driver (Teh et al., 2014) is not fully in place yet. Overall, participants highlight how the by-products from hydrogen production can be utilised in industrial symbiosis initiatives, in accordance with Chertow (2000) and how industrial symbiosis is viewed as a process to connect material flows.

5.1.4.2 Aquaculture

Our findings further highlight industrial symbiosis initiatives in the aquaculture industry, particularly in land-based aquaculture. Manager 11 (C6) describes land-based aquaculture as a “low-hanging fruit”, indicating that its controllable environment offers opportunities for the implementation of industrial symbiosis in accordance with the definition from Chertow (2000). Aquaculture facilities can be either land-based or sea-based, with different requirements for managing fish sludge:

> Actors with fish farming facilities on land is today required to manage the fish sludge, and this is done differently. There are not any requirements for fish farming facilities with the facility located at sea to collect the fish sludge, but we imagine that such requirements will be introduced in the future. (Facilitator 4)

In the extension of this, several participants highlight how fish sludge can be a valuable resource, that potentially has important minerals that can be extracted. This implies a reduction of overexploitation of resources (Scaler Project, n.d.; Bossilkov et al., 2005), thus an environmental benefit from industrial symbiosis (Domenech Aparisi, 2010):

> Fish sludge contains important resources, phosphorous amongst other, and the world-wide supply [of phosphorus] is declining. And of course, we need to handle it, utilise it and extract it (…) there are also nitrogen and other [minerals] that one must extract from the fish sludge, and [think about] how and what one should use the fish sludge for. (Facilitator 4)

Manager 8 (C5) also discusses phosphorous as a scarce resource, although in a different context related to sewer sludge. Facilitator 4 emphasises that measures like extracting valuable substances from waste are a starting point for building necessary circular value chains, and that the usage of fish sludge transcends the maritime sector. For instance, reuse of fish sludge, more specifically the extracted phosphorus can be used in fertiliser. The extraction of phosphorous from fish sludge, connects to the reduction of sourced raw materials in accordance with Scaler Project (n.d.). Following this, Manager 6 (C3) highlights the utilisation of waste from the fish farming into their biogas production and is currently discussing the establishment of a large foreign biogas company at their location because there is ample "feed stock" for energy production received from the refinery, the North Sea, and fish farming:

> We receive waste from all the fish farmers (…) and we transport this waste to our site. We are negotiating with the farmers to buy [the waste] or to get a hold of it, as we do not intend to pay for it. (…) we use this type of waste in our biogas reactor. (Manager 6 (C3))

Manager 6 (C3) explains how the cluster attempts to close gaps in the value chain, in accordance with Bocken et al.'s (2016) closing resource loops, by for instance reusing hot water and potentially reusing energy in land-based fish farming. The participant adds that a licence for a large land-based fish farming facility is in order, and when the fish facility is established, it holds the potential to further develop symbiotic effects within the cluster.

In conclusion, the idea of using hydrogen in land-based fish farming facilities has gained traction among several cluster participants. Alongside this, the conservation of resources, such as minerals from fish sludge, is viewed as important to reverse resource scarcity (Scaler

Project, n.d.). While these represent the primary synergies identified so far, there is potential for uncovering many more in the future.

5.1.5 Circular Initiatives in Maritime Clusters

We identified occurrences where participants, particularly those within Cluster 2, were involved in circular activities apart from industrial symbiosis. As this cluster has less progress in their industrial symbiosis initiatives than the other clusters, we have included findings related to other circular activities, as they may hold the potential to progress further into industrial symbiosis activities. For instance, Manager 3 (C2) explains how substantial investments and large efforts have been made to develop their solutions on shore power. As a result of these efforts, ships arriving at the port can connect to shore power in the docks. According to the Ellen MacArthur Foundation (2013) shifting towards renewable energy sources is a part of the circular economy. Thus, this is a good example of a company implementing circular measures towards the decarbonisation goals in the maritime sector (IMO, 2023). The manager adds that the use of "green electricity" from the "Norwegian waterfalls" has led to a substantial reduction in CO_2, NO_x and SO_x emissions in the docks because ships are connected to shore power.

Moreover, it is notable that the company does not take ownership of the waste they receive. As explained by Manager 3 (C2): "We do not possess many machines, and we do not really end up with the waste we receive, it is not our waste. There are other [actors] who handle it, like BIR, Ragnsells and other companies". The absence of waste ownership is also a factor we identified from Managers 4 and 5 (C2), who explain that a substantial part of the waste received from the North Sea is not under their ownership. Hence, their responsibility lies in ensuring that the incoming waste is managed correctly, i.e., recycled, before passed on to professional waste management actors. On a clarification note, both cluster participants are more service-oriented than production-oriented, potentially explaining the lack of waste ownership. In the extension of waste management, Manager 6 (C3) describes that circular initiatives have been incorporated in the management of incoming waste from the North Sea: "We send [oil platforms] everything, like valves, pipes (…), they need for operating in the North Sea. Then we accept everything that comes in return, like waste, and everything that can be reused or fixed". The underlying reason behind the project is to foster the green transition. The manager explains that the beginning of the project was connected to a potential environmental benefit (Domenech Aparisi, 2010):

> (…) a window of opportunity, and that was about decarbonisation of the [oil] refinery, and it was about this industrial symbiosis. We had to get the new industries in place so that they actually could make use of all the waste that was discarded [at the time]. (Manager 6 (C3))

Moreover, the interviews uncovered other ways in which participants are exploring and implementing circular practices within their operations. For instance, digital solutions could serve as a way to implement more sustainable activities, and Manager 2 (C2) exemplifies that using digital solutions for their customers can prevent offshore trips by helicopter. Furthermore, this participant explained that the organisation owns their own dock, where products and services are delivered to boats. Such services can be related to repair or upgrade of the equipment on board, which in turn can be categorised as circular activities (Geissdoerfer et al., 2017). We also found an example of a more circular mindset in the offshore industry, where Manager 5 (C2) underscores how their produced offshore equipment is rented out instead of sold. Rental can relate to Bocken et al.'s (2016) circular strategy, slowing resource loops through reuse (Geissdoerfer et al., 2017; Ellen MacArthur Foundation, 2013). Another circular measure, presented by Manager 7 (C4) is the opportunity to establish an energy station. This station, powered by a solar park, can serve as a refuelling hub where maritime vessels can recharge batteries or refill their fuel tanks with hydrogen and ammonia. This measure may encourage other stakeholders to pursue their own circular initiatives aligned with renewable energy practices (Ellen MacArthur Foundation, 2013), thus creating a mutually beneficial relationship (Lombardi & Laybourn, 2012) that share similarities with industrial symbiosis practises. Lastly, Manager 8 (C5) highlight possible reuse (Ellen MacArthur Foundation, 2013) of energy on production vessels, specifically those where fishing activities occur, as it can be difficult to implement industrial symbiosis in offshore, moving vessels. The manager states that several surplus resources are currently not optimally utilised. At a production ship like this, there may be surplus heat from, for instance, diesel motors and other processing systems. The manager underscores the importance of surplus energy as "[it] is a resource that is often overlooked", indicating that this resource should receive more focus when considering symbiosis initiatives. This inherently connects to Boons et al. (2016, p. 941) emphasis on "energy resource" exchange to connect industrial actors through material flows by recycling energy (Scaler Project, n.d.; Bossilkov et al., 2005).

5.1.6 Alignment of Thematic Selection with Research Objective

This section has explored the research objective related to industrial symbiosis practices within maritime clusters. The first thematic finding concerns the understanding of industrial symbiosis in reference to Chertow's (2000) definition. The finding relates to the research objective in the sense that the understanding of the concept could influence how industrial symbiosis practices further unfolds, and we found that the participants' understanding of the concept could correspond to the varying experience levels of industrial symbiosis within the clusters. Following this, we examined the objectives for participation, whereas the three interests to engage in industrial symbiosis could be seen in relation to Baldassarre et al.'s (2019) three pillars of technical innovation, collaboration and business model innovation. The third thematic finding relates to how industrial symbiosis blurs sectorial boundaries (Chertow, 2000). The first three thematic findings relate to the research objective by creating a deeper understanding of industrial symbiosis as a whole, hence the understanding of the concept, the reason behind involvement, and how it is not limited to occur only among actors in the same sector. Another thematic finding links to the concrete examples of industrial symbiosis practices within maritime activities, which were primarily related to hydrogen and ammonia production and land-based fish farming. The final thematic finding concerns more general circular activities (Ellen MacArthur Foundation, 2013; Geissdoerfer et al., 2017) and was included as a finding because such activities may develop into industrial symbiosis initiatives. Overall, the five thematic findings presented themselves during the analysis of the interviews and contributed to the understanding of industrial symbiosis in this specific context.

5.2 Cooperation and Competition within Maritime Clusters

RO2: Explore the dynamics of cooperation and competition within maritime clusters, investigating how knowledge is shared and exchanged to foster industrial symbiosis.

This section aims to explore the dynamics of cooperation, competition, and co-opetition within maritime clusters. By exploring these dynamics, we seek to understand how knowledge is shared and exchanged among cluster members and how this may promote industrial symbiosis. Initially, we investigate how cooperation occurs within maritime clusters and its role as a prerequisite for industrial symbiosis. Moreover, we identify how cooperation relates to industrial symbiosis, focusing on geographical proximity, the facilitator's role, and knowledge sharing. Lastly, we examine the implications of competition and co-opetition concerning industrial symbiosis, including implications and its role in driving innovation.

5.2.1 The Role of Cooperation in Industrial Symbiosis

5.2.1.1 Cooperation within Maritime Clusters

Our data collection reveals that the boundaries defining maritime clusters and their collaborative relationships are less evident than initially assumed. While all identified industrial symbiosis cooperative efforts conform to the cluster definition in terms of geographical proximity and interconnection (Porter, 1998a; 1998b) within a "regional community" (Doloreux, 2017, p. 216), the specific forms of cooperation demonstrate variation. Some relationships align more closely with industrial parks (Chertow, 2000), where businesses within the same geographical area collaborate on shared resources or services. These relationships often involve a high degree of physical resource sharing and are characterised by formalised ties between companies. In contrast, other relationships align more with less formal cluster definitions, and may not be as reliant on geographical proximity. Instead, they prioritise knowledge exchange, which often stems from intentional and selective linkages (Cantwell & Mudambi, 2011). These findings connect with Zhang and Lam (2017), suggesting that maritime clusters encompass various linked industries in the maritime sector. The essence of a maritime cluster lies in the interconnection among a diverse range of industries. Thus, our research suggests that these maritime clusters are not strictly confined by geographical proximity or sectorial boundaries. Instead, they are characterised by various interconnected industries and a blend of formal and informal cooperative relationships.

Another finding revealed that cooperation is not confined to businesses sharing resources or information within a cluster. It also extends to larger scale facilitating projects, exemplified by initiatives like Grøn Region Vestland and Symbiose Fjordane. These initiatives function as third-party facilitators (Boons et al., 2016) by bringing together various stakeholders and creating a platform for knowledge sharing and mutual learning for maritime activities, thus serving as an expansion of the individual clusters. As noted by Facilitator 3, having an "expanded perspective on how we collaborate in different directions" is essential. This expanded perspective encourages various collaborations, bringing together diverse stakeholders and their unique perspectives and knowledge. Facilitator 3 further highlights that while clusters provide a framework for cooperation, including actors outside clusters is equally important. This broader cluster cooperation should include not only businesses within a cluster but also supportive actors, aligning with Porter (1998a), who incorporates "associated institutions" (p. 213) in the cluster definition. Facilitator 3 underscores the role of cooperative partners surrounding the cluster:

> Right now, we are part of a cluster, but we also have cooperative partners who are not part of the development. And they are just as important contributors. Clusters are the basis for the value chain thinking, but we also need the support actors that lie outside the cluster. The government, for example, is not part of the cluster, but it is incredibly important that they are a cooperative actor to support the line of thinking that also focuses on industrial symbiosis. (Facilitator 3)

5.2.1.2 Cooperation as a Prerequisite for Industrial Symbiosis

The interviews portray cooperation as an integrated part of industrial symbiosis, which resonates with Teh et al. (2014), who identify collaboration as a fundamental driver for industrial symbiosis, and Chertow (2000), who presents collaboration as key to industrial symbiosis. This suggests that for businesses to engage in collaborative initiatives such as industrial symbiosis, finding new ways to cooperate is key, as noted by Facilitator 1:

> [Industrial symbiosis] is essentially about being able to lift one's gaze and think about the larger picture instead of solely focusing on one's own company. [It is about sharing common goals and objectives]. (…) There's something to be said about how, up until now, economies of scale have predominantly revolved around individual companies growing large and focusing on one thing. However, moving forward, achieving economies of scale will necessitate collaboration with others. This marks a significant shift from how things have been to how they will need to become. (Facilitator 1)

Industrial symbiosis encourages a broader perspective that extends beyond the boundaries of individual companies, promoting the sharing of common goals and objectives (Ehrenfeld & Gertler, 1997, referred in Domenech Aparisi, 2010). Facilitator 1 underscores a paradigm shift from focusing on individual companies towards collaborative efforts to achieve economies of scale. This shift is perceived as a necessity for the future, strengthening the idea of cooperation as a key prerequisite for success in industrial symbiosis. This perspective aligns with one of the components of industrial symbiosis, as presented by Teh et al., (2014), which involves inter-firm cooperation to share resources and exchange by-products. Consequently, cooperating efficiently with other actors becomes a critical skill for firms intending to participate in, and benefit, from industrial symbiosis.

However, as identified in subsection 5.1.1, most of the clusters we have interviewed are still in an exploring phase towards implementing industrial symbiosis, where collaborative relationships have been established to varying degrees. Facilitator 4 suggests that “well-established cross-functional collaborations” exist among the companies within the facilitating project. Facilitator 1 further emphasises the significant differences among the clusters within the project in terms of their progress in collaborative efforts, stating, “Some of them are already involved in collaboration, while others are completely new [clusters] that have not cooperated before. Meanwhile, others are well on their way and are already in close collaboration. So, there is a very wide range” (Facilitator 1). This quote indicates a broad spectrum of collaborative maturity among the clusters, ranging from emerging to well-established collaborations. The significant variations could be explained by the time aspect presented by Teh et al. (2014), suggesting that creating robust cooperation requires time. Nonetheless, these collaborative efforts are evolving, and the participants seems to agree that cooperation is necessary for companies to succeed in the green transition (Liao et al., 2021). This need for cooperation is summarised by Manager 3 (C2), who suggests that: “In many contexts, organisations cannot handle [the green transition] without collaborating in clusters”.

5.2.1.3 Geographic Proximity

In line with the adopted definition of clusters as geographically proximate and interconnected companies (Porter, 1998a; 1998b), the question arises as to whether these characteristics are needed for successful cooperation. Facilitator 3 suggests that “industrial symbiosis is geographically limited in many ways”, indicating that “to achieve industrial activity, one cannot stretch too far across the country”. This implies that collaborating actors must be located reasonably close to each other. This perspective is underscored by Chertow (2000), who perceives the “synergistic possibilities offered by geographic proximity” (p. 314) as key to industrial symbiosis development. However, there is no consensus on what constitutes geographical proximity (Domenech Aparisi, 2010). In some instances, cooperation thrives within local proximity, such as an industrial park, where Manager 9 (C5) suggests it might be “easier to collaborate when co-located”. The suggested benefits of absolute co-location are associated with achieving resource and information-sharing synergies, among other factors, resonating with Porter (1998a; 1998b) and Maskell and Malmberg (1999). Co-locating within an industrial park creates a "melting pot of industrial symbiosis" (Manager 9 (C5)), where frequent interactions among diverse companies foster dialogue and create opportunities for mutual growth and collaboration. Conversely, in other instances, cooperation might span across a broader geographical range, as exemplified by port collaborations scattered across the Norwegian coastline:

> In certain instances, it's highly beneficial for the [cooperation] to occur within a clearly defined area inside an industrial park. (…) As previously mentioned, it could also be a port collaboration that spans the entire coastline. It really depends on the specific cluster or cooperation we're talking about. (Manager 3 (C2))

This quote suggests that the geographical scope of cooperation can significantly vary depending on the nature of the industrial symbiosis. It indicates that the effectiveness of cooperation in industrial symbiosis is not strictly tied to geographical proximity, corresponding with Lombardi and Laybourn (2012) and Neves et al. (2020), who dismiss geographical location as an absolute requirement. Boschma (2005) further suggests that other dimensions of proximity are equally as important as geography, for instance, cognitive, social, organisational, and institutional. Thus, it is necessary to consider the characteristics of each cluster and the industrial symbiosis initiatives they are pursuing, including factors such as industry type, business activities, infrastructure and resources involved.

5.2.1.4 The Facilitator's Role in Fostering Interconnection

Interconnection is integral to the definition of a cluster (Porter, 1998a) and appears to play a central role in fostering cooperation alongside geographical proximity. Some participants underscored the importance of partaking in a facilitating project. Manager 9 (C5) suggests that the relative significance of interconnection through a facilitating project versus geographical proximity is context-specific. On the other hand, Facilitator 2 and Manager 8 (C5) highlight the role of facilitators in encouraging the forming of connections between companies, as they constantly engage with various stakeholders, fostering connections that can lead to collaborative problem-solving. Facilitator 2 suggests that the facilitator serves as a "driving force and facilitator for businesses to initiate industrial symbiosis on their own". A similar perspective is presented by Facilitator 1:

> The primary goal (…) is to establish connections where, ideally, the companies themselves recognise the value of collaboration. That is the most significant contribution we can make. (…) We can prepare them for the future, ensuring that the forthcoming changes don't take them by surprise. (…) and then there is this thing about highlighting the good examples, so that one can learn from others who have [successfully] walked this path. (Facilitator 1)

This quote from Facilitator 1 highlights critical aspects of their role in fostering cooperation. The aim is to establish connections where companies themselves can see the value of collaboration, by bringing together individuals from various industries and companies through meeting points. This indicates an emphasis on the self-driven initiative of the companies, suggesting that the most effective collaborations are those where the companies involved recognise the benefits of working together. Moreover, participation prepares the companies for the future by creating a shared understanding of the problem and gathering and compiling information to provide a comprehensive overview. Lastly, the participant underscores the importance of learning from each other's experiences. Showcasing successful examples of industrial symbiosis (Boons et al., 2016) may offer a roadmap for others to follow and motivate them by demonstrating the potential for success. Facilitator 4 shares a similar perspective to Facilitator 1 in terms of the importance of fostering connections, preparing for the future, and promoting a reciprocal exchange of knowledge:

> We seek to always be at the forefront and have an overview of what is happening in the world, both internationally, nationally, and locally. Then we can bring that competence down to a local level and mobilise among our actors to share experiences and knowledge. But of course, the process also involves the businesses sharing their insights and knowledge. It's a reciprocal exchange, one might say. (Facilitator 4)

Facilitators 1 and 4 underscore that while they provide tools, meeting points and showcase examples, it is up to the clusters themselves to identify potential synergies and industrial symbioses. This implies a balance between guidance and self-initiative, where the facilitator provides the necessary resources and support to create interconnections among companies. However, the clusters are expected to actively identify opportunities for collaboration themself. The facilitator's role is to serve as a catalyst to facilitate progress and action. The discussion on the facilitator's role in fostering interconnection can be related to the facilitation dynamics described by Boons et al. (2016). The participants' perceptions suggest a facilitation style that resembles collective learning facilitation and self-organisation. On the one hand, the facilitator's role aligns with the collective learning facilitation, as it involves a third-party organisation aiming to develop knowledge and share experiences to foster collaborative learning. This reflects the facilitator's role as described by Facilitators 1 and 4, where they aim to establish connections, prepare companies for the future, and promote knowledge exchange. On the other hand, the expectation that the companies identify potential synergies and independently create connections aligns with the self-organisation dynamic. The facilitators provide the necessary support to create interconnections among companies, but the clusters are expected to actively recognise opportunities for collaboration. These findings suggest that the facilitator's role is not strictly defined.

On the contrary, we also identify challenges associated with the facilitator role. Manager 9 (C5) underscores the practical challenges businesses face when trying to benefit from the opportunities that facilitators provide. While acknowledging the benefits of facilitators in fostering interconnections, in practice, businesses may face time constraints: "[Facilitators] creates a forum for meeting, but people don't always have time for that. (…) It is difficult to handle in everyday life" (Manager 9 (C5)). While facilitators provide platforms for interaction and collaboration, businesses are often restricted by time constraints and the demands of their day-to-day operations. This may hinder their involvement in the facilitating project and reduce the presented benefits of involvement.

5.2.1.5 Sharing of Knowledge

A recurring theme in the participants' responses is the emphasis on sharing of knowledge and experiences. Informational sharing emerges as a driving factor in fostering industrial symbiosis (Teh et al., 2014), which may contribute to effective synergies and connections among companies. Facilitator 3 underscores the importance of knowledge sharing:

> The key prerequisite for success in [industrial symbiosis] is knowledge sharing. If you intend to share knowledge, you cannot isolate yourself. This implies the necessity to co-create alongside other actors, to identify and benchmark those possessing superior knowledge. It is crucial to maintain a broad perspective on our collaborative efforts, recognising the diverse directions these collaborations may take. (Facilitator 3)

This quote suggests that knowledge sharing is not a solitary activity but requires active collaboration and co-creation with other actors. Knowledge sharing is about more than just distributing information. It is a process of mutual learning, co-creation, and collaboration that involves multiple actors. According to Porter (1998b), this happens through relationships that enhance the flow of information. Manager 8 (C5) underscores that different actors possess varying information about needs, opportunities, and potential solutions. By sharing this information, each actor can gain a more comprehensive understanding of industrial symbiosis (Teh et al., 2014). The same participant highlights the role of academic institutions (Porter, 1998a) and the public sector as support functions for businesses. These actors often have access to a broader range of information and can provide insights into areas businesses may not have complete insight into. It would be impossible for every actor to follow continuous updates and changes. Hence, there is a need for dialogue and cooperation to bridge knowledge gaps:

> There is information about needs, there is information about opportunities, and there is information about existing or possible solutions. Some have access to certain types of information, [while others have different insights]. (…) For example, a business will not have full insight into the UN's sustainability goals, which outline very clearly what needs we will have globally over the next almost 50 years. This is knowledge that one can perhaps get from educational institutions or from the public sector. (Manager 8 (C5))

Manager 8 (C5) further elaborates on the importance of knowledge sharing, illustrating how it is not a one-way interaction, but rather a dynamic process of dialogue and problem-solving. Through ongoing conversations and interactions, individuals gain information, ideas, and insights that may later connect to form innovative solutions. This process is facilitated within clusters, which provide a community "where people can discuss challenges and solutions" (Manager 8 (C5)).

5.2.1.6 Cooperation as a Competitive Advantage

Our findings underscore how cooperation can serve as a competitive advantage. Manager 6 (C3) highlights the importance of effective collaboration and teamwork, which often leads to superior results compared to individual efforts. By assigning tasks to each other or teaming up to win assignments, businesses can enhance their competitiveness within the maritime sector and across various sectors. Manager's 6 (C3) insights suggest a paradigm shift in business culture towards more cooperative practices. This shift is not just a current trend but a necessary approach for future success. As industries become more interconnected and the business environment becomes more complex, the need for effective cooperation becomes increasingly important. Thus, fostering a culture of collaboration can be a strategic move for businesses seeking to stay competitive into the future:

> When we become good at cooperating, which means we dare to assign tasks to each other or team up to win assignments, it leads to competitiveness within the maritime sector and other sectors. (…) We always worked in such a way that you almost have to have such good cooperation that it actually becomes better than when you are alone. We must do this in the future as well. (Manager 6 (C3))

The insights from Manager 6 (C3) align with the competitive advantage theory described by Porter (1990) through the "diamond of national advantage", which emphasises that cooperation can be a competitive advantage. According to Porter (1990), the interplay of factor conditions, demand conditions, related and supporting industries and firm strategy, structure, and rivalry within a geographically defined cluster can stimulate competitiveness. In this context, as Manager 6 (C3) highlights, effective collaboration can be seen as a strategic tool for outperforming competitors.

5.2.2 The Role of Competition and Co-opetition in Industrial Symbiosis

5.2.2.1 Competition in Industrial Symbiosis

Our research discloses diverse perspectives on the role of competition within the context of industrial symbiosis, not surprisingly as Porter (1998a) defines clusters as firms who "compete but also cooperate" (p. 214), implying that competition is integral to the cluster concept. Facilitator 3 acknowledges that competition is common across the facilitating project. This perspective is shared by Facilitator 1, who further suggests that while competition is an integral aspect of the business environment, it does not hinder collaboration. The participant emphasises the need to go beyond a competitive mindset to promote broader collaboration. Considering that cooperation is a prerequisite for industrial symbiosis (Chertow, 2000), discussing competition without acknowledging its interplay with cooperation may not make sense. The term "co-opetition" (Brandenburger & Nalebuff, 1996) describes the occurrence of cooperation among competing firms. This concept aligns with our findings, suggesting that competition and cooperation can coexist and even complement each other in industrial symbiosis. Facilitator 1 highlights this cooperative and competitive environment that companies operate in and its implications:

> Everyone is competitors to some extent, as they are competing for many of the same resources. And that's the thing. as of today, businesses are facing a highly competitive landscape. In the future, we need to move beyond that to be able to collaborate [on a wider range of issues]. But that is the industry: (…) They collaborate where possible and compete when they have to, which many are already good at. Competition is a reality. (Facilitator 1)

5.2.2.2 Co-opetition in Industrial Symbiosis

Co-opetition holds implications in the context of clusters, where, according to Brandenburger and Nalebuff (2021), companies that do not engage in co-opetition may miss out on promising opportunities. Several participants acknowledge the potential value of such competitive collaboration by forming symbiotic relationships with competitors. For instance, Manager 3 (C2) refers to an external "pressure" that necessitates collaboration within the cluster, even with competitors, to meet environmental demands. Manager 9 (C5) encapsulates the role of co-opetition with the phrase: "We collaborate where we can and compete where we must". This perspective aligns with the perception of Facilitator 1, who points out that the companies in the facilitating project are generally accustomed to navigating the balance between cooperation and competition: "They are quite good at it. They are used to being able to cooperate mostly about what they can, and then they compete when they have to". Manager 2 (C2) further provides an example of two competitors working together to mitigate a shared challenge, emphasising that in the cluster, competitors are not really competing:

> Yes, there are direct competitors, but the great thing about this network is that we are not competitors in that sense. Here, we are essentially just agreeing that we should build each other up, and if two competing businesses came together to find a joint solution to a waste problem (…), that is a brilliant example of two parties working together. They are competitors usually, but right here, they had the same challenge - okay, how can we work together to tackle this? (Manager 2 (C2))

As Porter (1998b) suggests, cooperation between competitors enhances the productivity of companies through improved efficiency in sourcing inputs and accessing information, technology and institutions. Manager 2 (C2) acknowledges that while there are direct competitors within the cluster, the focus is not on competition but rather on collaboration. While competitors often face similar challenges and produce similar products, they can still find ways to collaborate for mutual benefit: “If the intention is that our waste should be a raw material for another, then we are not direct competitors” (Manager 2 (C2)). This suggests that if one party’s waste can serve as a raw material for another company, they are not direct competitors but equal contributors. Manager 7 (C4) further promotes the idea that the nature of an industrial symbiosis might discourage direct competition, as the focus is on collaboration and mutual benefit. Manager 7 (C4) suggests that within a cluster, direct competition between members might not occur: “For instance, if we already have an actor [in the cluster] involved in hydrogen and ammonia, we would not establish another similar facility next to it” (Manager 7 (C4)). This quote implies that direct competition may be counterproductive in the context of industrial symbiosis. Businesses should focus on interacting with complementors rather than competitors, contributing to the overall robustness of the cluster (Porter, 1998b). The emphasis should be on leveraging each company’s unique capabilities and resources, thereby utilising each other’s advantages, to foster co-opetition that maximises mutual benefit (Brandenburger & Nalebuff, 2021).

5.2.2.3 Identified Implications of Co-opetition

Co-opetition might have implications, particularly concerning information sharing, culture, and regulatory landscape. Facilitator 3, for instance, highlights the challenge of sharing competence and information without infringing on each actor’s commercial activity. The participant underscores the trade-offs companies need to navigate when sharing information in a competitive environment. While the sharing of competencies and information is integral to cooperation and industrial symbiosis, it must not compromise confidential business strategies (Brandenburger & Nalebuff, 2021). Companies must therefore balance the benefits of sharing with the need to safeguard their competitiveness:

> As long as [the sharing of information) does not concern business solutions then it is ok. Because each individual company has its own business area. So, there is a balance in handling this sharing of competence, information, and so on, which does not compromise the business activities of each individual actor. (Facilitator 3)

Another challenge that may arise when trying to foster cooperation among companies that have historically been competitors is related to culture (Yang et al., 2022b). Manager 3 (C2) acknowledges that a cultural shift is often necessary to facilitate cooperation among competitors, which can be a difficult and time-consuming process. This highlights the potential cultural barriers to co-opetition. Companies that are used to competing may find it challenging to shift towards a more cooperative mindset, particularly if competition is deeply established in their business culture:

> Barriers [to industrial symbiosis] can arise when companies, which have historically been competitors, (…) are encouraged to cooperate. This shift can be challenging, as the culture within a company might be deeply rooted in competition, (…) making the thought of cooperation difficult to embrace. Transitioning to strong cooperation can take time, as it often requires a significant cultural shift, which can include changes in leadership or retirements. Particularly within the industry, such cultural norms can be firmly rooted. The importance of this cultural aspect should not be underestimated [when considering the dynamics of co-opetition]. (Manager 3 (C2))

In addition to implications in relation to business culture, Manager 3 (C2) underscores the importance of considering the regulatory landscape, particularly competition laws, when fostering co-opetition. While cooperation is not illegal, it must not compromise competition or lead to higher prices. This underscores the need for balance in co-opetition, where companies collaborate to create value but also compete to ensure market dynamics are not negatively affected. Regulatory bodies like the Norwegian Competition Authority are crucial in overseeing this balance and ensuring that cooperative efforts among competitors adhere to competition laws. This perspective aligns with the views of Brandenburger and Nalebuff (2021), who emphasise the need to adhere to competition regulations to ensure a balanced and fair competitive landscape:

> Competition is another aspect, and the Norwegian Competition Authority closely monitors it. (…) Cluster cooperation must be within the competition regulations. While cooperation is not illegal, it should not undermine competition or lead to higher product costs due to collaboration. Instead, it is necessary to demonstrate that such cooperation results in a market advantage. (Manager 3 (C2))

5.2.2.4 Co-opetition and Innovation

In our research, we observed an emphasis on innovation and technological developments in fostering industrial symbiosis, indirectly suggesting that co-opetition serves as a driver for innovation. This is consistent with research by Corbo et al. (2023), who present the benefits of co-opetition in relation to innovation as a source of competitive advantage. Porter (1998b) underscores this, stating that clusters are a competitive environment that drives innovation. In the context of industrial symbiosis, co-opetition can facilitate knowledge exchange, joint technological development, and risk and cost-sharing associated with innovation (Ritala et al., 2016, referred in Corbo et al., 2023). However, engaging in co-opetition also requires consideration in defining knowledge-sharing boundaries to avoid unintended knowledge spillovers (Brandenburger & Nalebuff, 2021). Insights from the interviews underscore these dynamics. Manager 9 (C5) discusses the company’s collaboration with subcontractors, highlighting how they jointly work towards shared goals by sharing information and testing equipment while maintaining a competitive relationship. Similarly, Manager 8 (C5) emphasises the importance of open dialogue and trust among competitors in a cluster, which is necessary to drive innovation through open dialogue. This corresponds to Gibbs (2003), who implies that the lack of trust may hinder the establishment of cooperation in symbiotic exchanges. As different actors bring their unique perspectives and insights to the table, they can collectively identify improved solutions that they might not have been able to come up with individually. This process of sharing information and collaborating on problem-solving can lead to innovative outcomes:

> Business actors possess solutions and the ability to develop new solutions. By bringing everyone [businesses, academic institutions and public actors] around a table and fostering open dialogue, we can share information about needs, opportunities and solutions. This approach can accelerate the process of finding optimal solutions. This is the [power] of a cluster if you get an open dialogue where you actually manage to share information without fear of compromising one’s interests. This is made possible by established trust among participants. (Manager 8 (C5))

5.2.3 Alignment of Thematic Selection with Research Objective

This section has explored the dynamics of cooperation and competition within maritime clusters. The role of cooperation was identified as a central topic in the literature, integral to the industrial symbiosis definition (Chertow, 2000), as a driver for industrial symbiosis (Teh et al., 2014), and as a key aspect of clusters, as firms who "compete but also cooperate" (Porter, 1998a, pp. 213-214). Thus, competition also emerged as relevant in a cluster context, although not emphasised in correspondence to industrial symbiosis in the literature. Firstly, the theme of cooperation was divided into sub-themes. Given the focus of this thesis on maritime clusters (Doloreux, 2017), it was logical to initiate the discussion on cooperation by exploring its nature within these clusters. This exploration aimed to understand the extent and form of cooperation among firms within the maritime clusters under study. Moreover, the emphasis on cooperation in literature (Chertow, 2000; Teh et al., 2014; Porter, 1998a; 1998b) encouraged an exploration of whether the findings from the study align with this emphasis, particularly whether cooperation is considered a prerequisite for industrial symbiosis within a cluster context. Geographical proximity and interconnection were selected as sub-themes due to their integral role in the cluster definition (Porter, 1998a). Given that most of the clusters in this study were co-located, it was interesting to investigate how this proximity influences cooperation among firms. Interconnection was explored in the context of facilitation due to third-party facilitators' central role (Boons et al., 2016) in the two cases of Grøn Region Vestland and Symbiose Fjordane. This raised the question of whether facilitators play a role in fostering interconnection. Knowledge sharing was further emphasised due to its role as a driving factor in fostering industrial symbiosis and cluster cooperation (Teh et al., 2014; Porter, 1998b). The last sub-theme of cooperation as a competitive advantage, was chosen to highlight how fostering a culture of collaboration can be a strategic move for businesses seeking to stay competitive, as suggested by participants and aligning with Porter's (1990) competitive advantage theory.

The second subsection was related to the concepts of competition and co-opetition. The theme explored how cooperation and competition coexist and potentially complement each other in a cluster context. Firstly, competition was included due to its central role in the cluster theory (Porter, 1998a; 1998b), which opens for exploration of its importance in relation to industrial symbiosis. Co-opetition was included as a sub-theme because we found, both in literature and through interviews, that it is illogical to discuss clusters with the absence of competition.

Moreover, we presented findings related to the identified implications of co-opetition, which were chosen based on the insights from the participants, suggesting that fostering co-opetition might have certain implications (Brandenburger & Nalebuff, 2021). Finally, co-opetition concerning innovation was included to illuminate how co-opetition can drive innovation (Corbo et al., 2023), which might further drive industrial symbiosis (Teh et al., 2014).

5.3 Drivers and Barriers of Industrial Symbiosis

RO3: Identify the drivers and barriers associated with implementing industrial symbiosis.

In this section, we will present our findings related to drivers and barriers to industrial symbiosis in maritime clusters. We will present the drivers and barriers that were most prominent, and they will be discussed individually. They are as follows: cooperative and competitive, environmental, social, economic, regulatory, institutional, market, technological, organisational and informational factors, and power access.

5.3.1 Cooperative and Competitive Factors

Findings related to cooperation and competition will not be discussed in this section as they have thoroughly been presented in section 5.2. However, we present a summary of the identified drivers and barriers. Firstly, the successful implementation of industrial symbiosis is primarily driven by cooperation within and beyond clusters (Teh et al., 2014), including active sharing of information (Teh et al., 2014; Porter, 1998b), geographical proximity (Chertow, 2000; Teh et al., 2014; Porter, 1998a; 1998b), facilitation (Boons et al, 2016), and co-opetition (Brandenburger & Nalebuff, 1996; 2021). However, industrial symbiosis can be stalled by barriers including the difficulty in shifting from a competitive to a cooperative business culture (Yang et al., 2022b), time constraints that may hinder involvement in cooperative efforts (Teh et al., 2014), and the need to avoid unintended knowledge spillovers (Brandenburger & Nalebuff, 2021).

5.3.2 Environmental Factors

Domenech Aparisi (2010) underscores the environmental benefits of engaging in industrial symbiosis, which resonates with our findings. We discovered that a primary motivation for participating in industrial symbiosis is to reduce overall emissions and make environmental progress. However, Facilitator 1 points out that although measures to reduce emissions have been implemented, they remain far from meeting 2030 emission reduction targets. This gap between current efforts and future goals can be seen as a barrier to industrial symbiosis. On the other hand, the ambition for net-zero emissions and the need to structure businesses with an industrial symbiosis mindset can be viewed as a driver:

> There has already been much work done in the industry when it comes to reducing its emissions. (…) nevertheless, there is still a large gap between [today] and where we are supposed to be in 2030 [regarding emission cut]. (…) there is the ambition for net-zero emissions, which is very far from where we are standing today. (…) To structure the business with an industrial symbiosis mindset is the licence to operate in the near future. (Facilitator 1)

Building on this, Facilitator 2 emphasises the need for clusters to identify green opportunities although there already exists collaboration between actors. A driver to industrial symbiosis relates to identifying new value chains that in its turn contribute to positive environmental outcomes, as outlined by Domenech Aparisi (2010):

> So, in a way we have to look at the green symbiosis, thus the green aspects involved in retaining the value within the chains for a longer period, to ensure that [the value chain] is not linear, but circular (…) in these clusters. So, in a way it is about the green opportunities there. (Facilitator 2)

These statements suggest that the reason to engage in industrial symbiosis is rooted in the aspiration to be more environmentally responsible (Domenech Aparisi, 2010). Environmental concerns can therefore be seen as a driver for industrial symbiosis. Hence, as these quotes suggest, reducing the negative impact on the environment is a key driver.

5.3.3 Social Factors

In accordance with Domenech Aparisi (2010) several participants mention social benefits associated with their initiatives, which is also highlighted by Jørgensen and Pedersen (2018). The social benefits underlined in the interviews primarily relates to job creation (Scaler Project, n.d.; Domenech Aparisi, 2010) and regional growth. Manager 6 (C3) emphasises that their cluster has created new job opportunities, and Manager 1 (C1) underscores that they want their local environment to succeed, emphasising growth in their own region. Furthermore, Facilitator 2 emphasises how industrial symbiosis may be beneficial for the workforce and that there are several ripple effects for the public:

> For the municipality, [symbiosis initiatives] are relevant to the workforce, thus having good job offers for the local inhabitants, and create growth for the municipality. This will in turn give more tax revenue that can turn into better living conditions (…). Thus, there is a lot of ripple effects for the public sector. (Facilitator 2)

Manager 11 (C6) acknowledges the local impacts their planned facility may introduced once it is built and operated. There will be a need for workplaces and outsourcing of various services. Thus, "direct employment opportunities, apprenticeships, framework agreements for procurement and the product can be used for industry purposes, including maritime". This illustrates how the planned facility can have a positive impact on the local community. CTTÉI (2013) suggests that industrial symbiosis may lead to conservation of landscape and heritage, amongst other. Nevertheless, we have identified some examples where this was not the case. Manager 11 (C6) notes that in their project some of the nature will be used for industrial purposes, and Manager 7 (C4) mentions they must liberate cultural heritage, which we interpreted as a specific barrier to further industrial development.

Finally, we acknowledge that the social benefits are not linked solely to engaging in industrial symbiosis, and other actions can stimulate the same benefits. Nevertheless, we are under the impression that the social benefits are not the primary driver behind the cluster participants' industrial symbiosis initiatives. The social benefits (Domenech Aparisi, 2010) can be viewed as positive effects, but ultimately, the main motivation is connected to reducing emissions and retaining resources.

5.3.4 Economic Factors

During the interviews, most participants underscored the economic costs and investments necessary for engaging in industrial symbiosis (UNIDO, 2011, referred in Teh et al., 2014), but also for the green transition in general. The economic aspect consistently emerged as a barrier, which was underscored by Facilitator 1: "Those who have started to [engage in industrial symbiosis], are not making so much money on it. It costs more than it's worth".

Manager 7 (C4) notes that "those who have enough resources to use on this type of work, automatically go faster forward", and Manager 6 (C3) highlights the importance of having actors that are positioned to carry out proactive investments. Being able to carry out such investments can indicate that there are some anchor tenants present with a large amount of capital (Teh et al., 2014):

> We need to be able to see economic benefits, and we need to have proactive investments. (…). And actors with the capital that can take these proactive investments. Because without capital, only good ideas and good atmosphere, we cannot pursue [industrial symbiosis]. (Manager 6 (C3))

According to Domenech Aparisi (2010) it is possible to gain economic benefits from engaging in industrial symbiosis, for instance through selling by-products to increase revenue (Scaler Project, n.d.). However, this perspective was not very prominent in the interviews, and a possible explanation be that several clusters were in an early stage of considering industrial symbiosis, and if the usage of by-products have not been fully determined, it may be challenging to conclude on the potential economic earnings from it. Nevertheless, Manager 7 (C4) exemplifies how selling by-products can be beneficial when the aim is to use renewable energy sources in production. This holds the potential for the economic perspective to develop into a driving force:

> [Other actors] will buy the by-products and thus bettering the OpEx situation for [the company] that gets the opportunity to price themselves closer to a market price. Today compressed hydrogen is produced by natural gas which is a cheaper energy source than for instance hydropower or wind power. Therefore, the price of the product will be higher [in comparison to] the way it is produced today. Selling oxygen can contribute to decreasing the product price, thus closer to today's market price. (Manager 7 (C4))

Manager 2 (C2) discusses the potential impact of higher costs due to implementing sustainability initiatives, which can increase product prices. The manager points out that companies need enough resources to support such initiatives, contextualised as economic resources. For instance, dedicating an employee solely to sustainability can be resource-intensive and could potentially lead to a competitive disadvantage if it results in higher product prices. This relates to Yeo et al. (2019) highlighting that the economic perspective is important to consider, and such initiatives can influence a company's profit (Yang et al., 2022b).

However, as illustrated by Manager 7 (C4), increased product prices due to more sustainable, and therefore costlier, actions could potentially be managed by selling by-products. This approach assumes that companies have by-products to sell, which might not always be the case. Even when companies do have such by-products, the benefits might not always be as substantial as in the contemplated case presented by Manager 7 (C4). Facilitator 4 highlights an example regarding usage of by-products, specifically fish sludge, stating that “today, with fish sludge, one does not profit from it (...) it is just an expense post for the aquaculture industry”. This implies that not all by-products increase the profit, and some might even result in additional costs, thus introducing an economical risk in accordance with Heeres et al., (2004). Lastly, Manager 11 (C6) emphasises the various advantages of industrial symbiosis, stating that it can lead to economic, environmental, and social benefits: “(…) if we earn money on selling the by-products and [the buyers] can reduce their emissions, this is a win-win situation. In addition, it can create more employment opportunities, and contribute to the circular economy development”. This underlines the potential of industrial symbiosis to transform waste into a valuable resource, leading to economic, environmental and social benefits in accordance with Domenech Aparisi (2010).

Despite Managers 7 (C4) and 11 (C6) suggesting potential economic benefits, we notice that economic factors, especially high costs and significant investments, unfold as a barrier rather than a driver for industrial symbiosis. Symbiosis initiatives are currently neither economically justifiable nor competitive to other strategies (Bossilkov et al., 2005). However, the potential future economic benefits indicate a shift where the opportunity to reduce cost or increase revenue through by-product exchange can potentially transform the economic barriers into drivers for industrial symbiosis initiatives.

5.3.5 Regulatory Factors

In accordance with the literature, we found that the regulatory environment could unfold both as a driver and a barrier (Teh et al., 2014; Domenech Aparisi, 2010; Yang et al., 2022b). The findings on this matter primarily revolved around the dilemma that without regulations businesses may not engage in necessary sustainable actions and operate on unequal grounds. Simultaneously, our findings suggest that regulatory efforts can hinder development. To elaborate on the former, Facilitator 1 highlights how a lack of regulations can lead to less action from businesses: “As it is right now, there is no requirement to [think differently]. There are not any regulations that [businesses] must do, and therefore they choose not to do it. Nevertheless, [the businesses] are preparing for [future regulations]”. In the extension of this, Manager 2 (C2) highlights that stricter regulations can ensure that businesses operate on more equal grounds. For instance, public organisations and customers should demand stricter requirements for suppliers, for example when it comes to environmental certifications. The latter can connect to Chiu & Yong’s (2004) perspective that policies do not align with innovation, thus hindering symbioses due to a lack of alignment with industrial innovation. In this regard, Facilitator 4 highlights an example regarding fish farming companies. The facilitator explains how these companies worry that EU requirements for by-product management might hinder their research and development efforts, which is highlighted as a driver for industrial symbiosis by Teh et al. (2014).

> A concrete example is related to the requirements slaughterhouses have encountered. If they shall follow the requirements from the EU in relation to the handling of blood water, they must make such big investments that smaller slaughterhouses do not have the economy to operate because the current technology is not adequate for clearing blood water. So, this means that the requirements do not correspond with the technology that exist on the market. (Facilitator 4)

In this quote, Facilitator 4 states that new EU regulations can hinder the development of solutions for managing blood water, as these regulatory conditions were introduced before the necessary technological advancements were made. Hence, there is a lack of appropriate technology in accordance with van Beers et al. (2007). Facilitators 3 and 4 have received feedback from stakeholders expressing concerns that introduction of regulations can hinder developmental work. Moreover, Facilitator 3 addresses the potential issues around new regulations forming a more challenging environment for businesses’ ability to realise projects of various kinds:

> If the regulations come before the opportunities to realise projects, then it becomes a huge challenge. If [businesses] have a law paragraph imposed upon them that they do not have the ability to handle, then the challenges arise. And in that case, the businesses will not be able to realise [projects]. It is important that there is a parallel process regarding the activities that the industry must undertake to arrive at solutions and what pertains to regulations. (Facilitator 3)

Nevertheless, Facilitator 1 emphasises that it is a fact that significant requirements are coming from the EU. The introduction of new regulations will have consequences for Norwegian actors, and these actors can approach the regulatory changes that come into effect in various ways; Businesses can shut down if unable to meet the requirements. Alternatively, they might resolve the concern by buying themselves out of the requirements or finding other creative solutions on how to comply. Facilitator 1 advocates for the latter: "if [the business] manages to see the opportunities through a circular mindset instead of buying their way out of it, that is the best business model going forward". In the context of incoming EU regulations, Manager 9 (C5) communicates how a business should have long term goals, and not only focus on the next regulatory requirement. It can be understood that regulatory factors may serve as a driver for circularity, as defined by Ellen MacArthur Foundation (2013), as Facilitator 1 also advocates for:

> If [the business] also has an ambitious goal to not only adhere to [a new] requirement, but instead see how far it is possible to progress to be ready for the next round of requirement introduction, then the business is not only implementing circular measures, but it is also future-oriented. This is a reasonable mindset if we shall achieve the EU directive[s], if not we are only building something that will be teared down (…) if we do this correctly, we have a continuous process of improvement that benefits everyone. (Manager 9 (C5))

In accordance with Heeres et al. (2004), we found that navigating the regulatory framework can pose challenges. The large volume of incoming regulations, as highlighted by Facilitator 1, can relate to Heeres et al.'s (2004) concern regarding an overwhelming regulatory environment. It is not just the large volume of requirements that increases complexity, and Manager 2 (C2) notes that the broader scale of climate debate often focuses on large-scale emission objectives, making it difficult to determine specific courses of action. More specifically, the complexity of the language used can make it challenging to comprehend, thereby raising the barrier of understanding where to start and how to initiate changes.

We also encountered findings related to regulations which do not directly concern sustainability initiatives from the EU. Some participants note that regulation of land use can serve as a barrier, but Manager 7 (C4) explains how an industrial area that has already been regulated can serve as an incentive for choosing a location for establishment. Manager 11 (C6) adds to this by noting that “parts of the [location] was regulated for industry. So, what we are doing now is area zoning where we regulate a larger area on the site that is already regulated”. This illustrates how land regulations potentially can unfold as a barrier, by being time-consuming for planned facilities which wants to engage in industrial symbiosis. Overall, we found that the regulatory factors discussed were largely connected to new regulations regarding sustainability, for instance, those related to reducing emissions and circularity. Such regulations can unfold as a driver (Teh et al., 2014) to industrial symbiosis because it is important to comply to the regulations, in reference to Facilitator 1. Nevertheless, as seen, new regulations on sustainability topics can also unfold as a barrier (Yang et al., 2022b) by hindering development.

5.3.6 Institutional Factors

The institutional factors relate to the government’s role in fostering industrial symbiosis. This necessitates effective coordinating of communication to secure necessary support (UNIDO, 2011, referred in Teh et al., 2014) for business actors, which in turn may unfold as a driver for engaging in industrial symbiosis. The policy instrument (“virkemiddelapparatet”) was highlighted by several participants. Facilitator 3 underscores that the policy instrument and priority areas, i.e., hydrogen, must correspond:

> The policy instrument must be tailored to the priority areas. It is really important that the different instruments are directed at the priority areas within the sector because it is an important incentive for the business to engage in various forms of development work. And there must be an opportunity to apply support to get [development] realised. (Facilitator 3)

Regarding the policy instrument, some specific drivers we have identified come in the form of incentives. In accordance with Barona et al. (2023), incentive mechanisms work as a driver for circular economy in the maritime sector. In some interviews, Enova’s public support scheme, or subsidisation in the words of Teh et al. (2014), for hydrogen/ammonia in maritime transport was highlighted. Manager 7 (C4) notes that “there are several incentives now through the policy instrument, and a good incentive being introduced now is the new programme from Enova”. This quote highlights the support that can be received for building hydrogen facilities, whereas Enova covers a significant portion of the construction costs. Furthermore, Manager 1 (C1) notes that there exists a support programme for the end users of hydrogen and ammonia:

> [Enova] has launched a support programme for the end users, thus [the companies] that shall use ammonia and hydrogen on ships. Approximately 30 projects have applied for the ammonia project and 15 projects has applied for the hydrogen project. This is a positive signal and a confirmation that they have realised that there are not enough drivers to get this market going. (Manager 1 (C1))

In line with Barona et al.'s (2023) findings on drivers for the circular economy, we identified that support and incentive schemes act as a catalyst, encouraging engagement in sustainable activities that can evolve into symbiosis initiatives. On the other hand, Facilitator 2 highlights the general challenge concerning the speed of public versus private processes as an institutional barrier. The private sector is driven by market forces (Teh et al., 2014) where businesses tend to operate at a faster pace with quicker decision-making processes. The public sector is more bureaucratic and must consider other societal factors that private actors do not need to worry about, which tend to slow down decision-making. The difference in the speed of the processes can be considered as an institutional barrier because it has the potential to slow down the introduction of, for instance, support programmes necessary for businesses to engage in industrial symbiosis:

> There is a barrier between public processes and the business sector because the business sector's pace is much faster, so the public [sector] is not able to follow. In addition, the public [sector] has the societal aspect, thus the need to consider a lot more [elements]. So, there is often a gap between these two in a way. (Facilitator 2)

5.3.7 Market Factors

Several participants discussed symbiosis initiatives related to hydrogen and ammonia production. The participants perceived a lack of market maturity as a significant challenge. According to Teh et al. (2014), the demand for greener products may unfold as a pull factor for industrial symbiosis, but we identified market demand as a potential barrier. Facilitator 2 emphasises this point, stating: "To reduce the climate emissions (…), there must be a market and a demand [for solutions] because at the end, the business sector needs to make money from [their activities]”. This notion is further supported by Facilitator 4, who suggests that the transition from a linear to a circular economy (McDonough & Braungart, 2002) requires the creation of new market and business opportunities. For instance, fish sludge, despite being a valuable resource in symbiosis initiatives, is currently considered a cost for the aquaculture industry, indicating that the business opportunity for its utilisation is not yet fully realised, in accordance with Bossilkov et al. (2005).

Managers 6 (C3) and 1 (C1) specifically highlight the challenges associated with the hydrogen market. Manager 6 (C3) notes that while a small market for hydrogen exists, a larger market is not yet established. This raises issues around the cost of hydrogen production and the price customers are willing to pay. According to Manager 6 (C3), a potential solution to this problem could be contracts for difference. However, the participant points out that the process for these contracts is progressing slowly in Norway and carries a “significant risk”. Supporting this viewpoint, Manager 1 (C1) notes that “A real barrier is that there is not enough market demand to defend an investment in a [hydrogen] facility with the previous support but now there is a new programme emerging”. While they could integrate hydrogen production into their operations today, they are waiting for the hydrogen market to mature. We found that it can be difficult for clusters to know how to proceed if a market is not mature. Regarding the hydrogen and ammonia market, Facilitator 2 highlights that there is currently not a definite answer about the future of alternative fuel for maritime transport. Thus, there is a challenge related to uncertainty and that the government in a way is not fully able to align with the business sector. Manager 8 (C5) highlights the issue around lack of market maturity in relation to financial support, and emphasises how a business should consider existing markets in development work:

> [The business] must do a prioritisation analysis because [it] cannot prioritise based on what it can get development funds for, but prioritise based on where the market is, right? There is no use of receiving funds for the development of something nobody wants to buy. (Manager 8 (C5))

On the other hand, Manager 11 (C6) emphasises that production and market go side by side. Following this, Manager 10 (C6) notes that they are most likely ready with their product before the market is fully matured, thus not basing their products on a market that already flourishes. The Manager further raises the concern around the problem of whether to wait until the market is mature or begin the production of products before the market is fully established:

> Whether the market for marine and propulsion engine is mature when we are ready to produce [ammonia] is perhaps a bit secondary, but it is that direction the development is headed, and we can be ready with the green ammonia when [such users of ammonia] are ready. We need to see what comes first of the chicken and the egg, but probably we have a full worthy solution before they have that offshore. (Manager 10 (C6))

The "chicken and egg" problematic from Manager 10 (C6), can relate to Manager 6's (C3) highlighting of the government's "Green industrial initiative". This initiative is a national plan to enter new markets, where hydrogen and ammonia are specifically mentioned by the Manager. If Norway adheres to the "Green industrial initiative", it could potentially mature the market faster, creating a demand for greener products (Teh et al., 2014). This may rationalise investments in immature markets for industry actors.

5.3.8 Technological Factors

Technology is a vital factor for achieving industrial symbiosis (Teh et al., 2014) and circular business models in the maritime sector (Barona et al., 2023). It is necessary that there exists technology that can convert by-products into useful resources in other processes (Teh et al., 2014; Bossilkov et al., 2005), and Manager 8 (C5) underscores how their technology is particularly suitable for exploiting surplus energy as a primary energy source, at least for certain waste streams. The manager suggests that when it comes to technological innovation it is important to have a dual focus on low-hanging fruits while keeping a long-term perspective. Manager 9 (C5) emphasises that there are major opportunities in relation to technology and reaching zero emissions. The industry in general has the potential to build a global requested expertise and technology to reach net-zero. Furthermore, Facilitator 1 acknowledges the importance of technological innovation in the work with industrial symbiosis:

> There are these front runners that we see pop up nowadays. That is, those who have technology that is exciting, that is important for the future. They have to research and figure out what is the right way to move forward, so there is a lot that will happened in relation to pilot testing. And that is important. It is an important phase in this work. (Facilitator 1)

The quote suggests that innovation is a major driver for technology companies, because technology is essential in the development of green solutions. Yet, the majority of the clusters main activities does not include their own development of technological solutions. This can indicate that technology is not perceived as a major driver for the clusters because they are more concerned with its application. Manager 1 (C1) embraces the technology aspect:

> There is probably a lot of technology that has to mature to succeed with [industrial symbiosis], and it is important to allocate sufficient time and resources, but that is not what we primarily work with, we utilise technology and follow as closely as possible, and have dialogue with [actors] that are at the forefront of innovation, and that is why we are a part of various collaboration programmes. (Manager 1 (C1))

Facilitator 3 highlights that many actors related to the facilitating organisation, are seeking their support for technological solutions, which, along with logistics, is one of the two main focus areas for the facilitating organisation. However, as Manager 9 (C5) points out, companies often do not consider new technology until a crisis occurs. Overall, we observed that the cluster participants that were more production-oriented did not have a significant focus on technological factors.

5.3.9 Organisational Factors

Yang et al. (2022b) identify organisational barriers related to culture, which may further relate to the motivational barrier also presented by Yang et al. (2022b). Our findings reveal organisational culture and motivation as drivers, which suggests that these factors can unfold as both drivers and barriers. In the extension of this, it is plausible that the organisational culture may affect the company's general motivation for industrial symbiosis. Facilitator 3's statement supports that the organisational culture can enhance motivation by explaining how people are motivated to engage in industrial symbiosis:

> It is fascinating to see the engagement from the actors to get [industrial symbiosis] realised. And what we have done as far as it comes to management of residual materials in the aquaculture industry, is a typical indicator on that. (…) It is the businesses that run after us to get support in solving issues typically related to technological solutions and logistics. (Facilitator 3)

Manager 6 (C3) further illustrates that there is a substantial motivation to succeed in the green transition: "It creates a positive atmosphere; it is a good feeling. (…) And it is important as not everything can be measured simply in terms of money anymore". Moreover, Manager 1 (C1) indicates that there is a high level of motivation towards the green transition, hereunder industrial symbiosis:

> Our motivation to [engage in different programmes and collaborations] is about the green transition. We are very dependent on the oil and gas industry today. Of all (…) people [working here], almost 100% of those jobs are connected to the oil and gas industry, expect the ones relating to land-based fish [farming], but if the oil and gas industry becomes obsolete, we need to have more legs to stand on. We need to adapt. (Manager 1 (C1))

On the other hand, we also identified organisational factors that unfolded as barriers, which were primarily connected to lack of time (Bossilkov et al., 2005) and resources. According to Manager 9 (C5): "A key barrier is that people should collaborate, but no one has the time. The way the global economy and situation is today, most companies are under the pressure of simply surviving". The participant explains how collaborating may serve as a tool to save time, as finding the best technological solutions is also highly demanding doing alone. Nevertheless, due to lack of time, companies often outsource their problem-solving to consultants who do not provide innovative technological solutions, instead of engaging in time-demanding collaboration efforts. Lastly, Facilitator 3 suggests that: "We know that business actors are primarily attentive to their operations. That is what they usually have the capacity for", which connects to some businesses struggle to put efforts towards actions outside their core business (Bossilkov et al., 2005). Thus, while the clusters appear motivated, the lack of time emerges as a barrier hindering the efforts necessary for industrial symbiosis.

5.3.10 Informational Factors

Information may serve dually as a driver and barrier to industrial symbiosis (Teh et al., 2014; Yang et al., 2022b). In accordance with Yeo et al. (2019), some findings were related to informational barriers when it comes to identify symbiotic opportunities. In example, Manager 9 (C5) states that "it can be somewhat challenging to know about each other. There always exist smart enthusiasts, but they are not always as easy to find". This issue was also brought up by Manager 6 (C3) who underlines that: “Industrial symbiosis increases the risk for failure in the sense that we cannot build new buildings and just invite anyone in. It is necessary with someone that fits in the symbiosis”. This showcase that holding the necessary information regarding potential material flows can be challenging (Heeres et al., 2004; Yeo et al., 2019). On the other hand, Manager 6 (C3) further emphasises that informing others about their work and projects is vital to enlighten potential partners that may become a new addition to the symbiosis. The manager’s active approach to share information to develop their symbiotic relationships indicate that information is also a driver for industrial symbiosis. Furthermore, the clusters are part of facilitating projects where industrial symbiosis is a central strategy for implementing circular value chains. Thus, being a part of a project that facilitate for information sharing (Teh et al., 2014) can unfold as a driver because the clusters gain access to information through meeting points. In the extension of this, we have previously presented the findings on knowledge sharing and the role of the facilitator (Boons et al., 2016), which is connected to the aspect of information and how it can be obtained through being a part of a facilitating project. Manager 7 (C4) discusses the importance of their involvement in a facilitating project in relation to information sharing: “You get taken out of your daily routine where you might be working on things alone, and then you meet other people who are doing the same as you, which has been very rewarding to be a part of” (Manager 7 (C4)). Such information sharing can increase the cluster’s knowledge, which in its turn has the potential to develop symbiotic initiatives.

5.3.11 Power Access

One factor that emerged from our findings, which was not identified in the literature, is the issue of power access as highlighted by participants and presented in a report from Grøn Region Vestland (2024). This could be considered a contextual factor, with several participants indicating that the power situation in their area could pose a barrier to the progression of the green transition. Facilitator 2 underscores the significance of power access:

> The power situation is an enormous barrier. The green transition is very power demanding, so we have to see what opportunities there are for local power, thus which local power sources that exists or can be created so that we can be more self-sufficient in a better way. (Facilitator 2)

Additionally, Manager 7 (C4) underlines that the power accessibility can affect the degree of new establishments on their site, thus slowing down the development of industrial symbiosis:

> There are varying degrees of establishment requests (…), and part of the framework conditions perhaps set the major limitations for the interest. Even though we have a new power line (…), Statnett introduced new rules last year that make it more difficult to reserve power in the grid. Statnett has some challenges with providing us reservations, and that creates challenges when working with new establishments, because we cannot secure the power, and [new establishments] seek other places where it is easier to access power. (Manager 7 (C4))

In contrast, Manager 1 (C1) suggests that power access may serve as a driver rather than a barrier:

> Electrical power is highlighted if we are to succeed in the green transition, it is an important condition that the access [is in order]. And the situation here, is that we have surplus power, and we have available industry area. (Manager 1 (C1))

Manager 11 (C6) further emphasises the importance of power, noting that they have a power agreement with Statkraft to secure the necessary power for future production, and that they have been granted grid capacity from Statnett. Thus, while the current power situation may pose a barrier for some, it can also present advantages for others.

5.3.12 Alignment of Thematic Selection with Research Objective

This section has explored the findings related to drivers and barriers to industrial symbiosis. We have aimed to utilise the overlap between the literature and the findings, as presented in Table 2, and the sub-themes relate to the factors presented in the literature. We identified most of the drivers and barriers presented by Teh et al. (2014) and Yang et al. (2022b) in our findings from maritime clusters in Western Norway. The environmental and social benefits (Domenech Aparisi, 2010) were present in the interviews, but it appeared that the environmental driver was a more significant motivation behind engagement than the social driver. Following this, we presented the other factors we identified, namely economic, regulatory, institutional, market, technological, organisational and informational, which largely overlapped with the literature. However, we found that organisational and motivational factors do not solely unfold as barriers but also as drivers, and we identified power access as a factor that was not prominent in the literature. Furthermore, the primary focus regarding drivers and barriers for the participants was economic barriers, which is plausible because, ultimately, the businesses need to be profitable. The above-mentioned factors directly connect to the research objective as it is concrete examples of drivers and barriers identified in our study.

5.4 Insights and Recommendations

RO4: Provide insights and recommendations for Norwegian maritime clusters to succeed in the green transition by implementing industrial symbiosis.

This section outlines insights and recommendations related to the identified drivers and barriers. The aim is to enhance industrial symbiosis, and further the green transition, within the maritime sector. Firstly, we present prerequisites for industrial symbiosis based on the identified factors, which create the foundation for providing insights and recommendations for Norwegian maritime clusters to successfully implement industrial symbiosis. The insights represent anticipated outcomes drawn from the participants' perspectives, while the recommendations are action-oriented strategies.

5.4.1 Prerequisites for Industrial Symbiosis

We have identified four prerequisites that form the foundation for industrial symbiosis: Cooperation, resource availability, knowledge and technology, and governmental support. *Cooperation* involves fostering a culture of collaboration (Chertow, 2000; Teh et al., 2014; Porter, 1998a; 1998b) encompassing co-opetition (Brandenburger & Nalebuff, 1996; 2021). *Resource availability* refers to the need to have access to the necessary resources for engaging in industrial symbiosis. These resources include sufficient financial resources to initiate symbiotic initiatives (Teh et al., 2014). Moreover, organisational resources, such as time and motivated employees, are needed. Time is required to prioritise symbiotic initiatives, while motivated employees are the driving force behind such initiatives, contributing their skills and dedication. Power access (Grøn Region Vestland, 2024) is another needed resource in the context of industrial symbiosis. Reliable and sufficient power supply is necessary for practices, particularly those involving energy-intensive processes. *Knowledge and technology* are needed to develop and implement industrial symbiosis initiatives, and relies on understanding market dynamics, leveraging technological advancements, and effectively managing information (Teh et al., 2014). Lastly, *Governmental support* can provide the necessary incentives for engagement in industrial symbiosis through policies and regulations (Teh et al., 2014), where governments recognise the social and environmental benefits of industrial symbiosis (Domenech Aparisi, 2010), can create a supportive institutional environment for industrial symbiosis. How these prerequisites relate to the factors identified in section 5.3 is illustrated in Figure 2.

5.4.2 Insights for Promoting Industrial Symbiosis

5.4.2.1 First Movers and Competitive Advantage

Our research findings suggest that being a first mover with implementing industrial symbiosis can offer advantages, as a proactive strategy can enable companies to establish a position in the market before others. The first mover advantage of implementing industrial symbiosis can be related to the economic, environmental, and social benefits, outlined by Domenech Aparisi (2010).

According to Facilitator 1, first movers may secure long-term economic benefits despite the initial challenges. While the implementation of industrial symbiosis can entail high costs and risks (Yang et al., 2022b; Heeres et al., 2004; Bossilkov et al., 2005), being a first mover positions a company at the forefront when market disruptions occur. As the company have already implemented industrial symbiosis, it is better positioned to seize opportunities when market conditions become more favourable. Being a first mover can provide a competitive advantage that can result in increased market share and profitability:

> Being a first mover inevitably comes with its challenges, but being a first mover also means that the moment things turn around, when a disruption occurs in some format, they are positioned at the forefront because they have already done it. (Facilitator 1)

Manager 5 (C2) further underscores the economic benefits of being a first mover. By pioneering new initiatives, exemplified by the implementation of shore power, first movers can establish new revenue streams (Domenech Aparisi, 2010), such as selling electricity. These economic benefits not only help retrieve the initial investment but also contribute to the company’s overall profitability. Moreover, being a first mover can attract attention to the company, potentially leading to increased business opportunities or partnerships, aligning with the perspective of Manager 1 (C1), who believes that "there is value in being a first mover as it brings attention [to the company], and it may also attract cooperative partners". The ability to find the right cooperative partners can lead to strategic collaborations (Teh et al., 2014), which may open new market opportunities or promote cost efficiency, which can have positive economic impacts. Such economic benefits can unfold as a motivational factor for engagement (Domenech Aparisi, 2010).

Being a first mover can also yield social benefits. When a company is at the forefront of a market disruption, it often leads to increased visibility and reputation, which can attract cooperative partners (Manager 1 (C1)), thus fostering a culture of collaboration and shared value, contributing to positive social outcomes. Other social benefits are expressed by Manager 6 (C3), underscoring that when a company takes the lead in undertaking green initiatives, it often triggers increased visibility and reputation, which can attract talent and create more job opportunities (Domenech Aparisi, 2010):

> The task of [Cluster 3] is to achieve decarbonisation, pushing [the large actors], and as you can probably imagine, it is not easy, but we are willing to take on the challenge. The goal is to stimulate the remaining activities in the wake of this. We currently have a massive investment portfolio at [Cluster 3]. If we succeed with this, we will have cut one million tons of CO_2 and created numerous new jobs opportunities. This is indeed a significant green transition. (Manager 6 (C3))

If the market disruption relates to environmental practices, being a first mover means the company has already implemented changes that others are just beginning to consider. This can lead to environmental benefits, as the company is ahead of others in reducing its environmental impact, which is evident in the quote from Manager 6 (C3). The quote highlights the company's efforts to achieve decarbonisation and cut CO_2 emissions, while others might just be starting to consider such changes. The impact of these early actions is substantial. An expected 2% reduction in Norway's total CO_2 emissions, as a result of their project, signifies the potential of proactive environmental practices from the reduction in resource utilisation (Domenech Aparisi, 2010).

In conclusion, being a first mover in industrial symbiosis can present economic, environmental and social benefits (Domenech Aparisi, 2010), and collaborative benefits in terms of attracting cooperative partners for symbioses (Teh et al., 2014). These benefits provide first movers with a competitive advantage that might surpass the initial risks and challenges they face. This reinforces the notion that industrial symbiosis is not just about economic gain. Additionally, market actors are driven by their motivation to contribute to environmental sustainability and social development.

5.4.2.2 Maturing Company Culture and a Generation Shift towards Cooperation

The evolution of company culture, driven mainly by a generational shift, is an identified factor in promoting industrial symbiosis and cooperation within the maritime industry. This aligns with the findings of Liao et al. (2021), suggesting that the ongoing evolution of maritime clusters presents promising opportunities for green transitioning. We find that the younger generation tends to foster a culture that values and encourages collaboration, breaking down traditional perceptions of business independence. Manager 3 (C2) underscores the significance of this maturing company culture in achieving industrial symbiosis, emphasising that “one should not underestimate the influence of culture”. This participant suggests that existing competitive dynamics and established company culture could pose barriers to inter-company cooperation, as identified in subsection 5.2.2.3, where organisational culture may hinder the emergence of industrial symbiosis (Yang et al., 2022b). However, transforming such a culture could be challenging. A similar perception is shared by Manager 6 (C3), who emphasises the importance of collaboration and shared goals in achieving green transition goals:

> When I started, there was a complete lack of cooperation within [cluster 3]. With 60 companies, the atmosphere was quite negative. This negativity stemmed from the fact that the companies were not used to collaborating. They were accustomed to thinking about their own turnover and bottom line. (Manager 6 (C3))

The quote suggests that the cluster needed to change this initial culture, characterised by a lack of cooperation, to succeed. The solution was to create a board of company leaders and the local mayor to facilitate communication and cooperation. This transformed business culture has improved the chemistry between the companies (Manager 6 (C3)). However, Manager 9 (C5) suggests that this collaborative and unified approach will happen naturally with the generation shift. As the industry evolves and a new generation of employees emerges, there is an increased understanding of the collective benefits that cooperation can bring. One such benefit is the information sharing (Teh et al., 2014) that occurs when firms interact, providing positive outcomes for the individual firms, according to Manager 8 (C5). This shift in mindset (Dahl et al., 2018) can according to Manager 9 (C5) help overcome the ‘king of the hill’ mentality of the older generation, which may hinder the successful implementation of industrial symbiosis:

> I believe that this is closely linked to a generational shift, particularly here in the old Sogn and Fjordane region. The younger generation naturally embraces cooperation where it’s feasible. In contrast, the older generation tends to have more of a ‘king of the hill’ mentality. Of course, and thankfully, there are always exceptions to this rule, with many commendable individuals fully recognising the value of cooperation. However, the general sentiment I perceive is that (…) the younger generation, is better at seeing the opportunities in cooperation than the older generation. (Manager 9 (C5))

Based on our findings, a cultural and generational shift is fundamental in implementing industrial symbiosis and may relate to cooperative and competitive, informational, and organisational factors. As the industry evolves and a new generation of employees emerges, there is a growing focus on collaboration and sustainability. This shift in culture and mindset, driven by the younger generation, will likely promote industrial symbiosis initiatives in the maritime industry.

5.4.3 Recommended Actions to Succeed in Industrial Symbiosis

5.4.3.1 A Holistic Approach to Cooperation and Knowledge Sharing

For the successful implementation of industrial symbiosis, we suggest a holistic cooperative approach in the industry, involving a diversity of stakeholders, following Liao et al. (2021). The authors emphasise that industrial interaction and support from local institutions are fostering the green transition within maritime clusters. According to our findings, stakeholders might include industry actors, private and public support functions, academic and research institutions, facilitators and policymakers, and collaboration among them may serve as a driver for industrial symbiosis (Teh et al., 2014). Facilitating organisations likely play a part in fostering and coordinating this comprehensive cooperation by linking various stakeholders (Boons et al., 2016). As proposed by manager 7 (C4), engagement with facilitators in projects, such as Grøn Region Vestland and Symbiose Fjordane, may serve as an arena for information sharing (Boons et al., 2016), where the sharing of information can contribute to well-informed decisions and effective synergies (Teh et al., 2014). In alignment, Facilitator 2 advocates for a broader cooperative landscape that exceeds the boundaries of individual clusters, enabling knowledge sharing and fostering understanding of shared needs. In particular, Facilitator 2 emphasises the role of academic institutions in tailoring study programmes to meet the needs of businesses. This is necessary for the industry to secure relevant competence in its workforce, ensuring that the labour market can supply the skills and expertise necessary for industrial symbiosis initiatives. For example, they may require workers with knowledge in areas like engineering, resource management and circular economy. The role of academic institutions may relate to the institutional driver suggested by Teh et al. (2014), where government support, for instance, educational programmes, is necessary to foster industrial symbiosis. Thus, such institutions should be included in the holistic industrial symbiosis cooperation:

> For [us] it is about following up on initiatives from the county, listening to the needs of the business community, getting the political body to be drivers and spokespersons, and using the public muscle on behalf of the industry. [Facilitating organisation 2] can be a link between the county, the municipality, the business community and academia. We frequently include academia in our projects to ensure a comprehensive approach. The direction of academic study programmes should align with the needs of the business community, fostering a synergy between educational institutions and industry to meet mutual needs. In essence, we act as a link. (Facilitator 2)

Facilitators 3 and 4 elaborate on the importance of close collaboration with academic and research institutions in driving development work and assessing its effects, whereas such institutions are included in the cluster definition (Porter, 1998a; Doloreux, 2017). The participants highlight the role of such cooperation in promoting knowledge sharing, technological development, and innovation:

> We have close dialogue with Høgskulen på Vestlandet and Vestlandsforskning, among others. (…) It is central for us to have this close cooperation with both universities and research institutions. Of course, in relation to hydrogen, we have close cooperation with SINTEF and others. (Facilitator 4)

Facilitator 4 acknowledges that while businesses are primarily focused on their own operations, they also aspire to develop technology and innovate. To engage in industrial symbiosis, there must exist technology that enable the conversion of by-products (Bossilkov et al., 2005). However, as identified, actors may lack the capacity or resources to independently acquire the necessary technological solutions. By engaging in holistic cooperation with stakeholders, including support functions, research institutions and facilitators, businesses can access the resources and assistance they need to drive their development efforts. Facilitator 3 encapsulates this need for external support: "[Industry actors] need to be pulled out of their everyday routine". This emphasises the importance of providing external support and resources to help businesses in the green transition, which necessitates businesses to adopt new technologies and activities that may be outside their routine operations. External support functions may provide expertise, funding, and guidance to help businesses navigate this transition and can assist in identifying opportunities, overcoming barriers and facilitating cooperation. While an organisational barrier that arose from our findings related to the lack of time to engage in symbioses (Bossilkov et al., 2005), other participants explained the benefits of collaborating as a tool to save time through collective problem-solving. Manager 8 (C5) summarises the need for comprehensive cooperation, and proposes how support functions, referred to as environmental architects, may assist the industry in their green transition, potentially reducing the time concern:

> Honesty is the keyword because if we can talk together and figure out what really is the best solution for Norway, or globally for that matter. The first step is to engage in these discussions, only then can we begin to structure a comprehensive approach. This necessitates the involvement of environmental architects, individuals who possess the understanding and the vision to recognise the best solutions. (Manager 8 (C5))

The environmental architects that Manager 8 (C5) mentions, aligns with the role of policymakers, academic and research institutions, and facilitators who can bridge the gap between different stakeholders, thereby creating a culture of collaboration (Dahl et al., 2018). They can help structure a comprehensive approach that considers the needs of the industry, the impact on the environment, and the broader societal implications. This further underscores the importance of a holistic approach beyond individual clusters (Liao et al., 2021). In conclusion, we suggest open dialogue and collaboration involving diverse stakeholders as significant to driving industrial symbiosis. Such an approach may prove beneficial in overcoming the identified barriers and promoting drivers, mainly related to the cooperative and competitive, institutional, technological, organisational, and informational factors.

5.4.3.2 Leveraging the Comparative Advantages of Western Norway

We further suggest that for successful industrial symbioses, industry actors must exploit the region’s natural resources, structural factors and expertise. Firstly, Western Norway possesses favourable natural resources, providing a foundation for maritime industrial processes. The region’s extensive coastline (Manager 3 (C2)) is favourable for industrial symbioses in maritime activities. Facilitator 1 further highlights access to minerals and hydropower as significant assets:

> Norway has many comparative advantages, among other, access to minerals. We have some natural advantages, including access to hydropower, which is very important and will become even more important in the future. It’s crucial that we are smart and think about how we can both preserve our natural and cultural landscapes and at the same time develop important industries. This will be decisive for how we, and especially Western Norway, succeed in the future. (Facilitator 1)

Moreover, Manager 8 (C5) points out the structural advantages of Norway, suggesting that: “Norway is kind of a giant laboratory. Because Norway is quite small. It is quite manageable, so it is possible to use Norway as a place where things are developed and tested out initially at a pilot level”. The country’s manageable size makes it an ideal “laboratory” for testing and developing new ideas and technologies on a pilot level. Teh et al. (2014) advocate for commercial technologies that require low costs and are simple to use. The ability to pilot initiatives on a smaller scale allows for identifying and mitigating potential challenges in the early stages of a project. Thus, Norway’s unique context provides an advantage in developing and implementing industrial symbiosis, as it enables testing and adaptation to ensure that technologies are cost-effective and user-friendly when they reach the market. Additionally, Managers 10 and 11 (C6) suggest that Western Norway holds a structural advantage in terms of its surplus power production, producing more power than what is consumed. This surplus enhances the region’s attractiveness for investment and provides a reliable energy source for industrial processes. Energy-intensive processes are a common feature of industrial symbiosis, and having a reliable power source is advantageous. However, power access is raised as a barrier to industrial symbiosis development by Grøn Region Vestland (2024) and some participants. This contradiction implies that local differences might exist in access to power. While it may be a comparative advantage for some, it could still pose a barrier for others.

Another advantage can be leveraged from the region’s rich oil and gas history. Western Norway holds strong expertise within the oil and gas sector, which can drive the green transition, according to Manager 1 (C1). By building upon established foundations, the region can repurpose or adapt the skills, knowledge, and infrastructure developed in the oil and gas sectors to green technologies. This might be related to technological and informational factors, reducing barriers to implementation as the technology needed might be less expensive or more accessible (UNIDO, 2011, referred in Teh et al., 2014; Yang et al., 2022b) while the necessary information (Heeres et al., 2004; Yang et al.,2022b) and expertise is already obtained. For instance, the expertise in managing complex supply chains in the oil and gas sector can be utilised to establish symbioses for the exchange of resources in maritime related industrial symbiosis.

In conclusion, Western Norway’s natural resources, structural advantages and industrial competence position it favourably in the green transition and present opportunities for leveraging these resources in industrial symbiosis. This recommendation relates to economic, technological, and informational factors, and power access. We advise industry actors to leverage these unique resources in their symbiosis initiatives to secure a competitive advantage. As Manager 1 (C1) suggests, “I believe that what determines who should do what, is the natural conditions that each actor possesses, which enable actors to conduct [these projects or initiatives] it in a cost-effective way” (Manager 1 (C1)). This quote implies that each actor should develop an approach based on its unique conditions and resources, thereby ensuring more cost-effective operations by leveraging its specific strengths. Such an approach may reduce the financial risks caused by industrial symbiosis, which may be substantial for small and medium-sized businesses (UNIDO, 2011, referred in Teh et al., 2014).

5.4.3.3 Engagement with Policymakers

Engagement with policymakers is a recommended solution to overcome identified barriers, including, but not limited to regulatory barriers (Yang et al., 2022b). Due to the overwhelming number of environmental laws (Heeres et al., 2004), uncertainty connected to the regulatory framework (van Beers et al., 2007) and policies that often do not harmonise with industry needs (Chiu & Yong, 2004), it is vital for the industry to communicate its needs and challenges to policymakers. Several participants pointed out this as a solution, emphasising that such interaction can shape policies and regulations to be more favourable to industrial symbiosis.

Manager 6 (C3) suggests that industry actors have a responsibility to express their needs to policymakers:

> We are currently in a critical phase of the project where we need to engage closely with four key departments (…). The purpose of these discussions is to address what we perceive as the current barriers to accomplishing the work at [Cluster 3]. The subsidies that we anticipate needing at [Cluster 3] do not align with the existing support scheme. However, we do not suggest tailoring a support scheme specifically for [Cluster 3]. We believe that the existing support scheme, which is functioning excellently, should continue as is, but it should be flexible enough to accommodate deviations. We are actively working on this and have received encouraging feedback. What is clear now is that it is up to us to establish a close relationship with the politicians and support functions and communicate our needs. In the past, we have been somewhat reluctant to do this. The approach has been more about sounding alarms. We need to change this approach and ensure that our needs and requirements are clearly articulated and understood. (Manager 6 (C3))

In this quote, the participant suggests that while Norway has a well-functioning support scheme that should continue, it should be more flexible to accommodate specific needs. By this, Manager 6 (C3) suggests a shift from a reluctance and alarm-raising approach towards a more proactive and communicative strategy, where industry actors should actively participate in policy development processes and advocate for policies that support their green initiatives, including industrial symbiosis. Since they are best conditioned to understand their own needs to succeed in the green transition, industry actors can ensure that their perspectives and insights are considered, resulting in policies that effectively address industry concerns. This can include policies incentivising collaboration, resource sharing and other symbiotic practices. For instance, Domenech Aparisi (2010) suggests a regulatory framework concerning pollution control as a measure that can build incentives for by-product exchanges. In contrast, some policies today do not harmonise with industrial innovation and may limit the emergence of industrial symbiosis (Chiu & Yong, 2004). Manager 3 (C2) further underscores the importance of industry actors actively participating in policy discussions and expressing their needs to policymakers. In the illustrated case, the companies in Cluster 2 took the initiative to contact politicians and propose a solution that would benefit their industry. This proactive approach allowed them to shape the discussion around the location of a public port and advocate for a solution that meets their needs:

> Bergen has a challenge as our container terminal is located in the city centre. The companies at [Cluster 2] contacted politicians in Bergen, proposing to relocate it near their industry, viewing it as advantageous to have a public port near their industry. (…) Usually, the public port attracts industry around it. (…) [The industry] would like to have the public port moved there because it would help them grow. Other businesses might establish themselves around this port, which would allow the already established industry to expand. (Manager 3 (C2))

Manager 9 (C5) and Facilitator 4 highlight the need for forward-thinking policymaking that addresses actual industry needs. They suggest that current regulations, often based on past or existing conditions, fail to anticipate future needs and developments and may not align with technological advancements (Chiu & Yong, 2004). A feasible solution to this concern is a proactive approach in policymaking to ensure that regulations are designed to accelerate, rather than hinder, future progress and ensure the future competitiveness of Norwegian industry. To achieve this alignment between industry needs and regulatory landscape, we recommend active engagement between industry actors and policymakers. We propose that this approach has the potential to address all of the factors identified from interviews with industry actors, as outlined in section 5.3.

5.4.4 Alignment of Thematic Selection with Research Objective

This section has offered insights and recommendations to aid Norwegian maritime clusters in their green transition through industrial symbiosis. Initially, the section identified four prerequisites for industrial symbiosis. These prerequisites serve as categories to group the identified drivers and barriers for industrial symbiosis, thereby providing a structured framework, illustrated in Figure 2. Moreover, insights and recommendations directly align with the identified drivers and barriers from our findings, aiming to provide suggestions that offer comprehensive solutions by simultaneously targeting several of the factors. These suggestions are mainly targeted at the industry actors but may also guide other stakeholders such as facilitators, politicians, and institutions. The selected sub-themes of insights, namely the potential benefits of being a first mover in industrial symbiosis and the significance of a maturing company culture and generational shift towards cooperation, are supported by research. Firstly, Chertow (2000) indicates that by engaging in symbioses, companies may create greater advantages than would be possible independently, and based on our findings, we further suggest that companies may reap benefits from being early movers. Moreover, Dahl et al. (2018) underscore that a cultural shift towards cooperation can facilitate the implementation of industrial symbiosis, and based on findings, this cultural shift appears to be emerging. Our action-oriented recommendations suggest that fostering a culture of cooperation and knowledge sharing, leveraging the unique resources of Western Norway, and active engagement with policymakers can facilitate the successful implementation of industrial symbiosis. The recommendation of a holistic approach to cooperation and knowledge sharing emphasises the importance of stakeholder collaboration (Liao et al., 2021). Leveraging the comparative advantages of Western Norway relates to our geographical scope, suggesting the benefits of exploiting local resources (Grøn Region Vestland, 2024) in promoting industrial symbiosis. Lastly, engagement with policymakers emerges as the most comprehensive recommendation, potentially impacting all identified factors from section 5.3. At the same time, it is primarily rooted in regulatory barriers where existing policies often do not align with industry needs (Chiu & Yong, 2004). Due to this misalignment, several participants raised the need for active dialogue between industry actors and policymakers.

5.5 Summary of Findings

This chapter has presented and analysed our findings concerning how Norwegian maritime clusters can succeed with industrial symbiosis practices. In this section, we summarise our findings, providing an overview of the key insights and implications for industrial symbiosis within Norwegian maritime clusters. Moreover, we present a summary of drivers and barriers illustrating their correspondence to literature and findings, and, lastly, our conceptual framework, which correlates the identified prerequisites, drivers, and barriers to insights and recommendations.

Our findings uncover a familiarisation with the term industrial symbiosis, per Chertow's (2000) understanding, while the implementation of symbiosis initiatives was less evolved than anticipated and not entirely in alignment with Chertow's (2007) "3-2 heuristic". However, we found that, in general, there exists a potential for symbiotic relationships. Moreover, we identified three objectives for participating in industrial symbiosis, aligning with the three pillars of technical innovation, collaboration, and sustainable business model innovation by Baldassarre et al. (2019). Following this, we found that the nature of industrial symbiosis does not necessarily restrict symbiosis initiatives to actors from the same sector. While most of the clusters indicated that they were in an early phase of symbiosis initiatives development, we found concrete examples of planned industrial symbiosis linked to hydrogen/ammonia production and land-based aquaculture in the maritime clusters. We also found that some clusters had implemented more general circular activities (Bocken et al., 2016; Ellen MacArthur Foundation, 2013; Baldassarre et al., 2019), which might hold the potential to develop into more symbiosis-like initiatives.

Moreover, we found that cooperation is a prerequisite for successfully implementing industrial symbiosis within maritime clusters. This cooperation extends beyond individual businesses to include diverse stakeholders, underscoring the importance of extended collaboration (Liao et al., 2021). The dynamics of cooperation and competition within these clusters are shaped by factors such as geographical proximity (Porter, 1998a; 1998b; Chertow, 2000) the role of facilitating organisations in fostering interconnection (Boons et al., 2016), the sharing of knowledge (Porter, 1998a; 1998b) and co-opetition (Brandenburger & Nalebuff, 1996; 2021). Our findings uncovered the dynamics between the need to remain competitive and the necessity for collaboration, which poses implications. Rather than taking advantage of the value of co-opetition, some actors may focus solely on their own areas of expertise, which may hinder industrial symbiosis initiatives. However, others are perceiving co-opetition as a matter of course, taking advantage of its benefits as a strategic approach for businesses to collaborate and innovate while maintaining competitiveness (Corbo et al., 2023).

Our study found a strong alignment between the drivers and barriers identified in our interviews and those found in existing literature related to implementing industrial symbiosis (Teh et al., 2014; Yang et al., 2022b) and circularity in the maritime sector (Barona et al., 2023; Okumus, 2023a). We uncovered that one of the main barriers to engaging in industrial symbiosis is related to economic factors (Yang et al., 2022b; Yeo et al., 2019) because it can involve substantial investments, making it a costly activity (UNIDO, 2011, referred in Teh et al., 2014). Market-related concerns, specifically the maturity of the hydrogen and ammonia markets and regulatory factors (Yang et al., 2022b; Teh et al., 2014), were also identified as significant barriers. Regarding drivers, the primary motivation for engaging in industrial symbiosis was primarily related to the desire to reduce emissions (Scaler Project, n.d.), thus environmental benefits (Domenech Aparisi, 2010), and comply with current and future regulatory requirements. Several identified factors could simultaneously unfold as a driver and barrier, presenting a complex situation for the clusters to navigate. Overall, we uncovered a larger focus on the barriers among participants.

Based on the factors identified in section 5.3, we offer insights and recommendations to enhance industrial symbiosis and advance the green transition in the maritime sector. The study also identified four prerequisites for industrial symbiosis related to these factors: cooperation, resource availability, knowledge and technology, and governmental support. Our findings highlighted two key insights that could guide businesses' symbiosis efforts. Firstly, being a first mover in industrial symbiosis can provide economic, environmental, and social benefits (Domenech Aparisi, 2010), allowing companies to implement sustainable changes ahead of others and attract cooperative partners (Teh et al., 2014). Additionally, maturing company culture and a generational shift towards cooperation can drive the adoption of industrial symbiosis through a collaborative environment (Liao et al., 2021). Moreover, we propose three recommended actions. Firstly, a holistic approach to cooperation and knowledge sharing involves fostering collaboration with diverse stakeholders (Liao et al., 2021). Such a cooperative landscape can promote knowledge sharing and understanding of shared needs, fostering industrial symbiosis (Boons et al., 2016). Moreover, leveraging comparative advantages, including natural resources, manageable size, and expertise in oil and gas, can provide a robust foundation for industrial symbiosis, facilitating the region's green transition and offering a competitive advantage for industry actors (Teh et al., 2014; Yang et al., 2022b). Engaging with policymakers can help overcome barriers, as government action needs to harmonise with industry needs (Chiu & Yong, 2004). Therefore, the industry needs to communicate its needs and challenges to policymakers. These insights and recommendations, grounded in our research findings, provide a roadmap for Norwegian maritime clusters seeking to implement industrial symbiosis as part of their green transition strategy.

5.5.1 Summary of Drivers and Barriers

Table 2 summarises the key drivers and barriers to industrial symbiosis and circularity within the maritime sector. The first column lists the drivers and barriers for industrial symbiosis as identified from the literature review in Chapter 2. The second column presents the drivers and barriers for circularity in the maritime sector, as presented in Chapter 3. The third column outlines the drivers and barriers for industrial symbiosis in the maritime sector as identified from the interviews conducted for this study.

Table 2 - Drivers and Barriers

Overview of drivers and barriers for (1) industrial symbiosis, (2) circularity in the maritime sector, and (3) factors identified from interviews with participants from Norwegian maritime clusters.

Drivers and barriers for industrial symbiosis (Chapter 2)	Drivers and barriers for circularity in the maritime sector (Chapter 3)	Identified drivers and barriers for industrial symbiosis in the maritime sector
Collaboration (driver)	Partnership and collaboration (driver)	Cooperative and Competitive factors
Geographical Proximity (driver)	Geography and asset tracking issues (barrier)	Cooperative and Competitive factors
Short mental distance (driver)	NA	Cooperative and Competitive factors
Environmental issues (driver)	Circular business models to implement for business sustainability (driver)	Environmental and social factors
Finance/Economic (driver/barrier)	NA	Economic factors
Laws and regulations/ Governmental (driver/barrier)	Regulatory and certification (barrier)	Regulatory factors
Institution (driver)	Incentive mechanisms (driver)	Institutional factors
Market (driver)	Perception and industry acceptance (barrier)	Market factors
Technology, research and development (driver/barrier)	Disruptive technology (driver)	Technological factors
Organisational (barrier)	NA	Organisational factors
Cognitive (barrier)	NA	Organisational factors
Motivational (barrier)	NA	Organisational factors
Informational (driver/barrier)	Low level of awareness (barrier)	Informational factors

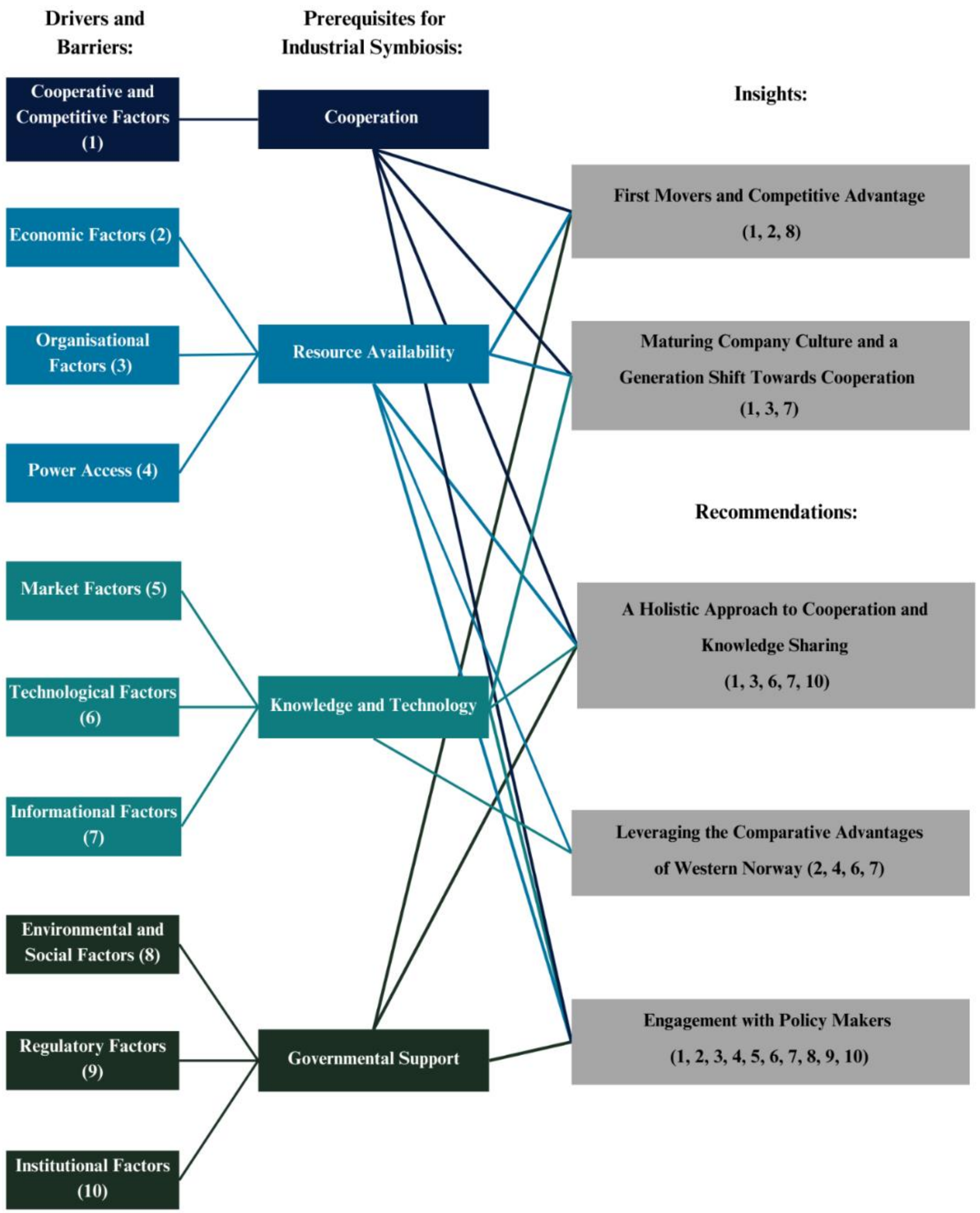
NA	NA	Power Access
Awareness and capacity building (driver)	Circular economy action plan and environmental plan (driver)	NA
Industry structure (driver)	NA	NA
Safety (barrier)	NA	NA
NA	Measurement tools (driver)	NA
NA	Long lifespan of vessels (barrier)	NA

Note. The table identifies similarities and differences in the drivers and barriers for (1) industrial symbiosis and (2) circularity in the maritime sector. 'NA' indicates that the factor was not addressed in the respective chapter (1) (2) or that it was not related to findings (3). 'Power Access' is a barrier identified for industrial symbiosis in the maritime sector that was not presented in the literature but emerged from documents published by Grøn Region Vestland (2024).

5.5.2 Conceptual Framework

Lastly, we present a conceptual framework that summarises the findings prominent in this chapter. The framework serves as a visualisation of the interplaying factors influencing industrial symbiosis. The four identified prerequisites form the backbone of industrial symbiosis, and we consider them necessary for its implementation. In relation to the prerequisites, we have identified drivers and barriers that can either facilitate or hinder the implementation of industrial symbiosis, and therefore need to be addressed effectively. To overcome the identified barriers and promote the driving factors, we propose a set of insights and recommendations. This framework serves as a roadmap for successfully implementing industrial symbiosis by understanding the interrelations between these elements.

Figure 2 - Conceptual Framework



6. Discussion of Findings

This chapter presents a discussion of our research findings by addressing the theoretical and practical implications, reviewing the study's limitations and introducing suggestions for future research. The theoretical implications explore how our research contributes to the existing literature on industrial symbiosis, while the practical implications discuss how our research can be applied in real-world contexts. Moving forward, we acknowledge the methodological limitations of our study and propose directions for future research.

6.1 Theoretical Implications

Our research supports existing literature on industrial symbiosis but narrows the focus to a maritime context and the perspectives of clusters located in Western Norway. The current body of research on industrial symbiosis in Norwegian clusters is notably limited, and our theoretical grounding is primarily based on international literature, as few examples of complete symbiosis exist in Norway. Our study fills these research gaps by offering insights into industrial symbiosis in Norwegian and maritime contexts. Following our research objectives, we specifically focus on its applications, the dynamics of cooperation and competition, and the drivers and barriers to its implementation. The fourth research objective offers insights and recommendations for Norwegian maritime clusters. While these findings are valuable in a practical context and offer specific, actionable strategies, their contribution to theoretical implications may be limited. Therefore, this research objective will not be explored in the context of theoretical implications.

6.1.1 Understanding Industrial Symbiosis in Maritime Clusters

In the following, we will discuss the applied industrial symbiosis definition, including the theoretical implications of this application, and we seek to explore why industrial symbiosis can be perceived as a dynamic process and draw parallels to the literature. Following this, we aim to discuss the implications of the three circular strategies: slowing, closing, and narrowing resource loops, rooted in our findings.

6.1.1.1 Industrial Symbiosis as a Dynamic Process

There are theoretical implications related to the definition of industrial symbiosis, thus what constitutes as industrial symbiosis according to literature. Referring to Chertow's (2007) "3-2 heuristic", which implies that basic industrial symbiosis involves at least three organisations and two resource exchanges, it could be argued that none of the clusters we studied can be directly categorised as industrial symbiosis engagers as of today. This is based on the findings from the interviews, as we did not identify symbioses involving three or more organisations within a cluster. We found occurrences of symbiotic relationships involving two actors exchanging one or two resources, which can be perceived as the beginning of a basic symbiosis in reference to Chertow (2007). The identified symbioses were mainly related to exchanging one resource at a time, for instance, utilising oxygen from hydrogen in a land-based aquaculture facility, or that fish sludge from land-based aquaculture could be used to extract scarce minerals, thus providing environmental benefits (Domenech Aparisi, 2010), by reducing sourced raw material (Scaler Project, n.d.). However, if a hydrogen facility provided a land-based aquaculture facility with a by-product, oxygen, and the aquaculture facility, in its turn, delivered fish sludge to a company that used the extracted mineral in its production, this would fall under a simple type of the "3-2 heuristic" (Chertow, 2007). This heuristic creates a tangible framework around industrial symbiosis, making the concept easier to understand, which is beneficial given that some participants described industrial symbiosis as a "high-flying" and vague concept.

While a cluster may not meet the requirements of the "3-2 heuristic" (Chertow, 2007), this does not diminish the value of the symbiosis initiatives we have identified. These initiatives can still lead to positive outcomes, like resource efficiency (Domenech Aparisi, 2010) and creating value from "waste" (Bocken et al., 2014). In the case of fish farming, phosphorus is a valuable resource that can be extracted from fish sludge. Thus, value is created from what is typically perceived as waste. If a fish farming facility provides phosphorus indirectly via fish sludge to a company for use in its production, this exchange may not technically meet the "3-2 heuristic" criteria (Chertow, 2007). However, it is a valuable symbiotic relationship as it represents a step towards reducing resource scarcity in accordance with Scaler Project (n.d.). Building upon this, if the production process that uses phosphorus generates surplus energy, this energy could potentially be transferred back to the fish farming facility. Some participants have already suggested that surplus energy could be used in land-based aquaculture. This illustrates that although these symbiosis initiatives may not meet the criteria of the "3-2 heuristic" (Chertow, 2007), they represent initial steps towards resource efficiency and hold the potential for further development into more advanced industrial symbioses. These smaller-scale symbiosis initiatives can also present environmental benefits (Domenech Aparisi, 2010) as exemplified by Scaler Project (n.d.) and Bossilkov et al., (2005). Therefore, we should not overlook the value and potential of the smaller, emerging symbiosis initiatives as stepping stones towards a circular economy (Ellen MacArthur Foundation, 2013).

Boons et al. (2016) describe industrial symbiosis as a process. This indicates that industrial symbiosis should be considered as an ongoing and dynamic process rather than a project with a definite end date. As our findings indicate, possible by-product exchanges have the potential to evolve continually and develop over time. In accordance with this, Chertow (2007) does not imply that symbiosis development ends once the "3-2 heuristic" is achieved. Instead, it serves as a starting point for further evolution by, for instance, including other actors or resources. However, achieving the heuristic can be challenging in practice. For instance, well-established clusters not necessarily created with symbiosis opportunities in mind will likely need to introduce industrial symbiosis initiatives gradually. This can be due to existing structures and practices within the company, which may relate to organisational barriers per Yang et al. (2022b), for instance related to organisational culture where the need for a cultural shift may be necessary. It may also connect to a lack of infrastructure or physical limitation of facilities. Our findings support the perspectives suggested by Boons et al. (2016), who suggest that industrial symbiosis is a process that has the potential to evolve and mature over time. On the other hand, it could be argued that new production facilities, which is the case in Cluster 6, could achieve the "3-2 heuristic" (Chertow, 2007) from the beginning if potential synergies are considered during the planning and construction phase. In other words, it could be designed and planned for industrial symbiosis from the initial phase, which contributes to eliminating potential barriers causing industrial symbiosis practices to evolve slowly. This approach corresponds with Baldassarre et al. (2019), suggesting that future research should explore how new clusters can intentionally be designed for industrial symbiosis purposes. Building on this, it could prove advantageous to perceive industrial symbiosis as a design project with an end date for a complete symbiosis rather than a gradually evolving process, although it is possible that such an approach can entail symbiotic practices that develop over time.

6.1.1.2 Industrial Symbiosis in Comparison to other Circular Strategies

Bocken et al. (2016) introduce three circular strategies: slowing, closing, and narrowing resource loops. Industrial symbiosis falls within the strategy of closing resource loops as a sustainable business model archetype for creating value from "waste" (Bocken et al., 2014). When comparing the three strategies, each strategy has advantages and challenges. The two strategies of slowing and narrowing resource loops, do not lead to the utilisation of by-products and are more concerned about the measures that can be taken into the production process instead of those that can be taken after it. An advantage of narrowing resource loops is that it can lead to economic benefits if fewer resources are used in the production, and a challenge is that it can be demanding to figure out how to decrease input factors. When it comes to slowing resource loops, an advantage is that it might be a more feasible strategy to implement, and a challenge, from a profit perspective, is that the number of products sold can decrease if the products last longer. Following this, a prominent benefit of closing resource loops is linked to the concrete usage of by-products in other production processes (Chertow, 2000; 2007; Boons et al., 2016). On the other hand, a challenge that may be more prominent in the strategy of closing resource loops, compared to the other two strategies, is the need for more complex collaboration. Teh et al. (2014) present collaboration as a vital factor for industrial symbiosis because exchanging by-products requires dialogue and interaction between companies. A concrete challenge concerning industrial symbiosis, is connected to a potential dependency on by-products (Bossilkov et al., 2005), and reliance on other actors (Brandenburger & Nalebuff, 2021). Such dependency is less prominent in the two other strategies because they involve less interaction.

As our findings primarily relate to industrial symbiosis initiatives in hydrogen production and land-based aquaculture, we can explore why a closing loop strategy (Bocken et al., 2016) was more prominent than other circular strategies. When valuable by-products are available, as in the examples of hydrogen production and land-based aquaculture, it seems reasonable to explore strategies for closing resource loops. This is because these by-products can be used in other production processes, thereby reducing waste (Ellen MacArthur Foundation, 2013; Scaler Project, n.d.; Bossilkov et al., 2005) and optimising resource use (Bocken et al., 2016), thus creating environmental benefits (Domenech Aparisi, 2010). On the other hand, the strategy of slowing resource loops, which involves extending the lifespan of a product, does not seem feasible as a strategy in land-based fish farming, as fish are consumable product intended for immediate consumption. Similarly, the strategy of narrowing resource loops, aimed at reducing resource usage in production, appears impractical considering that oxygen and water are required inputs for fish farming. Any significant reduction in water usage could have negative impacts on the production process, for instance in terms of water quality. These arguments strengthen the idea of adopting a strategy of closing resource loops in a fish farming facility, given the constraints associated with narrowing and slowing strategies. It indicates that the strategy of closing resource loops may have broader applicability in industries where by-products are generated.

6.1.2 Dynamics of Cooperation and Co-opetition in Industrial Symbiosis

We have found a complex interaction between cooperation and competition in developing symbiotic relationships within clusters. The balance between cooperation and competition adds a new aspect to the theoretical understanding of industrial symbiosis, presenting a theoretical dilemma: Is engaging in industrial symbiosis without co-opetition feasible? Moreover, a nuanced understanding of the role of facilitation, balancing the need for external guidance and internal motivation, can contribute to the existing theoretical framework for industrial symbiosis.

6.1.2.1 Striking the Balance of Co-opetition

Our findings suggest that the dynamics of cooperation and competition, co-opetition (Brandenburger & Nalebuff, 1996), can promote and hinder symbiotic relationships' development through its interplay. While cooperation is a prerequisite for industrial symbiosis (Chertow, 2000), enabling benefits more significant than those achievable through individual efforts via the exchange of by-products (Teh et al., 2014), our participants suggested that without cooperation, industrial symbiosis would not be feasible. This is due to factors such as geographic proximity (Teh et al., 2014; Porter, 1998a; 1998b), interconnection (Ehrenfeld & Gertler, 1997, referred in Domenech Aparisi, 2010; Porter, 1998a; 1998b), and knowledge sharing (Teh et al., 2014; Porter, 1998a; 1998b; Boons et al., 2016) acting as drivers for industrial symbiosis. Conversely, our findings underscore the role of competition within clusters, which, due to the collaborative nature of clusters (Porter, 1998a; 1998b), often presents itself as co-opetition. It would be illogical for cluster members to interact without some form of cooperation among them. However, companies may be hesitant to share resources or knowledge with potential competitors (Brandenburger & Nalebuff, 2021), for instance, due to identified implications related to information sharing, culture, and the regulatory landscape. While the literature primarily focuses on the presence or absence of co-opetition (Brandenburger & Nalebuff, 1996; 2021), rather than its inherent balance, it could be of importance to ensure the right balance between cooperation and competition. While excessive cooperation could lead to stagnation and a lack of innovation, an overemphasis on competition may hinder knowledge sharing and collaboration.

This discussion raises the question of whether it is feasible to engage in industrial symbiosis without the presence of co-opetition. On the one hand, the absence of competition within a cluster could foster greater information sharing and trust, driving resource exchange through industrial symbiosis (Teh et al., 2014; Domenech Aparisi, 2010). On the other hand, co-opetition stimulates innovation, which is also a key driver in the literature, as innovation drives technological development (Teh et al., 2014). The presented literature does not explicitly mention competition or co-opetition as drivers for industrial symbiosis. However, if co-opetition is necessary for driving innovation, it might be fair to imply its importance in promoting industrial symbiosis, thus working as an indirect driver. Porter's (1990) competitive advantage theory supports this by suggesting that the co-location of organisations in a cluster amplifies pressure to innovate due to an "intensely competitive business environment" (Porter, 1998b, p. 90). The extent to which this applies may depend on the context. As some participants suggest, direct competition might not naturally occur as two similar companies, and thus direct competitors, would not be established within the same cluster. However, a certain degree of co-opetition is likely present, even in the absence of direct competition. This is because companies within a cluster face similar resource constraints and are, therefore, to some extent, competitors, as our findings suggest. The dynamic of co-opetition could serve as a driver of industrial symbiosis by facilitating the sharing of resources and knowledge while maintaining a competitive environment (Brandenburger & Nalebuff, 2021).

6.1.2.2 The Role of Facilitation

The role of facilitation in fostering industrial symbiosis is a central aspect of our findings and opens for further theoretical exploration. Drawing upon the framework by Boons et al. (2016), our analysis suggests that the facilitator's role in the Norwegian maritime clusters shares similarities with two facilitation styles: collective learning facilitation and self-organisation. Collective learning facilitation underscores the importance of knowledge sharing and learning in promoting industrial symbiosis (Boons et al., 2016). In this context, third-party facilitators foster knowledge exchange and collaborative learning, thereby supporting companies in understanding the potential benefits and practical implementation of symbiotic relationships. This aligns with two of the prerequisites we have identified for industrial symbiosis: cooperation, and knowledge and technology. These prerequisites further associate with the theoretical drivers of information sharing and cooperation (Teh et al., 2014). In contrast, the self-organisation facilitation style suggests that industrial symbiosis is not a top-down process imposed by a single entity, the facilitator. Instead, it is a collaborative effort requiring involvement from various stakeholders, particularly the companies themselves (Boons et al., 2016). This style resonates with the expectation that companies are self-motivated and independently identify potential synergies and initiate connections incentivised by economic or environmental benefits (Domenech Aparisi, 2010). This corresponds with our findings, which show that motivation to engage in green initiatives among industry actors is strong, driven by environmental benefits although we find that the economic benefits have not emerged as a significant driver.

On the one hand, guidance and support from facilitators can provide the necessary push for industry actors to explore and implement industrial symbiosis. This aligns with Schlüter et al. (2022), who underscore the importance of a third-party facilitator when companies seek to engage in resource exchange. Without such assistance, the exploration of these exchanges might be overlooked due to barriers such as high costs and risks or lack of information (UNIDO, 2011, referred in Teh et al., 2014; Yang et al., 2022b; Heeres et al., 2004; Bossilkov et al., 2005). In contrast, one might argue that adapting to industrial symbiosis practices, involving efforts that may not yield profitable returns in the short run, demands a degree of self-organisation. This decision-making process cannot necessarily be externally imposed. Instead, it must be driven by the industry actors' intrinsic motivation. They need to be self-motivated (Boons et al., 2016) and recognise the potential benefits for themselves, for instance, the environmental benefits (Domenech Aparisi, 2010), which underscores the importance of individual initiative when engaging in industrial symbiosis. This balance between external support and self-motivation holds theoretical implications, as it challenges the understanding of facilitation styles in industrial symbiosis (Boons et al., 2016) and suggests a more flexible approach. Facilitation styles may need to adapt to the specific needs and characteristics of the clusters and how these factors evolve. In the two cases, Grøn Region Vestland and Symbiose Fjordane, the facilitators appear to hold an important role, which seems reasonable as these clusters are in the initial phase of their symbiotic efforts. However, the third-party facilitator might become less important in an established symbiotic relationship because the two companies would have already understood the processes, potential benefits and obstacles associated with industrial symbiosis. This understanding of the facilitator's role highlights the need to balance external guidance and internal motivation, and the importance of adapting facilitation strategies to the specific context and phase of industrial symbiosis development.

6.1.3 Drivers and Barriers Prominent in Norwegian Maritime Clusters

In this section, we aim to discover the interplay between the drivers and barriers, which holds theoretical implications, by highlighting the ones that were most prominent in our findings. In the interviews, there was a larger focus on the barriers than the drivers. The drivers and barriers identified in our study were primarily consistent with those outlined in the literature (Teh et al., 2014; Yang et al., 2022b) which were not presented with a specific location or sector in mind. This suggests that location or sector-specific factors may not significantly impact these drivers and barriers, as they remained relevant in our Norwegian and maritime context.

6.1.3.1 The Interplay between Drivers and Barriers

Our findings suggest a reinforcing relationship among the drivers of industrial symbiosis. Firstly, motivation can contribute to industrial symbiosis initiatives as indicated by the participants, thus obtaining environmental benefits (Domenech Aparisi, 2010). The environmental benefits serve as an initial driver, including a determination to implement green initiatives to remain competitive. In addition, we have identified that compliance with regulations can unfold as a driver of industrial symbiosis, in accordance with Teh et al. (2014). This can, in turn, influence the informational driver (Teh et al., 2014) by encouraging businesses to seek information, supporting the idea that there exists an interplay between the drivers. This motivation and determination to stay compliant is further sparking engagement in industrial symbiosis initiatives, which is demonstrated through the participants' voluntary involvement in the facilitating projects. As clusters become involved in these projects, which support them in their industrial symbiosis initiatives, information sharing is promoted, serving as an additional driver. Through this exchange of knowledge and experiences within the projects, in alignment with Boons et al.'s (2016) collective learning facilitation, clusters gain an understanding of the practices and potential of industrial symbiosis. The sharing of knowledge may further enhance awareness of the economic, environmental, and social benefits of industrial symbiosis (Teh et al., 2014; Domenech Aparisi, 2010). The environmental benefits, such as the reduction of greenhouse gas emissions and landfill waste (Scaler Project n.d.; Bossilkov et al., 2005), are often the most immediate and tangible outcomes, making them a key driver of industrial symbiosis initiatives. However, the social benefits, including job retention (Domenech Aparisi, 2010; Scaler Project, n.d.) and regional growth, also play a role, especially in the context of local community engagement. We have found a strong local culture that may enhance social benefits as a driver, as the clusters are motivated to contribute positively to the community. Moreover, the economic benefits (Domenech Aparisi, 2010), although not immediately apparent, may emerge over time as symbiotic initiatives lead to more efficient resource use and possible cost savings, adding another layer to the interplay of drivers. Thus, we notice that one driver, such as motivation, may influence another driver, information sharing, which further promotes awareness of economic, environmental and social benefits as drivers, hence there is a connection between them. As awareness increases, it can further reinforce motivation. In the literature, drivers such as motivation, information sharing, and awareness of benefits are discussed as separate entities influencing industrial symbiosis (Teh et al., 2014). However, our findings suggest that these drivers should not be perceived as isolated factors but as interconnected.

While the economic benefits (Domenech Aparisi, 2010) were highlighted by virtually no participants, economic concerns (Heeres et al., 2004) emerged as one of the most prominent barriers along with challenges related to regulatory factors (Yang et al., 2022b) and market factors. Economic barriers to industrial symbiosis (Yang et al., 2022b) are significant as they require the development of new, circular value chains, necessitating costly interventions and technology. For instance, establishing industrial symbiosis can involve significant costs related to new infrastructure for by-product transportation (Almasi et al., 2011, referred in Teh et al., 2014; Neves et al., 2020; Teh et al., 2014), implementation and operation of technological solutions and workforce training and competence development. It is, therefore, not surprising that the economic barrier turns out to be of great significance, but it is possible that such barrier can be reduced or reinforced by local frameworks surrounding research and development, technology, and regulations. In the extension of this, it was established that economic, market and regulatory factors (Teh et al., 2014; Yang et al., 2022b) are perceived by the participants as interconnected instead of being isolated barriers that must be overcome one at a time. The economic barriers will most likely not disappear on their own. Thus, it is necessary to introduce measures that can relieve the economic burden, for example through governmental support or stimulation of the market by introducing regulations. As noted by some participants, an imposed regulation can be necessary to encourage sustainable behaviour, but at the same time, it can hinder creativity and development if the regulations become overly constrictive. For instance, if a market, like the hydrogen market, cannot regulate itself, it is necessary to regulate it through legislation, such as taxes or fees, as highlighted by Teh et al. (2014). When a market is regulated, the purpose of the regulation follows the “carrot or stick” principle by either introducing incentive mechanisms (Barona et al., 2023; Domenech Aparisi, 2010) or introducing bans. Regulating a market using incentive mechanisms can affect businesses’ participation in the respective market development, which in turn can advance the market’s maturation, which again can reduce the economic barrier. The Enova support scheme is a concrete example of such incentive mechanisms highlighted in the interviews. Furthermore, the EU supports a substantial number of projects, however, accepting support is rarely without reservation and can paradoxically impose an economic risk. Overall, economic, regulatory and market barriers are significant because they directly influence the economic and legal feasibility, as well as market acceptance (Okumus et al., 2023a) of industrial symbiosis. Nevertheless, it is not plausible that a single driver is enough for a cluster to engage in symbiosis initiatives successfully. On the other hand, one single barrier can ultimately hinder engagement, potentially explaining the greater attention towards the barriers instead of the drivers. The literature separately presents the drivers (Teh et al., 2014) and barriers (Yang et al., 2022b) without further discussing exactly how they relate. Therefore, assessing the interplay between the drivers, and evaluating the connection between the barriers, can be beneficial as it may help actors to navigate in a complex business landscape.

6.1.3.2 Drivers and Barriers Spesific to the Norwegian and Maritime Context

Our findings suggest that drivers and barriers to industrial symbiosis are not explicitly sector- or location-specific, indicating the existence of some general factors as presented by Teh et al. (2014) and Yang et al. (2022b). However, we do acknowledge the presence of context-specific drivers and barriers. A notable example from our study is power access, which emerged as a factor impacting the clusters. Although not widely discussed in the literature, power access was identified as a barrier in our study, highlighted in a report by Grøn Region Vestland (2024). This suggests that power access can be a location-specific factor, particularly relevant in Western Norway, while not necessarily as relevant in other regions or countries. Depending on whether a cluster has sufficient power access, this factor can act as a driver or a barrier to industrial symbiosis. However, most participants perceived it as a barrier rather than a driver.

In the context of industrial symbiosis, a lack of sufficient power could hinder the production of certain products or diminish the willingness of new establishments to fit into an existing symbiosis. For instance, if a company lacks enough power to produce hydrogen, this can impact companies' dependence on such by-product. As emphasised by several participants, power access is a necessity in the green transition and emerges as a location-specific factor impacting industrial symbiosis initiatives in Western Norway. Our findings underscore the importance of considering location-specific factors in addition to general factors (Teh et al., 2014; Yang et al., 2022b) when examining the drivers and barriers to industrial symbiosis.

Following this, we consider context-specific drivers and barriers in a maritime context. The drivers and barriers for circularity in the maritime sector, as presented by Barona et al. (2023) and Okumus et al. (2023a) largely align with the drivers and barriers for industrial symbiosis (Teh et al., 2014; Yang et al., 2022b) identified in the study, as illustrated in Table 2. Only three of these maritime sector-specific drivers and barriers were not identified, indicating a significant overlap between the two contexts. This overlap is not unexpected, given that industrial symbiosis is a circular business model strategy (Baldassarre et al., 2019; Bocken et al., 2014), and therefore, the drivers and barriers for circularity and industrial symbiosis are likely to share similarities. Moreover, our findings suggest that sector-specific factors do not have a major influence, which further explains the similarities with the general drivers and barriers for industrial symbiosis (Teh et al., 2014; Yang et al., 2022b). Barona et al. (2023) consider disruptive technology as a driver for circularity in the maritime sector, suggesting that technological innovations can enable the implementation of circular business models and assist in closing material loops. This correlates with Teh et al.'s (2014) identification of technology as a driver for industrial symbiosis. On the other hand, some barriers are unique to the maritime sector. For instance, the long lifespan of maritime vessels can hinder circular initiatives (Okumus et al., 2023a). This barrier may explain why we did not identify symbiotic initiatives on ships or other floating units, as offshore operations might face challenges that are specific to such activities. Given our broad definition of the maritime sector (Kvamstad-Lervold et al., 2019), we have included land-based maritime activities. According to our findings, establishing symbiotic relationships might be easier in land-based settings. This suggests that the feasibility of industrial symbiosis can vary across different contexts within the same sector, highlighting the need for tailored strategies to assess the importance of drivers and barriers in a specific context.

6.2 Practical Implications

Our research holds practical implications for implementing industrial symbiosis, particularly for clusters located in Western Norway. The study is grounded in the maritime context, a sector increasingly recognising the need for sustainability and circular economy strategies. While our findings are rooted in this context, the implications could apply to other sectors and regions exploring industrial symbiosis. In the following, we will discuss the most prominent practical implications based on our findings. Firstly, by suggesting how industry actors may integrate industrial symbiosis in their operations, the role of cluster collaboration in promoting the green transition, the future implications of drivers and barriers, and lastly, we offer insights and recommendations for businesses considering investing in industrial symbiosis. We aim to provide an understanding of the practical challenges and opportunities associated with industrial symbiosis.

6.2.1 The Integration of Industrial Symbiosis in Maritime Clusters

In this subsection, we discuss the potential reasons why our findings are predominantly linked to land-based maritime activities, and the practical implications of this. Moreover, we explore the strategic integration of industrial symbiosis into business models as a part of the core business activity or as a side business activity. Through this discussion, we aim to provide an understanding of these aspects, enabling businesses to incorporate industrial symbiosis into their operations.

6.2.1.1 Exploring Industrial Symbiosis in the Intersection of Sea and Land

In our findings, we did not identify industrial symbiosis initiatives in traditional maritime activities, for instance related to ships and ports. Concerning symbioses on ships, our findings suggest that dynamic movement inherent in offshore activities could serve as a barrier. This can further relate to barriers such as the long lifespan of maritime vessels (Okumus et al., 2023a) and regulations not favouring remanufactured or reused items (Milios, 2019), which might make industrial symbiosis on ships more challenging. Additionally, the dynamic nature of ships, with their lack of fixed location and extensive supply chain, complicates recycling efforts and communication (Okumus et al., 2023a), thus creating infrastructure and collaborations for industrial symbiosis might be challenging. Nonetheless, some participants mentioned the potential for circular strategies on ships, such as utilising surplus energy in the specific context of production vessels. While there is limited literature on symbiosis involving ships, symbioses in ports are more common (Ceylani et al., 2022). Ports may play a significant role in industrial symbiosis, considering that ports can impact the surrounding environment negatively and positively, with waste management as the most prominent challenge in seaports (Cerceau et al., 2014). According to our findings, maritime clusters usually have port facilities, but we discovered no current symbiosis initiatives concerning ports during our discussions with participants involved in port activities. However, we discovered that shore power had a significant potential to provide environmental benefits (Domenech Aparisi, 2010) by reducing GHG emissions (Scaler Project, n.d.). As presented in subsection 5.1.5, the participants discussing port activities did not own their waste. Thus, there exist a lack of resources, which we identified as a prerequisite for industrial symbiosis. This can explain why we did not identify any symbioses in this context. Our participants, suggested that clusters need to assess which circular strategies can yield the greatest benefits, noting that the objective should not be industrial symbiosis in itself, but rather decarbonisation. Thus, other circular strategies could be initiated in ports if they are perceived as more beneficial options. This discussion indicates that the circular activities that deliver the best results in terms of economic, environmental and social benefits (Domenech Aparisi, 2010) should be chosen.

According to Liao et al. (2021), some researchers claim that there is limited inter-industry interaction in maritime clusters. However, our findings highlight industrial symbiosis initiatives across industries, particularly related to hydrogen production and aquaculture. These initiatives were perceived by some participants as low-hanging fruits, and more feasible industrial symbiosis initiatives than those related to offshore operations. This may be explained by geographical proximity (Chertow, 2000; Teh et al., 2014), where co-location is more feasible to obtain in land-based maritime activities than in offshore activities. Our findings suggest that geographical proximity is beneficial for symbiotic initiatives, which aligns with Chertow (2000), proposing that a common approach to achieving industrial symbiosis is through co-location. Our findings underscore the importance of adopting a balanced approach to industrial symbiosis that targets both easily achievable goals and long-term strategies. Thus, we propose an initial focus on the industrial symbiosis initiatives on land because they present lower barriers and are feasible to undertake in the short term. It is easier to connect industries with each other, which in its turn can create more complex synergies (Teh et al., 2014). Given the barriers that complicate industrial symbiosis initiatives on ships (Okumus et al., 2023a, Milios, 2019), land-based symbioses may be more realistic in the near future. In the long term, as identified barriers are eventually diminished, clusters could consider more challenging symbiosis initiatives that include both sea-based and land-based industries, such as those involving ship-related operations.

6.2.1.2 Strategically Integrating Industrial Symbiosis into the Business Model

Another consideration that emerges from our findings is how industrial symbiosis can be strategically integrated into a company's business model (Osterwalder et al., 2005; Ellen MacArthur Foundation, 2013). As Lüdeke-Freund et al. (2019) suggest, sustainable business models incorporate environmental and social considerations. Industrial symbiosis can serve as a sustainable business model strategy, given the social and environmental benefits we have identified (Domenech Aparisi, 2010). Our findings suggest that the decision to engage in industrial symbiosis can be driven by three interests: possessing a surplus resource, needing a surplus resource, or facilitating the conversion/exchange of a surplus resource between businesses. In the extension of this, we will further elaborate this in the light of Baldassarre et al.'s (2019) three pillars on how industrial symbiosis relates to circular business models. Firstly, the actors that need a surplus resource engages in technical innovation, in the sense that surplus resources or waste are exchanged through such an innovation (Baldassarre et al., 2019). It is possible to include actors who are providing a surplus resource, as an exchange process requires one of each type of actor: an actor needing a resource and an actor possessing the resource. Baldassarre et al. (2019) relate the second pillar, collaboration, to identifying the stakeholders involved in the symbiosis. The argument as to why the actor providing a surplus resource can be categorised in the collaboration pillar is in the sense that without such a surplus resource, there would not be anything to collaborate about, more specifically, without a surplus resource, there would not be a need even to identify stakeholders, this contributes to our identification of resource availability as a prerequisite for industrial symbiosis. Industrial symbiosis can be integrated into a business in a way that resembles a side activity. To build upon this, we can argue that the engagement in industrial symbiosis will often serve as a side activity, whereas the core activity for an actor providing or needing a surplus resource will still be producing and selling the final products.

Secondly, the businesses that facilitate the exchange of by-products, inherently connects to sustainable business model innovation, thus the third pillar (Baldassare et al., 2019). This link can be understood as a business integrating its business model around industrial symbiosis, perhaps through its technological solutions. Baldassarre et al. (2019) underline that this type of innovation relates to eliminating the concept of waste. Providing a technological solution can facilitate the exchange of by-products, indicating that the technology's users can experience innovation regarding their business model. Moreover, the development of technology facilitating the conversion of by-products is most likely the company's core business activity. Hence, if the business sells its technical solution to facilitate for industrial symbiosis, it further substantiates that industrial symbiosis is a part of the core activity. While this approach may present a higher financial risk due to the uncertainty of how industrial symbiosis will evolve, it also offers the potential for higher profits if industrial symbiosis becomes more prominent in the future. In conclusion, we propose that businesses may incorporate industrial symbiosis as a core activity or side activity in their business model. This choice has significant implications for the company's strategic direction as it poses varying financial risks and profits.

6.2.2 Is Cluster Collaboration Promoting the Green Transition?

Moreover, we examine the role of cluster collaboration in promoting the green transition, discussing the positive aspects, such as innovation and information sharing, which can drive industrial symbiosis, and the negative implications, like over-reliance and silo mentality, which may entail that clusters do not engage in green initiatives due to lacking innovation and development. This examination leads us to question whether cluster cooperation drives industrial symbiosis in a real-world context. These insights are relevant as they can guide clusters in fostering effective collaboration and overcoming potential obstacles in implementing industrial symbiosis.

6.2.2.1 Cluster Collaboration as a Driver

Dahl et al. (2018) emphasise the significance of a robust collaborative culture among cluster members, whereas such a culture can assist actors in transitioning to a circular economic mindset. Hence, collaboration in clusters can be a driver for successfully implementing industrial symbiosis (Teh et al., 2014). A key identified aspect of cluster collaboration is the exchange of knowledge, which can enable the sharing of innovative practices, enhance problem-solving capabilities and bridge knowledge gaps (Porter, 1998b). Companies within clusters are encouraged to actively participate in knowledge exchange, which can lead to new opportunities for symbiotic relationships. One practical implication derived from our findings is the need for strategies to foster stronger inter-industry relationships within maritime clusters to promote the exchange of knowledge, which can be achieved through a holistic, collaborative approach as proposed in subsection 5.4.3.1. However, this necessitates mechanisms to prevent unintended knowledge spillovers and define knowledge-sharing boundaries. These mechanisms could be formal, such as intellectual property rights, or informal, like relationships of trust (Rouyre & Fernandez, 2019). On one hand, formal mechanisms may be easier to implement due to their precise structure. On the other hand, informal mechanisms like trust could hold greater power as they become integrated into the business culture. Although building such a culture may be challenging and time-consuming, our insights suggest that the generational shift is driving a change in business culture. This shift might foster the development of trust, which could enhance knowledge exchange within the clusters and among surrounding stakeholders, further driving the green transition. Additionally, Porter (1998b) suggests that proximity fosters improved coordination and trust, while Boschma (2005) proposes that trust-based relationships are driven by interconnection. Thus, considering that geographical proximity and interconnection are integral to the cluster concept (Porter, 1998a), this could imply that cluster collaboration is driving the formation of trust.

6.2.2.2 Cluster Collaboration as a Barrier

Potential obstacles to collaboration within clusters should be considered in the context of industrial symbiosis. One concern we draw from our findings is the risk of over-reliance on cooperators within the cluster, which may relate to what Brandenburger and Nalebuff (2021) call collective action. An implication of our findings is the similarity in the insights from the participants. While this cohesion could be beneficial due to the knowledge exchanges, potentially driving innovation and green initiatives within the clusters (Corbo et al., 2023), it also presents a potential pitfall. The common perception among firms in cooperative initiatives might be influenced by the views of other actors, leading to an over-reliance. This over-reliance could foster a silo mentality, where businesses become excessively focused on shared solutions and initiatives within the cluster, potentially dismissing broader innovation. However, as Boschma (2005) points out, geographical proximity alone is insufficient for firms to benefit from knowledge spillovers. Excessive proximity is unlikely to facilitate learning and innovation. This suggests that while close collaboration within a cluster can offer advantages, there is a need for a balanced approach that also encourages external interactions and independent initiatives. Companies becoming overly dependent on their cooperators or facilitators (Brandenburger & Nalebuff, 2021) could hinder problem-solving, leading to contentment and reduced efforts to develop new solutions. Businesses might assume that others are leading the green initiatives, making it easy for them to follow. However, this could reduce the pace of green initiatives, as companies may become passive followers rather than active initiators, resulting in a lack of proactive action. This issue is further complicated by the dynamics of power and influence within the cluster. Larger businesses, so-called anchor tenants (Teh et al., 2014) might steer its direction in terms of operations, activities, and investments, potentially at the expense of smaller businesses or broader environmental goals. Given the potential implications of silo mentality and over-reliance, cluster members need to balance between collaboration and independent action. While cluster collaboration can offer benefits and drive green initiatives, businesses should also maintain an individual focus to avoid relying too strongly on their collaborators.

6.2.3 Future Implications of Drivers and Barriers

In this subsection, we discuss factors that may strongly influence the future progression of industrial symbiosis initiatives. Firstly, we delve into the technological aspect of industrial symbiosis, where technological challenges are likely to become more prominent, and the need for investment in technology and complementary policies will become increasingly evident. We also discuss the practical implications of perception and industry acceptance of circular principles, whereas a holistic approach to cooperation and knowledge sharing could foster a broader understanding and acceptance of circular principles in the industry.

6.2.3.1 Addressing the Technological Implications

As identified in the literature, technology can unfold as a driver and a barrier for industrial symbiosis (Teh et al., 2014; Yang et al., 2022b). On the one hand, technology is essential for implementing industrial symbiosis, as it requires specialised solutions, such as the transportation of by-products from one location to another. We have identified knowledge and technology as a prerequisite for industrial symbiosis and one could argue that technology is needed for the exchange of by-products (Bossilkov et al., 2005; van Beers et al., 2007). On the other hand, the participants did not perceive technology as a significant factor, possibly because they had yet to reach a point where technological solutions were being discussed in detail. This could be due to the early phase of industrial symbiosis in these clusters, making it difficult to view technology as a barrier (Yang et al., 2022b) without a detailed plan for by-product conversion. Another possible explanation as to why technology was not viewed as a significant factor for the participants could be due to Western Norway's comparative advantages in the maritime sector, including maritime expertise, structural characteristics, and existing infrastructure, perhaps indicating that there is a belief that the technological solutions will be present once the planning of initiatives advances. However, we anticipate that once the clusters advance in their symbiosis initiatives, the cost of technological solutions may be perceived as a significant barrier, and according to UNIDO (2011, referred in Teh et al., 2014), such a financial commitment is prominent for small and medium-sized businesses. As a participant highlighted, several small actors exist in a particular region in Western Norway, indicating that this issue is relevant for some local actors. From a practical standpoint, this can be mitigated by governmental support (Teh et al., 2014), another prerequisite we have identified for industrial symbiosis. As indicated by some participants current regulatory conditions may not align with technological advancements (Chiu & Yong, 2004), and in some cases, regulations may even hinder further technological progress. Thus, there has to be a balance between introduced regulations and how they relate to the technological advancements of the actors they affect. The technological implications can be addressed through engagement with policymakers, which we have enhanced as a recommended action because regulatory factors can impact technological development. Engaging with policymakers opens up a two-way communication channel between industry actors and policymakers.

6.2.3.2 Perception and Acceptance of Circular Principles

Another practical implication of our study relates to how circular principles are perceived among industry actors and stakeholders. This relates to Okumus et al. (2023a), who suggest the barrier of perception and industry acceptance of circular practices. In Table 2, we categorised this barrier as a market factor. We draw this parallel from Teh et al. (2014), who propose that stronger awareness and demand for greener products work as a pull factor for developing industrial symbiosis. Therefore, we suggest that this factor may serve as a driver and as a barrier. While market factors were highlighted as a driver among participants, they were not explicitly mentioned as barriers. Industry actors may express concern about the quality and safety of remanufactured or reused items in accordance with Okumus et al. (2023a), reflecting cognitive barriers to implementing industrial symbiosis (Ehrenfeld & Gertler, 1997). Furthermore, perception and acceptance align with the safety barrier identified by Yang et al. (2022b), which suggest that businesses need to assess the appropriate use of by-products, considering potential environmental and health concerns (Chertow, 2007). Consider a hypothetical scenario where a company wants to engage in industrial symbiosis to gain environmental benefits (Domenech Aparisi, 2010). If involvement in a by-product exchange negatively impacts the quality of the final product, this may lead to problems regarding responsibility. For instance, industry actors or even consumers might be sceptical about whether the by-products from hydrogen production, utilised in land-based fish farming, could negatively impact the quality of the fish, causing potential economic obstacles to the owner of the aquaculture facility or health concerns for consumers. Such scepticism about circular principles can also relate to market maturity. While Teh et al. (2014) propose that the demand for greener products can serve as a pull factor for industrial symbiosis, we identified market demand as a potential barrier. If organisations are hesitant to use by-products, it can hinder the development of a market for these materials, thus acting as a barrier to industrial symbiosis.

We suggest two explanations for why the participants did not raise concerns about industry acceptance of circular practices (Ellen MacArthur Foundation, 2013). On the one hand, their involvement in symbiosis projects and demonstrated commitment to sustainability already suggest a certain level of faith in circular practices. This aligns with the finding that trust among competitors in a cluster is necessary for driving innovation, and Domenech Aparisi (2010) proposes that trust between actors can lead to reduced transaction costs, risk, and uncertainty in the exchange of by-products. On the other hand, implications related to industry acceptance may have been overlooked because the actors are in the initial phases of industrial symbiosis development, where they have not yet started to exchange by-products. However, it could present itself as an obstacle in developing of industrial symbioses. To overcome this, it would be beneficial to address these issues proactively. As recommended, a solution could involve holistic cooperation and knowledge sharing, educating stakeholders about the controls and safety measures (Yang et al., 2022b) associated with industrial symbiosis, or showcasing successful examples as suggested by Boons et al. (2016). In this context, the distribution of knowledge and information (Teh et al., 2014) about industrial symbiosis among stakeholders could play a role in building trust and further maturing the market. By promoting transparency and open communication, industry actors can collectively reduce barriers to acceptance. This approach can help ensure that the transition towards industrial symbiosis is not only theoretically feasible, but also socially and economically sustainable in reference to the triple bottom line (Jørgensen & Pedersen, 2018; Domenech Aparisi, 2010).

6.2.4 Final Insights and Recommendations: Industrial Symbiosis and the Green Transition

Building on the insights and recommendations presented in section 5.4, this subsection explores whether industrial symbiosis is necessary for succeeding in the green transition. This question has practical implications for companies considering investment in industrial symbiosis, and our aim is to provide insights and recommendations that can guide companies in their strategic planning and implementation processes.

6.2.4.1 Is Industrial Symbiosis Necessary for Succeeding in the Green Transition?

Our research uncovers a strong motivation and commitment among industry actors to adapt to the changing business environment, driven by the climate crisis and the expectation for businesses to contribute to the green transition. This commitment is reflected through various initiatives, including those related to industrial symbiosis, enhancing resource efficiency by creating value from "waste" (Bocken et al., 2014). However, we acknowledge that industrial symbiosis alone may not be sufficient for a successful green transition within the maritime sector or other sectors, which will likely require various strategies (OECD, 2021, referred in Cedergren et al., 2022). While industrial symbiosis can initiate the exchange and reuse of waste and by-products among companies (Chertow, 2000), reducing the demand for virgin materials and decreasing waste generation (Scaler Project, n.d.; Ellen MacArthur Foundation, 2013; Bossilkov et al., 2005), it is not the only solution. Other green practices, for example the adoption of renewable fuel sources such as hydrogen and ammonia, as highlighted by some participants, are also integral to reducing the vast emissions of the maritime sector (Morante, 2022; IMO, 2023). In alignment, our findings suggest that the participating clusters consider industrial symbiosis as part of a larger picture. Some of the clusters have initiated projects to produce green hydrogen and ammonia while utilising the by-products. This dual approach contributes to producing green energy sources and promotes resource efficiency by finding uses for by-products. While industrial symbiosis holds the potential for emission reduction through waste mitigation, it should be viewed as part of a broader, multi-faceted approach to sustainability. Thus, the green transition will likely require a combination of strategies, where industrial symbiosis plays a central but not exclusive role.

6.2.4.2 Is it Worthwhile Investing in Industrial Symbiosis?

The decision for industry actors to invest in industrial symbiosis involves complex considerations. As suggested by Barona et al. (2023), industrial symbiosis is more likely to emerge when its economic and environmental benefits are evident. Our findings reflect this, with businesses gradually integrating industrial symbiosis practices into their operations, primarily due to perceived environmental benefits (Domenech Aparisi, 2010). Real-world examples from the maritime sector, such as the implementation of industrial symbiosis in ports like Rotterdam and Amsterdam, demonstrate how waste management challenges can be transformed into collaborative opportunities. These examples highlight the potential benefits of industrial symbiosis (Barona et al., 2023). Our study has also found that being a first mover in industrial symbiosis can offer benefits, including economic gains, reputational advantages, and the possibility to secure partnerships (Domenech Aparisi, 2010; Teh et al., 2014). However, the future of industrial symbiosis, like other green initiatives, is uncertain. It is impossible to predict which technologies, strategies or initiatives will emerge as the winners in the green transition. There is a risk that industrial symbiosis could become a buzzword, eventually replaced by more competitive circular economy strategies (Bossilkov et al., 2005), some of which might not even exist today.

Given the complexity of identified drivers and barriers and their interactions, it is worth questioning whether it is possible to succeed with industrial symbiosis. Some participants noted that very few complete symbioses exist today and building them has taken several decades. This actuality underscores the risks and complexities which might hinder investment in industrial symbiosis (Heeres et al., 2004; Yang et al., 2022b). Businesses must weigh the decision to adopt a risk-averse strategy, waiting for the market to mature or for regulatory action (Teh et al., 2014; Yang et al., 2022b), against the option to adopt a risk-willing strategy by being a first mover. The former approach might mitigate the risk of investing in an initiative that does not evolve as expected, but it could result in missing out on first mover advantages. The latter approach might entail higher risks and the potential for greater rewards if successful. While investing in industrial symbiosis presents potential risks and rewards, a strategic approach can help industry actors navigate uncertainties. Businesses must make decisions based on risk tolerance, strategic objectives, and confidence in different initiatives in the green transition. Additionally, when deciding whether to invest in industrial symbiosis, one should consider the prerequisites identified in subsection 5.4.1: cooperation, resource availability, knowledge and technology, and governmental support. The prerequisites are based on the factors driving and hindering industrial symbiosis, which our insights and recommendations build upon. Companies should assess their current situation and future prospects concerning these factors, which may either promote or hinder their success in implementing industrial symbiosis.

6.3 Limitations

In this section, we discuss the potential limitations of our thesis. We elaborated in Chapter 4 on the exploratory nature of the research, along with a qualitative data collection based on a case study, which was the most fitting way to answer our research question. Nonetheless, the chosen research design presents several limitations. In the introductory chapter, we presented the overarching delimitations functioning as the foundation for the thesis, and in this section, we will discuss the methodological limitations. Given the thorough review of our research design in Chapter 4, we refer to this chapter where we deem it necessary.

6.3.1 Time and Resource Constraints

By its design, this research is a cross-sectional study, thereby providing findings contextualised within a specific time frame (Saunders et al., 2019). As such, the research represents a snapshot of the current state of industrial symbiosis, with the potential implication that it may not account for future changes within the dynamic field of industrial symbiosis. Consequently, the practices, drivers and barriers we have identified are specific to the time the study was conducted and may not remain valid as circumstances change over time. This limitation is relevant given that the participants are in an initial phase of industrial symbiosis development. Thus, it would be beneficial to conduct longitudinal studies (Saunders et al., 2019) to assess changes and progress in industrial symbiosis initiatives over time, as further discussed in subsection 6.4.2 Moreover, due to time and resource constraints, the study was limited to a mono-method approach, particularly semi-structured interviews with 15 participants. While this method provided profound insights, it also imposed limitations concerning the breadth of the data collected. A larger, more diverse participant selection might have offered a wider range of perspectives and experiences, thereby increasing the transferability of our findings to other clusters. Additionally, the study is sector-specific, focusing solely on maritime clusters. While this provides in-depth insights into this particular sector, it may limit the generalisability of the findings. As we have identified, industrial symbiosis often transcends sectorial boundaries, and future studies could benefit from exploring its implementation across sectors. However, this could make the research process more time- and resource-demanding. Another limitation concerning our mono-method approach is the lack of data triangulation (Saunders et al., 2019; Yin, 2014), where we did not employ a multi-method qualitative study (Saunders et al., 2019). As such, our findings derived from a singular data collection method, semi-structured interviews, without the benefit of triangulation through multiple methods. A multi-method study, incorporating, for instance, surveys or observational studies, could provide a more nuanced understanding of industrial symbiosis implementation. This brings forward a limitation concerning credibility.

6.3.2 Participant Selection and Statistical Significance

We prioritised diversity over depth in our selection, choosing to interview participants from multiple clusters rather than focusing on a single cluster within each case. The context-specific nature of this study means that our findings are largely related to the two cases we interviewed. Therefore, the results might not be the same if we interviewed other cases. This is a common limitation in qualitative research, especially in case study research, where the depth of understanding about a specific context is prioritised over breadth (Saunders et al., 2019). We included two cases, given the limitations of a single case study, which is a strength according to Meyer (2001). Nonetheless, the limited selection of participants in this study may raise concerns regarding the transferability of our findings, as we cannot draw statistical generalisations based on the entire population (Saunders et al., 2019). However, Saunders et al. (2019) argue that transferability in qualitative research is linked to the ability to test and relate to existing theory. Given that our findings substantially support existing theory, they exhibit broader theoretical significance. Our study’s context within the maritime sector, along with our finding that industrial symbiosis blurs sectorial boundaries, suggests potential transferability of our findings to other sectors. Through our selection of participants, we aimed to include a wide range of perspectives, thereby providing a varied understanding of industrial symbiosis. However, this approach also presented certain limitations. We interviewed between one and four participants from each cluster, which may present an imbalance or over-representation of perspectives from certain clusters. This could potentially affect the credibility of the findings, with the risk of certain views or experiences dominating the results. Furthermore, we did not have the opportunity to interview all actors within a cluster, which might have limited our ability to gain a comprehensive understanding of each cluster's dynamics. This limitation could affect our ability to draw conclusions on behalf of the entire cluster.

6.3.3 Errors and Biases

Errors and biases relate to data quality aspects of dependability and confirmability. The use of qualitative methodologies in this study, while offering rich and detailed insights, is subject to the researchers' interpretations and potential biases (Saunders et al., 2019). This is a common characteristic of qualitative research, particularly in exploratory studies where the aim is to explore complex phenomena and uncover underlying patterns. Thus, the findings may not be universally applicable and should be understood within the context of the research setting. This is because the data is drawn from a specific sample, maritime clusters in Western Norway, and analysed based on the researchers' understanding and interpretation. In terms of dependability, the use of semi-structured interviews can introduce concerns related to lack of standardisation (Saunders et al., 2019). The interview questions have been adjusted as the study progresses, which can lead to inconsistencies in the data collected. Different participants may face slight variation in the questions asked during interviews, which can make it challenging to compare and analyse the data. Furthermore, Saunders et al. (2019) emphasise how the first minutes of an interview can set the tone and direction for the conversation, which can influence the outcomes. This element relates to interviewer and interviewee biases (Saunders et al., 2019), which can be regarded as a limitation. Additionally, while we aimed for both researchers to be present in all interviews, unforeseen circumstances led to only one researcher being present for two of the interviews, which prevented us in taking the assigned roles as described in subsection 4.6.4. Throughout section 4.8, we have detailed the measures implemented to reduce potential errors and biases. However, given the nature of the study, it would be unrealistic to claim complete bias reduction.

6.4 Suggestions for Future Research

While our study provides an initial exploration into industrial symbiosis practices within maritime clusters in Western Norway, it underscores the need for further research to gain a more comprehensive understanding of this evolving field. Our study lays the foundation for further exploration and research within the field, particularly within the context of Norway, where academic research on industrial symbiosis practices is still relatively sparse. We identify several opportunities for future research, which we believe are of importance for advancing the understanding and implementation of industrial symbiosis in the Norwegian context.

6.4.1 Feasibility Study to Map Industrial Symbiosis Across Sectors

Firstly, a feasibility study could be carried out to map the potential for industrial symbiosis across a broad selection of Norwegian clusters. Our findings on the absence of sectorial boundaries in industrial symbiosis present an opportunity for future research to explore the potential for cross-sector collaborations and which industry structure may be beneficial in driving synergies (Teh et al., 2014). We recommend that such a study includes a larger sample size, although cost and resource-demanding (Saunders et al., 2019), to identify a broad spectrum of symbiotic possibilities across various sectors and industries. This would involve a detailed analysis of the resources, capabilities, and activities of companies within these clusters to identify potential symbiotic relationships within and among clusters. Following suggestions by Baldassarre et al. (2019), such a study should explore how to intentionally design cooperative efforts for symbiotic purposes. Moreover, in conducting this study, regional differences and comparative advantages should be considered, as certain regions may have unique resources or capabilities that make them suited for exchanging specific by-products. Feasibility-oriented research could serve as a foundation for realising the full potential of industrial symbiosis in Norway, and by identifying the most promising opportunities, the study could inform the implementation of specific strategies or policies.

6.4.2 Longitudinal Study to Examine Changes over Time

A longitudinal study (Saunders et al., 2019) could be conducted to map the evolution of industrial symbiosis practices over time. Such research would involve tracking the progress of industrial symbiosis initiatives over a certain period, providing insights into the long-term impacts and obstacles. This approach is valuable when considering industrial symbiosis as a process (Boons et al., 2016; Chertow, 2000). Our findings indicate that no complete industrial symbioses exist within the participating clusters, per definition (Chertow, 2007). Despite this, the identified potential and ambitions within these clusters, although the selection not being statistically significant (Saunders et al., 2019), suggest growth potential. A longitudinal study could track the evolution of these initial connections from the starting phase to the establishment of more comprehensive and mature symbioses. Moreover, longitudinal studies could explore how drivers and barriers to industrial symbiosis evolve over time, whereas Teh et al. (2014) and Yang et al. (2022b) do not explicitly mention how the drivers and barriers evolve. For instance, specific drivers or barriers may become less significant as companies gain more experience with industrial symbiosis, the market matures, or new support schemes are developed. On the other hand, new benefits and challenges that are not currently apparent may emerge over time. This study could provide a dynamic understanding of industrial symbiosis through changes over time.

6.4.3 Cost-benefit Analysis to Provide a Holistic View of Economic Factors

One of the key findings from our study is the economic barriers preventing industry actors from engaging in industrial symbiosis due to the associated costs and risks (Yang et al., 2022b; Yeo et al., 2019; Heeres et al., 2004; Bossilkov et al., 2005). To address this, we propose a comprehensive cost-benefit analysis of industrial symbiosis as a future research direction to provide a detailed understanding of the economic implications. The cost side of the analysis could evaluate the initial investment and operational costs. Investment costs may include investing in technology and infrastructure for symbiosis, while operational costs can include maintenance and transportation costs. Regarding economic benefits (Domenech Aparisi, 2010), the analysis could assess potential savings or revenues generated from exchanging by-products or utilising surplus resources. Moreover, the cost-benefit analysis should consider the effect of less tangible benefits, for instance, environmental or social (Domenech Aparisi, 2010), through enhanced reputation from engaging in environmentally friendly practices. While such benefits might not have a direct financial impact, they could contribute to the long-term success and reputation of the companies involved. A cost-benefit analysis could provide a holistic view of the economic implications of industrial symbiosis, which might help stakeholders better understand the potential gains and risks, enabling them to make informed decisions about engaging in industrial symbiosis.

6.4.4 The Role of Political Landscape

Given that economic concerns are associated with regulatory barriers, future research could build on the work by Teh et al. (2014) to further explore the political landscape and how laws and regulations might incentivise actors to engage in symbioses. Research exploration could include the feasibility of funding models or policy schemes targeted at symbiotic projects and aimed at overcoming economic obstacles or stimulating investment in industrial symbiosis. Such research would require a review of existing, proposed, and hypothetical policies aimed at reducing the financial risk associated with industrial symbiosis projects (Heeres et al., 2004). This could provide insights into how policy changes could enable more extensive adoption of industrial symbiosis. Additionally, to enhance the economic benefits (Domenech Aparisi, 2010), particularly those arising from the exchange of by-products, further research could examine the potential role of tax laws in incentivising participation in industrial symbiosis, through for instance, deductions for companies that trade by-products. Research in this area could involve a review of existing tax laws and recommendations for new policies that support the trade of by-products. A key question for consideration could be whether regulatory actions should employ a “stick or carrot” approach.

6.4.5 Practical Implementation of Industrial Symbiosis

The practical implementation of symbioses offers an additional research path. This exploration could focus on the implications and challenges that emerge when the theoretical concept of industrial symbiosis is applied in a real-world context. A key component of such research should revolve around logistics and infrastructure (Boons et al., 2016), specifically addressing how resources involved in industrial symbiosis should be transported from one entity to another. For instance, transporting oxygen, identified as an exchangeable resource in industrial symbiosis, could present challenges. Oxygen is typically transported in either liquid or gas form, each requiring specific handling and storage conditions. In terms of the infrastructure required for transporting and storing such resources, establishing new infrastructure, for instance, the construction of pipelines, could involve considerable costs and planning. Almasi et al. (2011, referred in Teh et al., 2014) raise the concern of pipeline infrastructure for longer distances, which may be a costly investment, particularly for symbioses where the companies are not co-located. Another option could be to repurpose existing pipelines from oil and gas industries. Since our thesis has focused on exploring clusters in their initial phase, the practical application of industrial symbiosis has yet to be examined. However, such research could prove helpful in a national and maritime context and in a broader, global, and cross-sectional context.

7. Conclusion

This thesis has explored the role of industrial symbiosis in fostering the green transition within maritime clusters in Western Norway. Guided by four research objectives, the study has examined the practices of industrial symbiosis, investigated the dynamics of cooperation and competition within maritime clusters, identified the drivers and barriers to implementing industrial symbiosis, and suggested insights and recommendations for maritime clusters to succeed in the green transition through symbiotic practices. Our findings uncover a high level of familiarity with industrial symbiosis (Chertow, 2000), although the implementation of symbiosis measures is in the early stages. However, the potential for industrial symbiosis is evident, driven by a motivation among the clusters to contribute to the green transition (Yang et al., 2022b; Domenech Aparisi, 2010) and favourable contextual conditions (Yin, 2014) relating to the comparative advantages of the region such as geography, expertise and infrastructure, as well as culture. Moreover, the study has highlighted that the sectorial boundaries surrounding the maritime sector are not rigid, suggesting that industrial symbioses benefit from the absence of such boundaries (Chertow, 2000), and symbiosis initiatives appeared to be more accessible in land-based maritime activities. The study has highlighted cooperation as a prerequisite for industrial symbiosis (Teh et al., 2014; Chertow, 2000). Factors like geographical proximity (Porter, 1998a; 1998b; Teh et al., 2014), third-party facilitation (Boons et al., 2016), knowledge sharing (Teh et al., 2014; Porter, 1998a; 1998b; Boons et al., 2016), and co-opetition (Brandenburger & Nalebuff, 1996; 2021) influence the dynamics of cooperation and competition within maritime clusters. Moreover, we found that actors considering investing in industrial symbiosis navigate a complex interplay of drivers and barriers (Teh et al., 2014; Yang et al., 2022b; Barona et al., 2023; Okumus, 2023a), often acting as both a driver and a barrier. We suggest insights concerning the implications of being a first mover and a changing company culture, and we recommend that the industry actors adopt a holistic cooperative approach, leverage their comparative advantages, and engage with policymakers. We have uncovered industrial symbiosis as a realistic option for Norwegian maritime clusters to adapt to a changing economic environment. Despite its economic risk, industrial symbiosis may represent a strong investment opportunity. Nonetheless, additional research is needed to understand how industrial symbiosis can be effectively implemented and scaled up within and beyond Norwegian maritime clusters.

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Appendices

Appendix A: Interview Guide and Questions

Intervjuguide

Hei, så hyggelig at du tar deg tid til et intervju med oss. Vi setter stor pris på din tid og deltakelse. Vi er Elida og Lise, to masterstudenter ved Norges Handelshøyskole (NHH) som denne våren skriver masteroppgave om industriell symbiose i norsk maritim industri.

Vi ønsker å undersøke hvordan industriell symbiose forekommer i maritime klynger. Studien er svært aktuell i lys av de ambisiøse klimamålene vi står overfor både på nasjonalt og globalt nivå. Det er også spesielt relevant for den maritime næringen i Norge, en sektor som historisk har vært viktig for Norge, men som også er ansvarlig for betydelige klimagassutslipp.

Vårt mål er å kunne bidra med verdifull innsikt som kan hjelpe disse klyngene i det grønne skiftet. Det å utnytte potensialet i industriell symbiose kan støtte den maritime næringen i å oppnå sine bærekraftsmål, og samtidig bevare sin konkurransekraft. Takk for at du tar del i dette prosjektet!

Under følger spørsmålene vi vil stille deg i intervjuet.

Innledende spørsmål

1. Beskriv kort deres organisasjon og virksomhet.
2. Kan du fortelle litt om deg selv og din rolle?

RO1: Undersøke praksiser for industriell symbiose innenfor klynger som er involvert i maritim aktivitet.

3. Hva legger du i konseptet industriell symbiose? Hvordan arbeider organisasjonen din med dette? // Hvordan arbeider dere med å innføre industriell symbiose og eventuelt andre sirkulærøkonomiske strategier i klyngenettverket?
4. (Hvilken rolle har dere i å identifisere mulige symbiotiske synergieffekter hos klyngemedlemmene?)

5. Vil du klassifisere noen av deres aktiviteter som ressursintensive? Hvis ja, har dere vurdert/innført tiltak for å gjenbruke eller resirkulere avfall, ressurser (vann, energi, etc.) og annet materiale internt i organisasjonen eller fra andre aktører?
6. Kan du gi eksempler på hvordan industriell symbiose har bidratt til å redusere avfall, forbedre ressurseffektiviteten eller redusere miljøpåvirkningen i organisasjonen?
7. Industriell symbiose kan betraktes som en form for bærekraftig forretningsmodell der verdi skapes fra det som tradisjonelt ville blitt betraktes som avfall. Er det noe i deres virksomhet som kan tilsi at dere utnytter avfall for å skape verdi?
8. Hvordan måler dere effekten av symbiosetiltak?

RO2: Utforske dynamikken i samarbeid og konkurranse innenfor klynger, og undersøke hvordan kunnskap deles og utveksles blant klyngemedlemmer for å fremme industriell symbiose.

9. Hvilke aktører samarbeider organisasjonen/medlemmer med relatert til industriell symbiose i klyngen/utenfor klyngen? Hva er motivasjonen bak samarbeidet og hvem har tatt initiativet?
10. Hvordan samhandler organisasjonen/medlemmene med andre i klyngen for å dele ressurser og/eller informasjon? Eventuelt, hvilke typer ressurser eller materialer utveksler organisasjonen med andre i klyngen?
11. Har dere noen konkurrenter // er det noen konkurrerende aktører som er medlem i klyngen? Hvis ja, har dette en betydning for hvordan dere deler informasjon?
12. Kan du forestille deg å danne et symbiotisk nettverk med en konkurrent?
13. (Har du inntrykk av at medlemmene har kunnskap om industriell symbiose, og vilje til å innføre slike strategier? Hvis ikke, hvordan kan dere bidra til å fremme kompetanseheving og motivasjon blant medlemsbedriftene?)

RO3: Identifisere drivere og barrierer forbundet med implementering av industriell symbiose.

14. Hvilke utfordringer/barrierer ser dere med å innføre og videreutvikle initiativer for industriell symbiose i deres organisasjon/for medlemmene?
15. Hvilke spesifikke utfordringer ser du ved å implementere industriell symbiose i maritime prosjekter/aktiviteter.
16. Hvilke muligheter ser dere? Hvilke konkrete gevinster ser dere at organisasjonen // medlemmene kan få av å drive med industriell symbiose?
17. Hvilke faktorer anser dere som viktige for at dere skal lykkes med industriell symbiose?

RO4: Bidra med innsikt og anbefalinger for norske maritime klynger med å lykkes i det grønne skiftet ved å implementere industriell symbiose.

18. Ser du noen endringer på nasjonalt/globalt nivå som kan tilrettelegge for i industriell symbiose?
19. Hvordan tror du at klyngesamarbeid kan bidra til grønn omstilling i den norske maritime næringen?
20. Hva tenker du er de viktigste tiltakene organisasjonen deres må innføre for å lykkes i det grønne skiftet?

Merk: Spørsmålene som stilles tilpasses avhengig av om vi snakker med et klyngemedlem eller en fasiliterende organisasjon. Spørsmål i parentes stilles kun til fasilitator 1-4.

Appendix B: Participation Information Sheet and Consent Form

Informasjonsskriv om intervjudeltakelse i masterutredning

Vi er to studenter som fullfører masterstudiet ved Norges Handelshøyskole (NHH) denne våren. I den forbindelse, skal vi utarbeide en avsluttende masterutredning innenfor våre fagområder, henholdsvis *Strategi og Ledelse* og *Energi, Naturressurser og Miljø*. Du har godtatt vår forespørsel om å delta i forskningsprosjektet. I forkant av intervjuet sender vi deg dette skrivet for å informere om prosjektets formål, hva deltakelse innebærer, samt dine rettigheter.

Formål

Formålet med vår masterutredning er å undersøke rollen industriell symbiose har i norsk maritim sektor. Norge har lange maritime tradisjoner og næringen er viktig for norsk verdiskaping og eksport. Imidlertid står næringen for betydelige nasjonale og globale klimagassutslipp, og for at Norge skal beholde sin konkurransekraft er vi avhengige av å omstille oss ved å ta bruk grønne løsninger.

Vi ønsker å utforske følgende problemstilling: *Hvordan kan industriell symbiose bidra til det grønne skiftet i norsk maritim sektor?*

Industriell symbiose kjennetegnes som en strategi for å oppnå en sirkulær økonomi ved at virksomheter innenfor et geografisk avgrenset område samarbeider om bruk av ressurser. Dette kan eksempelvis innebære materialer, energi, vann og/eller biprodukter.

Hvem er ansvarlig for forskningsprosjektet?

Ansvarlige for forskningsprosjektet er Elida Frafjord Landa og Lise Tenold-Kollstrøm, masterstudenter ved Norges Handelshøyskole (NHH). Prosjektets veileder er professor Marcus Selart, ansatt ved avdeling for Strategi og Ledelse ved NHH.

Hvorfor får du spørsmål om å delta?

Du har fått spørsmål om å delta fordi organisasjonen du jobber i er involvert i prosjekter relatert til industriell symbiose.

Hva innebærer det for deg å delta?

Vi vil gjennomføre et semi-strukturert intervju for å samle inn data. Det er viktig at du kan snakke fritt slik at egne tanker og erfaringer fremkommer. Intervjuet vil vare i 30-60 minutter og vil gjennomføres digitalt. Spørsmålene vi kommer til å stille finner du i intervjuguiden.

Vi vil transkribere og ta videoopptak av intervjuet slik at dataene som samles inn er mest mulig pålitelige. Du velger selv hvorvidt du ønsker å ha på kamera. Dersom det er ønskelig, vil det være fullt mulig å få tilsendt transkripsjon av intervjuet i etterkant. Utredningen vil gjengi navnet på organisasjonen, men vil ikke nevne hverken navn eller stillingstittel. Eksempelvis kan vi omtale deg som «leder x». Det skal ikke være mulig for deg som deltaker å identifiseres i den publiserte masterutredningen.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Dersom du velger å delta, har du når som helst mulighet til å trekke samtykket tilbake uten begrunnelse. Alle dine personopplysninger vil slettes. Dersom du velger å ikke delta, eller trekker deg senere i prosjektet, vil ikke det ha noen konsekvenser for deg. All informasjon fra intervjuet vil bli anonymisert i oppgaven og slettet i etterkant.

Utdypende om personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil utelukkende bruke opplysningene om deg til formålene vi har oppgitt i dette skrivet. Opplysningene vil bli behandlet konfidensielt og i samsvar med personvernregelverket. Det er kun prosjektansvarlige som vil ha tilgang til opplysningene dine. Lise Tenold-Kollstrøm og Elida Frafjord Landa er de som vil samle inn, bearbeide og lagre intervjudata.

I etterkant av intervjuet vil dataen behandles og anonymiseres, og dersom det er ønskelig kan du be om sitatsjekk. Videopptakene vil lagres adskilt fra annen data, med anonymiserte titler.

Hva skjer med personopplysningene dine når forskningsprosjektet avsluttes?

Forskningsprosjektet avsluttes når masterutredningen er levert ved innleveringsfrist 01.06.2024. Alt av innsamlet datamateriell, samt personopplysninger om deg vil følgelig slettes når oppgaven er levert.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke, som bekreftes ved underskrift på samtykkeerklæringen.

Dine rettigheter

Dersom du kan identifiseres i datamaterialet, har du rett til å få innsyn i hvilke personopplysninger som er registrert om deg. Du har rett til en tilsendt kopi av opplysningene, og mulighet til å korrigere opplysninger om deg som er feil eller misvisende. Du har også rett til å få slettet personopplysninger om deg. Du kan klage til Datatilsynet eller Personvernombudet dersom behandling av opplysningene dine er gjort på en kritikkverdig måte. Vi understreker dog at det ikke skal være mulig å identifisere enkeltpersoner i den publiserte utredningen.

Har du behov for mer informasjon?

Dersom du har spørsmål til forskningsprosjektet, eller ønsker å mer informasjon eller benytte deg av dine rettigheter, ta kontakt med:

- Norges Handelshøyskole (NHH), representert av veileder Marcus Selart:
  Epost: marcus.selart@nhh.no eller telefon: 55 95 96 95
- Vårt personvernombud: NHHs personvernombud, personvernombud@nhh.no

Dersom du har spørsmål knyttet til Sikts vurdering som er gjort av prosjektet, kan du ta kontakt med:

- Epost: personverntjenester@sikt.no eller telefon: 73 98 40 40.

Tusen takk for ditt bidrag og deltakelse i forskningsprosjektet!

Med vennlig hilsen,
Elida Frafjord Landa og Lise Tenold-Kollstrøm

Samtykkeerklæring

Ved å skrive under på denne samtykkeerklæringen bekrefter jeg (intervjuobjekt) å ha mottatt og lest det tilsendte informasjonsskrivet angående deltakelse i forskningsprosjektet. Jeg gir med dette mitt samtykke til innsamling av data i forbindelse med masterutredning ved Norges Handelshøyskole (NHH). Jeg samtykker til:

- Intervjudeltakelse
- Transkribering og digitalt opptak av intervju
- At innsamlede data kan brukes i utredningen
- At direkte sitat kan brukes i utredningen
- Anledning til å lese transkribert intervju før publisering av masterutredning
- At dine opplysninger slettes ved avslutning av forskningsprosjektet 01.06.2024

Intervjuet gjennomføres av Elida Frafjord Landa og Lise Tenold-Kollstrøm. Jeg bekrefter med dette min frivillige deltakelse i studien. Jeg bekrefter videre at jeg har blitt informert om egne rettigheter angående personopplysninger, og at jeg kan trekke min deltakelse uten videre begrunnelse.

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet.

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Prosjektdeltakers signatur, Dato

Appendix C: Sikt Approval

Vurdering av behandling av personopplysninger

Skriv ut 28.03.2024

Referansenummer	Vurderingstype	Dato
765882	Automatisk	28.03.2024

Tittel
Masterutredning ved Norges Handelshøyskole (NHH)

Behandlingsansvarlig institusjon
Norges Handelshøyskole / Institutt for strategi og ledelse

Prosjektansvarlig
Marcus Selart

Student
Lise Tenold-Kollstrøm

Prosjektperiode
09.01.2024 - 01.06.2024

Kategorier personopplysninger
Alminnelige

Lovlig grunnlag
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Behandlingen av personopplysningene er lovlig så fremt den gjennomføres som oppgitt i meldeskjemaet. Det lovlige grunnlaget gjelder til 01.06.2024.

Meldeskjema

Grunnlag for automatisk vurdering
Meldeskjemaet har fått en automatisk vurdering. Det vil si at vurderingen er foretatt maskinelt, basert på informasjonen som er fylt inn i meldeskjemaet. Kun behandling av personopplysninger med lav personvernulempe og risiko får automatisk vurdering. Sentrale kriterier er:

- De registrerte er over 15 år
- Behandlingen omfatter ikke særlige kategorier personopplysninger;
  - Rasemessig eller etnisk opprinnelse
  - Politisk, religiøs eller filosofisk overbevisning
  - Fagforeningsmedlemskap
  - Genetiske data
  - Biometriske data for å entydig identifisere et individ
  - Helseopplysninger
  - Seksuelle forhold eller seksuell orientering
- Behandlingen omfatter ikke opplysninger om straffedommer og lovovertredelser
- Personopplysningene skal ikke behandles utenfor EU/EØS-området, og ingen som befinner seg utenfor EU/EØS skal ha tilgang til personopplysningene
- De registrerte mottar informasjon på forhånd om behandlingen av personopplysningene.

Informasjon til de registrerte (utvalgene) om behandlingen må inneholde

- Den behandlingsansvarliges identitet og kontaktopplysninger
- Kontaktopplysninger til personvernombudet (hvis relevant)
- Formålet med behandlingen av personopplysningene
- Det vitenskapelige formålet (formålet med studien)
- Det lovlige grunnlaget for behandlingen av personopplysningene
- Hvilke personopplysninger som vil bli behandlet, og hvordan de samles inn, eller hvor de hentes fra
- Hvem som vil få tilgang til personopplysningene (kategorier mottakere)
- Hvor lenge personopplysningene vil bli behandlet
- Retten til å trekke samtykket tilbake og øvrige rettigheter

Vi anbefaler å bruke vår mal til informasjonsskriv.

Informasjonssikkerhet
Du må behandle personopplysningene i tråd med retningslinjene for informasjonssikkerhet og lagringsguider ved behandlingsansvarlig institusjon. Institusjonen er ansvarlig for at vilkårene for personvernforordningen artikkel 5.1. d) riktighet, 5. 1. f) integritet og konfidensialitet, og 32 sikkerhet er oppfylt.

Appendix D: Use of AI tools in the Thesis

Erklæring om bruk av KI-verktøy i arbeidet med denne masteroppgaven

Sikt. (2023). *Sikt KI-chat* (versjon GPT 3.5). [Stor språkmodell]. https://ki-chat.sikt.no/

Formålet med bruken av verktøyet: Vi har kun brukt verktøyet som et språklig hjelpemiddel, spesielt tilknyttet oversettelse av sitater fra norsk til engelsk i kapittel 5, samt som et verktøy for korrekturlesning gjennomgående i oppgaven. Vi gjør oppmerksom på at det ikke forekommer henvising til verktøyet i teksten, da vi ikke har brukt verktøyet til å generere ideer, tanker, argumenter, løsninger og konklusjoner, men kun som et språklig hjelpemiddel.

Vi er klar over at vi er ansvarlig for alt innhold i denne masteroppgaven, inkludert de deler der KI-verktøy er benyttet. Vi har ansvar for at oppgaven følger etiske regler for personvern og publisering.