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Industrial Symbiosis in Norwegian Industrial Clusters

A Qualitative Study of Drivers and Barriers Faced by Norwegian Industrial Clusters when Initiating and Implementing Industrial Symbiosis Practices

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Abstract

We are currently facing a global economy in need of becoming more circular and it is necessary for the industry to be a part of this transition. To accomplish this, the industry needs to engage in cross-industrial collaboration through the exchange of excess resources, also recognized as industrial symbiosis. While international research on industrial symbiosis is extensive, limited studies have been conducted on this topic within a Norwegian context specifically. In this master's thesis, we will therefore investigate how industrial symbiosis practices can be successfully initiated and implemented in Norwegian industrial clusters.

For this thesis, we have chosen an exploratory, qualitative approach to study eleven Norwegian industrial clusters engaging in industrial symbiosis. We have conducted interviews with representatives from the cluster management organizations to gain valuable insight into the perspectives on initiating and implementing industrial symbiosis.

The thesis yields several findings, primarily related to four aspects. Firstly, we have identified the main drivers for the initiation of industrial symbiosis, both internal: economic benefits and environmental responsibility, and external: stakeholder pressure on environmental production practices and upcoming international regulations. Secondly, we have identified ten barriers that Norwegian industrial clusters might face in their implementation of industrial symbiosis, related to technical, organizational, social, economic, and institutional dimensions. Subsequently, we found that these barriers might be overcome through seven suggested solutions: fostering pride and community; establishing a shared vision, strategy, and goals; having a third-party to identify and initiate industrial symbiosis; having a third-party to facilitate negotiations; learning about industrial symbiosis by engaging with other clusters; collaborating with other stakeholders; and influencing policymakers. Furthermore, we related these potential solutions to four identified overarching goals, namely: building a collaborative culture, establishing trust, cultivating knowledge of industrial symbiosis, and finding feasible solutions. Finally, we have explored the significance of the key stakeholders of industrial symbiosis activities, which we have identified as significant companies and individuals, cluster facilitators, research institutions, and governmental actors.

The purpose of this thesis is to contribute to filling the addressed research gap and to serve as a tool for Norwegian clusters that want to initiate or are in the process of implementing industrial symbiosis practices.

Acknowledgements

This master's thesis is written as a part of the Master of Science in Economics and Business Administration at the Norwegian School of Economics (NHH), within the major of Business Analysis and Performance Management. Throughout our time at NHH, we have gained a profound interest in both business and sustainability, as well as the integration of these two aspects. Our research has enabled us to investigate the integration of circularity in the Norwegian industry and has increased our interest and curiosity in both subject areas. We hope that our thesis will provide our readers with increased knowledge and potentially interest on this topic.

We would like to express our gratitude to our supervisor, Marcus Selart, for the valuable guidance provided to us in the process of writing this thesis. Your contributions, guidance, and constructive feedback have been highly appreciated.

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Sofie Karlsen

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Contents

List of Figures and Tables

1. Introduction

1.1 Background and Actualization

The need for a sustainable and circular economy has become increasingly urgent as the world's population and resource consumption continue to grow. The linear economy that has been around since the industrial revolution, with its "take-make-waste" approach, has led to the depletion of natural resources and increased environmental damage (Ellen MacArthur Foundation, n.d.). In response to the pressing need for change, the circular economy emerges as a promising alternative, focusing on the reduction, reuse, and recycling of materials and resources (McDonough & Braungart, 2002). Transitioning toward a circular economy encompasses a multitude of benefits, including a reduction in the use of the world's natural resources, a reduction in greenhouse gas emissions, and a reduction in the world's dependence on raw materials (European Parliament, 2023). Several international efforts have been made to facilitate this transition, including the European Green Deal that has been created with the goal of making the European Union climate neutral by 2050 (European Commission, n.d.). A key pillar of this deal is the Circular Economy Action Plan which sets out a comprehensive strategy for making the EU's economy more sustainable and circular, by, for instance, reducing waste, increasing resource efficiency, and promoting the use of secondary raw materials (European Commission, n.d.; European Commission, 2020).

The global industry is recognized as a significant contributor to resource consumption, waste generation, and increased emissions, and it is crucial to include the industry in the transition toward circularity (European Commission, 2020). According to the World Economic Forum (2023), this transition will require cross-industry collaboration, which will reinforce resource-efficient operations and innovative business models. These cross-industrial collaborations are in the literature referred to as industrial symbiosis, which is based on the idea that excess resources from one company can be used as inputs for another (Chertow, 2000). This may include by-products, waste, excess heat, excess water, shared infrastructure and services, and more. Industrial symbiosis may be beneficial for both the industrial actors and the environment through, for instance, the reduction of waste and promotion of resource efficiency, fostering innovation and collaboration, reducing costs and increasing competitiveness, and reducing greenhouse gas emissions (Neves et al., 2020; HighEFF, 2021; Jacobsen, 2008). Support for increasing engagement in industrial symbiosis is evident in European and national action

plans, as well as in expert group reports (European Commission, 2020; Deloitte, 2020; Norsk Industri, 2019; Norsk Industri, 2016; Prosess21, 2020) and the Norwegian government expresses that they want to facilitate the creation of industrial networks and recognize the importance of resource sharing (Regjeringen.no, 2021).

In Norway, several industrial clusters have already successfully implemented industrial symbiosis practices. Some clusters have adopted these practices organically over time, typically driven by the economic benefits resulting from the collaborations. However, an increasing number of clusters have engaged in the process in more recent years, as part of their broader sustainability strategies. As a result, traditional industrial parks are transforming into what the literature defines as eco-industrial parks. Essentially, an eco-industrial park is a community of companies situated on shared property, collaborating to achieve improved environmental, economic, and social performance by jointly addressing environmental and resource-related challenges (UNIDO, n.d.). However, there are also examples of clusters where the companies have been able to realize synergies between each other despite not being located in the same industrial area. In both cases, the initiation and implementation of industrial symbiosis projects are often facilitated by a cluster management organization. Presently in Norway, we observe instances where existing industrial parks and clusters are adopting industrial symbiosis practices, as well as the emergence of newly designed eco-industrial parks that incorporate symbiotic principles from their inception. However, even more clusters need to engage in this transition to make the Norwegian industry more circular.

1.2 Research Question and Research Objectives

Despite an extensive body of literature on industrial symbiosis and its implementation, research examining this in a Norwegian context is limited. Simultaneously, there is a growing need for more Norwegian industrial clusters to engage and succeed in implementing industrial symbiosis practices. The purpose of this thesis is to contribute to filling the research gap of industrial symbiosis practices in Norway and to serve as a tool for clusters that want to initiate or are in the process of implementing industrial symbiosis practices. This has led us to the following research question:

> *"How can industrial symbiosis practices be successfully initiated and implemented in Norwegian industrial clusters?"*

To ensure a comprehensive response to the research question, we have identified four research objectives that we will examine throughout this paper.

RO1: Identify existing internal and external drivers for Norwegian industrial clusters to implement industrial symbiosis practices.

RO2: Identify the key barriers Norwegian industrial clusters are facing when implementing industrial symbiosis practices.

RO3: Investigate potential solutions to overcome the identified barriers.

RO4: Explore the significance of the key stakeholders in the process of initiating and implementing industrial symbiosis practices in Norwegian industrial clusters.

By addressing the research objectives and ultimately answering the research question, the study seeks to provide deeper insights into industrial symbiosis in Norway and assist clusters in succeeding with its implementation.

1.3 Scope of Thesis and Delimitations

For this thesis, we have established specific delimitations to define the scope and focus of our research. These delimitations are necessary for the feasibility of the thesis, as the study is limited by time constraints (Saunders et al., 2012). While there are many aspects of industrial symbiosis that would be interesting to research, this thesis will focus specifically on the successful initiation and implementation of industrial symbiosis practices within Norwegian industrial clusters. Consequently, our research scope excludes, for instance, an examination of the environmental, social, or economic impacts of industrial symbiosis, as well as other related aspects. However, Chapter 7 will provide suggestions for future research, including areas that are beyond the confines of our scope and delimitations.

Furthermore, we have limited the scope of the study to include only Norwegian clusters, primarily due to our interest in the Norwegian context and the limited existing research on industrial symbiosis on a cross-cluster level. This selection also serves the purpose of making the scope more feasible. While our scope is limited to a national level geographically, numerous characteristics explored in this thesis may also have relevance on a global scale.

The sample selection for this thesis will prioritize clusters from the process industry, as the process industry includes companies and industries with great potential for resource exchanges, due to their many side-streams. Relevant information related to the Norwegian process industry will be presented in Chapter 3. Moreover, the sample selection will focus on representatives from the cluster management organizations, as we believe they are the ones with the most comprehensive view of the industrial symbiosis processes. As these processes involve collaboration among various parties, several other stakeholders will also be involved including multiple companies within the cluster, as well as governmental actors, research or academic communities, and investors. Given that cluster organizations typically act as facilitators of this collaboration, we believe that they are the best positioned to provide us with the most insightful and information-rich answers. While it would have been interesting to capture even more aspects of the process by interviewing other stakeholders as well, the time constraint of our thesis prevents us from including additional parties.

Lastly, there are also methodological delimitations connected to our choice of research approach and research design, however, this will be discussed in Chapter 4.

1.4 Clarification of Terminology

For certain key concepts addressed in this thesis, there is a gap between the terminology used in literature and the terminology employed in the real world. Moreover, there are variations in the terminology used by different actors or in different regions. Thus, we will clarify the variations of the main concepts and specify which terminology we will use throughout our study.

Industrial symbiosis

Although the term industrial symbiosis is gaining traction in literature and we observe increasingly more examples of its practice, we also find that not all industrial actors explicitly employ this terminology. In Norway, we observe an increase in the adoption of the term, however, some actors still refer to it as circular activities or simply describe their practices of sharing excess resources within the cluster without labeling it. The theoretical definition and background of the concept documented in literature will be explained in section 2.3.1. However, for the purpose of this thesis, we will refer to the term as a cross-company exchange

of resources, such as by-products, waste, excess heat, and excess water, often combined with shared infrastructure and services.

Eco-industrial park

The concept of eco-industrial parks comprises significant variation in terminology, however, the meaning remains largely consistent. A brief overview of these variations is presented in Figure 1 below.

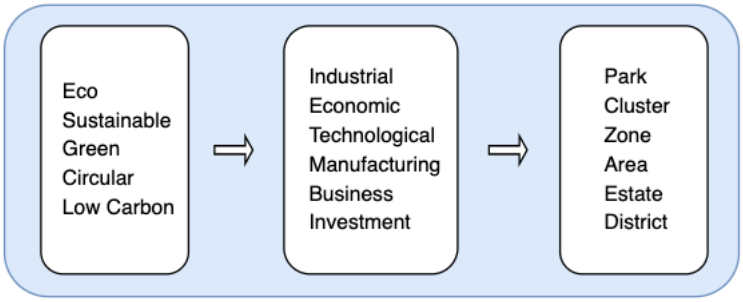

Figure 1 - Terminology of eco-industrial parks used internationally. Adjusted from World Bank (2021).

Although the terms eco-industrial park or eco-industrial cluster are the most commonly used in literature, the variations presented in Figure 1 may also be used to refer to this concept. In Norway, clusters are typically described as either green, sustainable, or circular. Furthermore, as this thesis will focus on clusters from the process industry, they will typically be called industrial, as this part of the terminology depends on the type of cluster. Finally, most Norwegian clusters refer to themselves as either parks or clusters, which may be influenced by the geographic proximity of the companies. While the term "park" typically implies a defined physical area, we have observed that the term "cluster" can encompass both neighboring and more distantly located companies. Consequently, in this thesis, we have opted to employ the term “cluster(s)” when referring to this concept to encompass all the participants included in the study.

Cluster facilitator

Similarly, there are multiple ways to refer to the organization managing the clusters. Within the literature, we observe variations such as cluster facilitator, symbiosis institute, anchor tenant, initiator, third-party organization, intermediary, mediator, and more. In this thesis, we will primarily employ the term (cluster) facilitator, however, we may also use other variations of the term. Regardless of this, we will be referring to the organization managing the clusters.

1.5 Thesis Structure

The thesis consists of seven subsequent chapters, each addressing different aspects of the research. Chapter 2 serves as the theoretical foundation of our thesis and will begin by reviewing the literature on industrial ecology and circular economy, and their respective perspectives on industrial symbiosis, followed by literature on industrial symbiosis, including key drivers and barriers, and the role of significant stakeholders. Chapter 3 describes the current environment for Norwegian industrial clusters, including an overview of the Norwegian process industry. Chapter 4 outlines the methodology employed in the study and we will discuss our research design, data collection, and analysis techniques, as well as our data quality and ethical concerns. Chapter 5 presents the findings from the interviews with Norwegian industrial clusters including our analysis. This chapter will also present our proposed conceptual framework for the implementation of industrial symbiosis. Chapter 6 offers a discussion of the findings, exploring the implications of the results and how they relate to the existing literature. Finally, Chapter 7 concludes the study by summarizing the key findings and their significance, highlighting the theoretical and practical implications of the study, followed by a discussion of the research limitations and suggestions for future research.

2. Literature Review

In this chapter, we will present the theory that is relevant for understanding and addressing the research question and its respective research objectives. Section 2.1 Industrial Ecology and Section 2.2 Circular Economy will establish a fundamental understanding of the concepts from where industrial symbiosis emerges. Section 2.3 Industrial Symbiosis will describe this concept, as well as the concept of eco-industrial parks, in addition to reviewing drivers of industrial symbiosis, the emergence and the embeddedness of industrial symbiosis networks, relevant stakeholders, and finally, assess barriers of industrial symbiosis identified in the literature.

2.1 Industrial Ecology

In this section, we will first introduce the definition and background of the concept of industrial ecology. Subsequently, we will present the biological analogy upon which industrial ecology is based. Finally, we will elaborate on the industrial ecology perspective on industrial symbiosis.

2.1.1 Definition and Background

Industrial ecology is a multidisciplinary field of study that seeks to create industrial systems that function in a manner similar to natural ecosystems (Isenmann, 2003; Erkman 1997; Chertow, 2000). The concept of industrial ecology is rooted in the discipline of ecology (Erkman, 2001), which examines the intricate connections between living organisms and their environments (Picket et al., 1989). The emergence of the industrial ecology concept can be credited to the growing concern regarding the ecological implications of industrial operations, with its origins dating back to the 1950s (Erkman, 2001). However, the notion of industrial ecology did not receive significant recognition until the latter part of the 1980s, when Robert Frosch and Nicholas Gallopoulos' highly influential article "Strategies for Manufacturing" was published (Erkman, 1997; Ehrenfeld, 2006). The article proposes an alternative economic model that can replace the current resource-inefficient approach that relies on an unsustainable linear production strategy (Frosch and Gallopoulos, 1989). In contrast, the model proposed by Frosch and Gallopoulos (1989) is based on the basic principles of natural ecosystems, wherein resources and energy are self-contained within the system. Thus, industrial ecology is based on the creation of an economy that mimics the closed processes observed in natural ecosystems

with the aim of reducing its impact on the environment (Erkman, 1997; Lowe & Evans, 1995). In this system, organisms consume waste materials, allowing for the indefinite reuse of resources and energy with no input or output (Ayres, 1994; Graedel et al., 1992). This closed-loop system can be replicated in industrial systems to reduce resource consumption and associated costs and thus is regarded as more sustainable and economically viable than the conventional "end-of-pipe" method (Frosch and Gallopoulos, 1989).

Currently, it exists no universally recognized definition for the concept of industrial ecology (Saidani et al., 2020). However, Erkman (1997) posits that the primary objective of the field of industrial ecology is to investigate the material flows that transpire within an industrial ecosystem and to acquire an understanding of the interplay between this ecosystem and the environment. Furthermore, in order to provide a more tangible understanding of the concept of industrial ecology, Erkman (1997) has identified three key elements of the concept that are widely acknowledged within the academic community. First, industrial ecology is a holistic and systematic perspective of all aspects of the industrial economy and its interactions with the environment. Second, it highlights the intricate patterns of material fluxes within and outside the industrial system. Lastly, it views technical dynamics, particularly the long-term evolution of clusters of essential technologies, as a critical component in the transition from an unsustainable industrial system to a viable industrial ecosystem.

2.1.2 The Biological Analogy

Industrial ecology is based on the creation of an economy that mimics processes observed in natural ecosystems (Erkman, 1997), and thus understanding the concept of industrial ecology may require acknowledging the resemblance between biological systems and industrial systems. According to Ayres (1994), there is a striking resemblance between biological organisms and industrial activity. Firstly, both systems operate as materials-processing systems driven by a flow of free energy. Secondly, they can be described as self-organizing dissipative systems which, described by Ayres (1988), is a system that “depends on a continuous flow of free energy and materials from and to the environment”. Graedel et al. (1992) show the similarities between these two systems by offering a framework that outlines the various types of ecosystems that exist and compares them to our current industrial system. This framework is founded on the development of the planet’s biological systems as a function of the system’s capacity to reuse resources and explains how its ability to reuse these inputs impacts resource and energy flow within the system. The framework distinguishes three types

of ecosystems, namely Type I, Type II, and Type III systems, which are all classed based on their ability to reuse resources and energy.

Type I Ecology is recognized as the earliest material cycle on Earth, marked by the extensive availability of resources, leading to small consequences from the presence of living organisms on their accessibility. Consequently, the ecosystem is developed in a linear and sequential manner, wherein the transfer of resources from one phase to another unfolds independently from other resource flows. Type II and Type III Ecology both express situations where resources are limited, causing living forms to become highly interconnected and form intricate networks. In Type II Ecology, the ecosystem is both closed and sequential, with large material flows within the system and small material flows entering and leaving the system. Type II ecology is more efficient than Type I ecology due to its more circular resource flow, which results in a decrease in the outflow and inflow of resources from the system. However, it is critical to note that this type of ecosystem is not long-term sustainable on a global scale, since resources continue to enter and depart the system. Graedel (1996) appropriately describes this condition as "the system is running down," suggesting that the availability of resources inside the ecosystem is reducing with time.

Type III Ecology, on the other hand, is completely cyclical, with "resources" and "waste" left indefinite. Intricately, waste from one component of the system serves as resources for another, and the system is considered to be completely closed (Graedel et al., 1992). According to Graedel et al. (1992), the current industrial system can be classified as a Type I system due to its linear resource flow. At the same time, the present state of the global industrial ecosystem is resource-constrained, and therefore industrial systems must endure selective pressure to evolve from Type I to Type II Ecology. However, for the industrial system to be completely sustainable, it must embrace Ecology Type III. The Type III model represents optimal material and resource utilization in industrial activities. By establishing an industrial ecosystem that converts waste into a valuable resource, the demand for fresh raw materials can be reduced, mitigating the environmental impact of industrial processes.

2.1.3 View on Industrial Symbiosis

In the field of industrial ecology, industrial symbiosis is commonly regarded as a socio-technical process (Baldassarre et al., 2019), which is found on the inter-firm level (Chertow, 2000). This implies that the field of industrial ecology encompasses the technical and

organizational components that play a role in the formation of industrial symbiosis (Short et al., 2014). Consequently, the industrial ecology perspective on industrial symbiosis allows for a historical inquiry into the growth and effect of an industrial cluster over an extended period of time (Boons et al., 2014). Additionally, this perspective encourages a cross-organizational approach to industrial symbiosis initiatives (Mulrow et al., 2017). However, because it does not take a firm-centric approach to such initiatives, it may place less emphasis on the economic basis of symbiotic activities (Baldassarre et al., 2019).

Baldassarre et al. (2019) have identified three key pillars of research on industrial symbiosis within the field of industrial ecology. These pillars encompass the initial conditions, events, and outcomes. The first pillar is concerned with the factors that contribute to the establishment of an industrial symbiosis project, such as the firms involved, their business features, and previous relations. The events pillar highlights the series of technological, social, and policy acts that result in the realization of the industrial symbiosis from its starting conditions. Finally, the outcomes pillar studies the economic, environmental, and social consequences of the implementation of industrial symbiosis.

2.2 Circular Economy

In this section, we will first introduce the definition and background of the concept of circular economy. Then, we will present literature on circular business models, before we elaborate on the circular economy perspective on industrial symbiosis.

2.2.1 Definition and Background

The concept of circular economy has gained significant attention and interest in recent years (Saavedra et al., 2018), with its origins dating back to Kenneth Boulding's seminal 1966 article "The Economics of the Coming Spaceship Earth" (George et al., 2015). Boulding (1966) argues that the coexistence of the economy and sustainability can be attained by adopting a closed-loop system of resources. The notion that the circular economy can simultaneously achieve environmental objectives and foster economic growth is an appealing idea to multiple actors (Baldassarre et al., 2019). Despite its rising popularity, there is no widely accepted definition of the circular economy. However, Kirchherr et al. (2017) have discovered that the definition provided by the Ellen MacArthur Foundation (2013) is the most frequently

employed. According to this 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).

Fundamentally, the circular economy is about shifting from a linear economic model to one based on a closed-loop system (Bocken et al., 2016). The linear economy is defined as a system with a "cradle-to-grave" material flow, implying a take-make-throw-away approach to resource extraction, whereas the circular economy keeps materials and resources inside a closed-loop system by promoting a "cradle-to-cradle" resource flow (McDonough & Braungart, 2002). The overarching goal of the circular economy is to establish a system in which materials are continuously recycled, as opposed to being used once and then discarded (Kirchherr et al., 2017; Baldassarre et al., 2019). Consequently, the concept of circular economy can be founded on five principles, namely design out waste, developing resilience through diversity, relying on renewable energy, waste as food, and thinking in systems (Lewandowski, 2016). In further detail, the adoption of a circular economy may be promoted by a framework comprised of three strategies, namely narrowing, slowing, and closing resource loops, and three pillars, namely technical innovation, business model innovation, and collaboration (Baldassarre et al., 2019).

2.2.2 Circular Business Models

Within the topic of circular economy, industrial symbiosis is part of sustainable business model research and, more specifically, circular business models (Baldassarre et al., 2019). In essence, a business model can be understood as a comprehensive approach that outlines how organizations engage in business activities (Baldassarre et al., 2019). Elaborately, a business model may be defined more precisely as a framework that defines the logic that underpins how organizations generate, deliver, and capture value (Osterwalder & Pigneur, 2010). This entails understanding the customer and what the customer values in order to create value for the customer, as well as the economic logic that allows the company to deliver value to the customer at an appropriate cost, and, finally, how the firm generates revenue from the business (Magretta, 2002).

Sustainable business models extend the notion of traditional business models by adopting or implementing sustainability principles and goals into the mechanisms of a company's value creation, delivery, and capture processes (Geissdoerfer et al., 2020). According to Kirchherr et al. (2017), the research literature on sustainable business models emphasizes the need for proactive multi-stakeholder management, the generation of both monetary and non-monetary value for a broad variety of stakeholders, and the adoption of a long-term perspective. Circular business models are a subcategory of sustainable business models (Bocken et al., 2014), and have a more narrow focus on environmental and economic outcomes (Geissdoerfer et al., 2020). Circular business models constitute a set of circular economy strategies, such as closing, narrowing, slowing (Bocken et al, 2016), intensifying, and dematerializing (Geissdoerfer et al., 2018a). These strategies will support the sustainable and efficient use of resources by reducing waste, hence reducing the environmental impact created by business activities (Geissdoerfer et al., 2018b). Accordingly, Geissdoerfer et al. (2020) define circular business models as: "Business models that are cycling, extending, intensifying, and/or dematerialising material and energy loops to reduce the resource inputs into and the waste and emission leakage out of an organisational system. This comprises recycling measures (cycling), use phase extensions (extending), a more intense use phase (intensifying), and the substitution of products by service and software solutions (dematerialising)."

2.2.3 View on Industrial Symbiosis

Through the circular economy concept, industrial symbiosis has been recognized as a business model archetype for closing resource loops (Bocken et al., 2016). The circular economy approach to industrial symbiosis focuses primarily on the operational aspects of the cluster's engagement in industrial symbiosis (Baldassarre et al., 2019). This perspective aligns with business-oriented objectives and is well-suited for practical implementation as it is easy to plan, communicate and execute effectively (Baldassarre et al., 2019). In addition, the circular economy approach differentiates stakeholders based on their roles within the industrial symbiosis, however, the approach retains a firm-centric perspective (Short et al., 2014). Moreover, the perspective concentrates on a specific point in time (Bocken et al., 2014) and thereby does not account for its temporal dimension and potential fluctuations over time (Baldassarre et al., 2019). According to Baldassarre et al. (2019), the study of industrial symbiosis as a circular business model is generally centred around three fundamental pillars: technical innovation, collaboration, and sustainable business model innovation. The initial

pillar, technical innovation, involves a technical advancement that facilitates the closing of resource and energy loops. The second pillar, collaboration, entails identifying and defining the roles of key stakeholders for the development of industrial symbiosis, while the third pillar entails incorporating the approach for closing resource and energy cycles into the company value creation, delivery, and capture.

2.3 Industrial Symbiosis

In this section, we will first review the literature pertaining to the definition and background of the concept of industrial symbiosis, followed by a similar exploration of the concept of eco-industrial parks. Subsequently, we will review how industrial symbiosis may emerge in eco-industrial parks and explore factors that drive industrial symbiosis. Then, we will explore the concept of embeddedness of industrial symbiosis networks, followed by an assessment of significant stakeholders. Finally, we will present the literature on barriers associated with implementing industrial symbiosis and conclude by reviewing strategies outlined in the literature for overcoming these barriers.

2.3.1 Industrial Symbiosis: Definition and Background

Industrial symbiosis refers to a collaboration among industries and businesses to exchange resources in a mutually beneficial manner, and the most established definition of the term, given by Chertow (2000), reads 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 term is based on the biological concept of “symbiosis”, in particular mutualistic symbiosis, which describes a relationship between two dissimilar organisms where both organisms benefit from the relationship. Placing this in an industry context, industrial symbiosis involves identifying and exploiting the synergies and complementarities between different businesses and industries to create a system where waste from one company becomes a resource for another (Chertow, 2000). Industrial symbiosis contributes to creating a more sustainable and efficient industrial ecosystem by several means, including reducing waste and resource use, lowering costs, and creating new business opportunities (Jacobsen, 2008; Neves et al., 2020). Hence, by sharing resources and collaborating, companies can reduce their environmental footprint, enhance their competitiveness, and foster innovation.

The first appearance of the term industrial symbiosis in literature was in 1989 in an article written by Frosch and Gallopoulos on industrial ecology, the same year the term was first used to describe the symbiotic relationships between the companies at Kalundborg in Denmark, which today is likely the most cited example of successful industrial symbiosis (Chertow, 2007; Neves et al., 2020). Since then, a significant amount of literature has been produced on the topic, as more businesses and industries recognize the benefits of collaboration and resource exchange (Neves et al., 2019). This trend reflects the growing scientific interest in the topic, as well as the development of several European and national programs and policies that encouraged the practice of industrial symbiosis and recognizes its potential to achieve sustainability (Neves et al, 2019; Neves et al, 2020).

While the term industrial symbiosis implies the exchange of resources between companies, there have been various attempts to delineate the scope of what is encompassed by this term. Chertow (2007) has adopted a "3-2 heuristic" to distinguish industrial symbiosis from other types of exchanges between companies, as a minimum criterion to describe the term. The author states that for an exchange to be counted as industrial symbiosis, there must be at least three entities exchanging at least two different resources. However, other literature does not consider this as an absolute criterion (Neves et al., 2020). When it comes to the synergetic benefits that can be obtained from this relationship, there are three primary opportunities, according to Chertow (2007). As addressed in the definition of the term, there is (1) the physical exchange of by-products, materials, energy, and water, however, both (2) sharing of utilities or infrastructure and (3) having joint provision of services are also possible synergetic benefits. Furthermore, Chertow (2000) states that "the keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity." While geographic proximity often functions as a contributing factor to realizing synergies, e.g., through reduced transportation costs, it is not a delimiting factor for the definition of the term as there are several examples of industrial symbiosis where the collaborating companies are somewhat distantly located (Neves et al, 2020).

2.3.2 Eco-Industrial Parks: Definition and Background

The most common way of implementing industrial symbiosis in a real-world context is through eco-industrial parks (Gibbs & Deutz, 2007). There are several definitions of this concept, however, the international framework for eco-industrial parks, developed by UNIDO, the World Bank Group and GIZ, defines it as "a dedicated area for industrial use at a suitable

site that supports sustainability through the integration of social, economic, and environmental quality aspects into its siting, planning, management and operations." (World Bank, 2021). One of these integrated aspects is typically industrial symbiosis, as the businesses within the park work together to share resources, such as energy, water, and materials, to reduce waste and optimize their production processes (Tudor et al., 2007). Hence, the terms of industrial symbiosis and eco-industrial parks are interrelated, as most eco-industrial parks will have industrial symbiosis between the firms cooperating in the park. Martin et al. (1996) describe the creation of synergies as a key aspect of a successful eco-industrial park with the quote "by working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only.".

Industrial parks have been around for over a century (Vidova, 2010), and while they have contributed positively toward economic growth and social development, there have also been several negative impacts associated with such parks (World Bank, 2021). This includes pollution, resource depletion, workplace concerns, and adverse effects on local communities. Thus, through efforts of making industrial development sustainable and more inclusive, the concept of eco-industrial parks emerged in 1992 at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro (World Bank, 2021). The concept was initiated to contribute to the transition toward sustainable production practices and a more circular economy. The development of eco-industrial parks primarily occurs in one of two ways (Lambert & Boons, 2002). Some eco-industrial parks are designed from the outset to be sustainable and environmentally friendly, while others evolve from conventional industrial parks through the adoption of sustainable practices, such as industrial symbiosis. Other measures, such as the adoption of cleaner production practices, building green infrastructure, and the use of renewable energies within the park, may also be used to describe eco-industrial parks (Neves et al, 2020), however, in our study will primarily address the aspects of eco-industrial parks related to industrial symbiosis.

2.3.3 Emergence of Industrial Symbiosis in Eco-Industrial Parks

In earlier literature, the emergence of industrial symbiosis was primarily described in one of two ways, either through self-organized or planned industrial symbiosis (Chertow, 2007). In this context, planned industrial symbiosis refers to a top-down planning approach, typically initiated by governmental actors. According to Chertow (2007), the planned eco-industrial

park model is a concept that "includes a conscious effort to identify companies from different industries and locate them together so that they can share resources across and among them". This method will typically feature a stakeholder group in charge of driving the process, as well as a government or quasi-government body responsible for supporting expansion through land use planning, grant giving, or long-term finance (Chertow, 2007). In contrast, the self-organized symbiosis model does not emerge with the primary intention of establishing an industrial symbiosis network. Instead, it results from the decisions of individual actors to participate in the process (Boons et al., 2017). These networks are typically based on conventional business motives, such as cost reductions, increased competitiveness or long-term resource security, and hence arose due to market powers (Chertow, 2007). In these cases, participants typically did not perceive the sustainable long-term effects of these processes until some time had passed (Chertow, 2007).

Later, facilitation by individuals or organizations has also been recognized as means of developing industrial symbiosis (Paquin & Howard-Grenville, 2009; Hewes & Lyons, 2008). Facilitated industrial symbiosis may be described as a middle ground between self-organized and planned industrial symbiosis and the facilitator is typically represented by a third-party organization (Paquin & Howard-Grenville, 2012). A facilitator of industrial symbiosis can, for instance, address the challenges of cross-sectional collaboration, including awareness of opportunities, knowledge of potential partners, and the time to discover this information (Lombardi, 2017). According to Boons et al. (2017), industrial symbiosis may also emerge from organizational boundary change, where an industrial actor seeks to become more eco-efficient through vertical integration and internal exchanges, or from eco-cluster development, initiated by local governments and/or industrial actors as part of a broader eco-innovative strategy. An industrial symbiotic network may also change its dynamic from one period of time to another, and it may also emerge in other ways as well (Boons et al., 2017).

Industrial parks are recognized in the literature as an advantageous context for the development of synergetic resource exchanges, owing to the geographic proximity and the general tendency of inter-firm collaboration (Hewes & Lyons, 2008; Taddeo et al., 2017). The presence of existing relations between the firms in the industrial parks may be beneficial in terms of creating more forms of collaboration, including industrial symbiosis, and a greater willingness to share knowledge and data (Taddeo et al., 2017). For an industrial park to successfully develop industrial symbiosis, Jacobsen & Anderberg (2004) argue that an analysis of the physical preconditions and possibilities is necessary to identify existing and

potential resource exchanges within the network and to explain network developments at specific locations. Furthermore, an assessment of the economic and environmental benefits of the identified exchanges should be made, based on the previous analysis, both for the involved company and the local region. Finally, there should be made an analysis of the central conditions and mechanisms behind the development of industrial symbiosis which identifies non-economic barriers that affect this development.

2.3.4 Drivers of Industrial Symbiosis

Industrial symbiosis can be driven by a number of factors, and often the initiation of industrial symbiosis is the result of a combination of several factors rather than a singular one (Neves et al., 2019). This section will provide an overview of the factors that drive industrial symbiosis initiatives.

The initiation of industrial symbiosis is often driven by the pursuit of economic benefits (Chertow, 2007), as engaging in industrial symbiosis has the potential to decrease costs through the reduction of raw material consumption and waste generation (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021), as well as presenting opportunities to increase competitiveness and long-term resource security (Chertow, 2007). However, the motivation behind firms' adoption of industrial symbiosis is not exclusively rooted in their attempt to attain financial advantages. The adoption of industrial symbiosis practices is also influenced by firms' social and environmental awareness, and their acknowledgment of possible environmental and social benefits that can be derived from such practices (Henriques et al., 2021; Neves et al., 2019). Moreover, the company's encouragement in improving working conditions, stimulate local employment creation, enhance health and safety measures, and provide social infrastructure for workers and communities has also been identified as a driving factor in the adoption of industrial symbiosis practices in clusters (World Bank, 2021).

The initiation of industrial symbiosis practices is influenced not only by internal factors within clusters but also by external factors. For instance, World Bank (2021) has asserted that environmental and social concerns from consumers and neighbouring communities are drivers for industrial symbiosis. In addition, policies and regulations are recognized as pivotal catalysts, as they establish incentives and frameworks to incentivize enterprises to embrace sustainable practices (Neves et al, 2019; Mortensen & Kørnøv, 2019). In this context, industrial symbiosis practices have been highlighted as being encouraged by climate change

commitments at both national and international levels (Henriques et al., 2021). The adoption of measures such as taxation policies that impose penalties on environmental pollution (World Bank, 2021; Henriques et al., 2021) and inefficient resource utilization are acknowledged as important mechanisms for firms to adopt industrial symbiosis practices (Henriques et al., 2021). In addition, policies that encourage national, regional, and local financing of circular solutions, as well as regulations that foster frameworks that support a circular economy and synergy networks, are regarded as important drivers (Henriques et al., 2021; Valentine, 2016).

2.3.5 Embeddedness of Industrial Symbiosis Networks

Industrial symbiosis is a process that stimulates collaboration among companies through a network of interconnected linkages and inter-organizational alliances (Doménech & Davies, 2011). These networks can facilitate embeddedness (Boons and Howard-Grenville, 2009), which is a concept that pertains to the social factors that influence economic behaviour (Granovetter, 1985). Embeddedness can impact the decision-making processes of organizations involved in the creation and development of industrial symbiosis networks (Doménech & Davis, 2011). In order to gain a deeper comprehension of the attributes of industrial symbiosis networks, it is imperative to look into the concept of social embeddedness as it pertains to these networks.

Social embeddedness can be conceptualized as the institutionalization process that arises from repeated interactions among firms within a network (Walls & Paquinn, 2015). To describe industrial symbiosis network relations, Doménech and Davis (2011) present a continuum that spans from less integrated and impersonal setups to more deeply embedded industrial networks based on Powell's (1990) continuum of exchange and network relations. The loose and impersonal setups are typified by exchanges that prioritize price and lack personalization, whereas embedded networks place significant emphasis on long-term, close, and collaborative relationships (Doménech & Davis, 2011). Establishing embedded networks requires trust, transparent communication, and collaborative problem-solving (Noorderhaven et al., 2002), which are also regarded as essential for achieving embeddedness in the context of industrial symbiosis (Doménech and Davis, 2011). Embeddedness in industrial symbiosis networks can be attributed to a few critical factors, namely spatial and temporal proximity of network participants, commonly held norms and trust, network position, government power allocation, and similar mental frameworks (Boons and Howard-Grenville, 2009).

Moreover, industrial symbiosis networks have been found to rely on both formal and informal connections (Ashton, 2008). However, the existence of trust within the network facilitates the emergence of more complex network configurations (Hewes & Lyons, 2008) and has been claimed to be a critical component in lowering contracting and monitoring costs (Walls & Paquin, 2015). Furthermore, social embeddedness is positively associated with economic performance (Domenech & Davis, 2011), with the presence of embeddedness having a positive impact on economic outcomes such as decreased transaction costs (Chertow & Erhnfeld, 2012), heightened adaptability, and enhanced opportunities for knowledge acquisition and innovation (Domenech & Davis, 2012). Nonetheless, some scholars argue that dependence on other entities in densely coupled networks may result in lower flexibility when faced with abrupt changes, such as the exit of a resource-rich entity (Walls & Paquin, 2015). Despite this, research has found that social connection plays a significant role in the development and effectiveness of industrial symbiosis initiatives (Paquin & Howard-Grenville, 2012).

2.3.6 Stakeholders in Industrial Symbiosis

Industrial symbiosis is a collaborative approach that entails sharing of resources and knowledge, where there are typically various stakeholders involved (Mortensen & Kørnøv, 2019). There are often two different forms of collaboration that are present in the context of industrial symbiosis (Hein et al., 2017). The initial form of collaboration pertains to the transfer of energy and materials with the symbiotic partners (Hein et al., 2015). The second type of collaboration concerns actors who are not directly involved in the activities of industrial symbiosis but rather engage with the symbiotic partners in an alternative way (Mortensen & Kørnøv, 2019). The participation of these actors has an influence on the success of industrial symbiosis endeavours (Walls & Paquin, 2015), and are frequently referred to as stakeholders. Freeman (1984) defines a stakeholder as any entity or individual that has the ability to impact or be impacted by the attainment of an organization's goals. Industrial symbiosis entails the cooperation of multiple entities; therefore, the term “stakeholder” in this case can refer to individuals or groups with a stake in a symbiotic relationship (Hein et al., 2017). In the following, we will introduce stakeholders that literature regard as significant contributors within the context of industrial symbiosis.

Research communities and academic institutions

Collaboration with research communities such as universities or research institutions has been found to play an important role in the establishment of industrial symbiosis (Henriques et al., 2021; Morten & Kørnøv, 2019). According to Henriques et al. (2021) collaboration between corporations and research institutions and universities is a key enabler for industrial symbiosis practices. Furthermore, Morten and Kørnøv (2019) discovered that collaboration was critical at all phases of industrial symbiosis process implementation. The significance of this collaboration lies in how these stakeholders serve as advocates for the development and dissemination of knowledge to the industry in order to consolidate the initiatives (Mortensen & Kørnøv, 2019; Spekkink, 2013). One of the methods by which they achieve this is assisting in the discovery of new synergies through collecting data and creating new synergies through the analysis of material flow and the evaluation of economic and environmental factors (Costa and Ferrão, 2010). In addition, they may contribute to the organization of various activities, such as innovation forums, with the intent of identifying the most effective approach to establish new synergies (Behera et al., 2012). Furthermore, it has been found that these establishments have the potential to facilitate collaborative processes by overcoming barriers to effective collaboration that arise due to misinterpretations and imbalanced information dissemination among groups of stakeholders (Mortensen & Kørnøv, 2019).

Cluster facilitators

While some industrial parks evolve gradually and naturally, most parks develop through the support and intermediation of cluster facilitators, which can be represented by e.g., individuals, firms, public authorities, and government agencies (Ingstrup & Damgaard, 2011). According to Ingstrup (2010), the role of a cluster facilitator can be viewed in three different ways. First, as a framework-setting facilitator, with the cluster environment as their primary focus, second, as a project facilitator that engages directly in specific projects, and third, as an all-round facilitator, which is a combination of the first two roles. Furthermore, Mesquita (2007) regards building trust and a platform for cooperation as the main goal of a cluster facilitator, while Gagné et al. (2010) stress that the goal should also include establishing a flow of information and resources within the cluster. However, as these facilitators lack positional power over the cluster, i.e., legitimate authority, they are limited to the mandate the participants in the cluster have given them, which may limit their ability to perform valuable activities (Zagorsek et al., 2008). Nevertheless, the importance of the facilitator's role has been identified in all the phases of industrial symbiosis endeavours (Mortensen & Kørnøv, 2019). Furthermore, Neves et al.

(2019) have emphasized the indispensable role of a facilitator as a driver and enabler for the successful implementation of industrial symbiosis initiatives. Walls and Paquin (2015) emphasized the importance of the facilitator's role in achieving industrial symbiosis activities. They identified two primary purposes served by facilitators in this context. The primary objective is to foster a sense of trust between the symbiotic partners by means of consistent engagement in a continuous dialogue with other firms. The secondary objective is to promote institutionalization through the establishment of commonly held standards of behaviour, which serve to alleviate cognitive barriers among actors.

Companies

Moreover, several scholarly studies have emphasized the significance of anchor firms in enabling industrial symbiosis practices (Walls & Paquin, 2015; Henriques et al., 2021). These companies are typically the biggest and most prominent entities within the industrial symbiosis network (Henriques et al., 2021). Furthermore, it is typical for these companies to possess a substantial and steady supply of resources that can be exchanged with other entities within the network (Mulrow et al., 2017; Walls & Paquin, 2015). In essence, these corporations function as physical anchor tenants, serving as pivotal entities that facilitate industrial symbiosis by generating substantial material and energy streams within a given location (Sun et al., 2017). Furthermore, it has been observed that these corporations play a role in constructing infrastructure that could facilitate future exchanges with other entities (Costa & Ferrão, 2010). Apart from serving as physical anchor tenants, these firms have also been found to undertake a coordinating function for enhancing efficiency and resource sharing, fostering communication, cooperation, and innovation within the cluster (Walls & Paquin, 2015).

The municipality

The involvement of the municipality in the initiation and establishment of industrial symbiosis has also been highlighted in literature (Mortensen and Kørnøv, 2019), and Henriques et al. (2021) have identified the participation of this stakeholder as a crucial factor in enabling industrial symbiosis practices. Burström and Korhonen (2001) note that municipal environmental management can influence the initiation of symbiosis practices and distinguish between two distinct municipal environmental management practice approaches. Initially, territorial municipal environmental management pertains to the strategic planning and administration of natural resources within a given locality. The second approach pertains to political municipal environmental management, which encompasses the municipality's

comprehensive endeavors towards upholding environmental sustainability. The latter approach, as explained by Burström and Korhrhonen (2001), entails "formulating overall environmental policies and goals, planning, co-ordinating, balancing and prioritizing different municipal initiatives and actions." According to Henriques et al. (2021), enabling industrial symbiosis activities depends on the promotion of industrial sustainability by municipalities and their commitment to transitioning to a less polluting industry. Furthermore, the municipality has the potential to serve as a facilitator by convening relevant companies and providing a place for them to come together, share information, and organize industrial symbiosis initiatives (Rosado & Kalmykova, 2019). Furthermore, the municipality's territorial approach can also potentially have a significant impact on the implementation of industrial symbiosis initiatives. As highlighted by Mortensen and Kørnøv (2019), the issuance of licenses and permits by the municipality can play a pivotal role in facilitating the effective implementation and operations of industrial symbiosis initiatives. Lastly, the municipality's function as a funding body that provides financial support for new symbiotic initiatives has been identified as a critical success factor for industrial symbiosis (Mortensen & Kørnøv, 2019).

2.3.7 Barriers to Implementing Industrial Symbiosis

Literature identifies various barriers to the initiation and implementation of industrial symbiosis practices. In this context, barriers are factors that hinder or obstruct the development of industrial symbiosis (Henriques et al., 2021). The barriers are classified in different ways, including by stage of the process or organizational level, however, we find that most barriers can be classified as either technical, social, economic, organizational, or institutional, and will therefore follow this approach.

Technical barriers

According to literature, when implementing industrial symbiosis practices, there are several technical challenges companies may encounter. Barriers can be linked to, for instance, the lack of appropriate technology, infrastructure, or technical workforce, and to the lack of necessary financing for R&D activities (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021; Goley et al., 2015). Furthermore, there can be capacity issues regarding energy conservation and pollution prevention, disruptions related to the implementation of new technologies, and integration problems with the new technologies and procedures (Henriques et al., 2021; World Bank, 2021; Goley et al., 2015). Companies must also consider the quality, magnitude, and

predictableness of the resource they are receiving from the collaboration, especially if the resource is an essential part of their inputs (Henriques et al., 2021; Neves et al., 2019; Johansen & Haavik, 2019; Norsk Industri, 2019; HighEFF, 2021; Madsen et al., 2015). Johansen & Haavik (2019) argue that disruptions in the stream of the resource pose challenges ranging from threats to daily operations to economic viability of the production and that involved companies can be very vulnerable if a supplier company relocates or shuts down. The associated risks emerging from these dependencies may discourage companies from initiating industrial symbiosis or create challenges during implementation. In addition, due to the immaturity of the market, there can be a discrepancy in desired quantities between supply and demand, which can pose difficulties in finding buyers for available by-products (Norsk Industri, 2019; Madsen et al., 2015). Several studies also highlight the significant challenge of maintaining consistent and sufficient product quality in industrial symbiosis, as variations in quality, particularly when dealing with waste materials, can discourage companies from considering it as a viable option (Madsen et al., 2015; Johansen & Haavik, 2019; Norsk Industri, 2019).

Organizational barriers

One of the most common organizational barriers to implementing industrial symbiosis is linked to the lack of structure in the new cluster network. This lack of structure can manifest as insufficient management resources, a lack of protocols, or a lack of communication channels among stakeholders (Henriques et al., 2021; World Bank, 2021; Norsk Industri, 2019; Madsen et al., 2015). Particularly, the absence of standards, protocols, or guidelines for effective collaboration is a recurring issue. This can result in challenges concerning cost allocation, defining the new business model, and overall coordination of collaborative efforts (Fichtner et al., 2005; Madsen et al., 2015). Another challenge highlighted in the literature is the absence of promoters or individuals who can effectively coordinate the actions of the involved companies (Fichtner et al., 2005; Goley et al., 2015). Additionally, the lack of knowledge regarding potential synergies is often highlighted as a barrier to initiating industrial symbiosis (Madsen et al., 2015; Corsini et al., 2023, Fichtner et al., 2005; Neves et al., 2019). Furthermore, a lack of external support from owners, the value chain, or other parts of the company network can also impede progress (World Bank, 2021; Henriques et al., 2021). Finally, there can be challenges related to the complexity of necessary changes across several dimensions, which can, in some cases, make the implementation unviable (Henriques et al., 2021).

Social barriers

A central element of industrial symbiosis is collaboration, between companies, stakeholders, and often a cluster facilitator. Accordingly, overcoming social barriers to initiating and implementing industrial symbiosis practices is crucial. A key social barrier is the lack of trust, whether towards the other involved companies or the cluster facilitator (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021; Goley et al., 2015; Madsen et al., 2015; Corsini et al., 2023). Furthermore, trust issues can often lead to resistance to sharing confidential data required to identify feasible resource streams and projects (Neves et al., 2019; Fichtner et al., 2005; Goley et al., 2015; Corsini et al., 2023). Other barriers that are identified in literature include conflict of interest between the involved companies (Henriques et al., 2021; Madsen et al., 2015), fear of dependence related to the collaboration (Neves et al., 2019; World Bank, 2021; Fichtner et al., 2005), or simply a closed or competitive company culture (Fichtner et al., 2005; Madsen et al., 2015). Moreover, a lack of knowledge can be a barrier, especially to initiating industrial symbiosis projects. This may be related to a lack of knowledge of industrial symbiosis practices and their potential benefits, resulting in a lower interest (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021; Goley et al., 2015; Madsen et al., 2015; Fichtner et al., 2005). Furthermore, it can be linked to the lack of knowledge of surrounding companies that may have the potential of starting symbiotic relationships (Neves et al., 2019; Fichtner et al., 2005; Corsini et al., 2023). Different levels of motivation or priority of the collaboration (Madsen et al., 2015), a size difference between the companies and thus relational power (Madsen et al., 2015; HighEFF, 2021), or ineffective communication may also be hindering factors for implementing industrial symbiosis (Fichtner et al., 2005).

Institutional barriers

For institutional barriers, a key barrier identified is the lack of appropriate legislation and policies that encourage industrial symbiosis and eco-industrial parks (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021; Norsk Industri, 2019; Fichtner et al., 2005; Goley et al., 2015; Madsen et al., 2015; Corsini et al., 2023). Furthermore, there is an absence of policies discouraging a linear economy, which, for instance, could include higher taxes on landfills (Neves et al., 2019; Goley et al., 2015; Corsini et al., 2023). On the other hand, existing regulations may also be impeding the implementation of synergetic relationships, for instance, through policies regulating the use of water or energy, limitations on the use of waste, or simply from the regulation being too unclear or inconsistent (Henriques et al., 2021; Neves et al., 2019; Madsen et al., 2015). In addition, the lack of public funding to support the initiation

of these synergies, including research and development funding and support for regional facilitators (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021; Norsk Industri, 2019; Corsini et al., 2023). Moreover, uncertainty regarding future national frameworks and policies for environmental and waste management may contribute to a lower willingness to initiate an industrial symbiosis project (Henriques et al., 2021; Goley et al., 2015; Madsen et al., 2015). For instance, it might be difficult to obtain approvals for waste reuse projects or the working processes between companies and authorities may be too unsynchronized (Goley et al., 2015; Madsen et al., 2015).

Economic barriers

There are several economic barriers identified in the literature, including the uncertainty connected to the profitability of a project, as well as to associated costs and risks (Henriques et al., 2021; Neves et al., 2019; Fichtner et al., 2005; Madsen et al., 2015). This stems from factors such as uncertainties related to the resource streams, immature markets, and changes in collaboration dynamics. Furthermore, for certain synergies, such as sharing of excess heat, the implementation of industrial symbiosis requires significant upfront capital investments, and may initially offer low profitability, which may deter companies from initiating projects (Neves et al., 2019; World Bank, 2021; Norsk Industri, 2019). The industrial symbiosis must be economically beneficial for the companies to have incentives to collaborate, and if the value of raw materials is close to the value of waste, these incentives may be deficient (Henriques et al., 2021; Neves et al., 2019; Madsen et al., 2015; Corsini et al., 2023).

Potential solutions suggested in literature

Most literature addressing barriers to initiating or implementing industrial symbiosis also proposes solutions for overcoming them. These solutions are presented in different ways, including sector-specific recommendations (Henriques et al., 2021), solutions based on the type of barrier (World Bank, 2021; Goley et al., 2015) as well as the organizational level (Madsen et al., 2015), or strategies that will collectively overcome the identified barriers (Neves et al., 2019; Fichtner et al., 2005). Among the mentioned solutions, the use of intermediary networks is frequently highlighted (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021; Fichtner et al., 2005; Madsen et al., 2015). These networks can contribute to promoting trust, fostering collaborative environments, engaging stakeholders, facilitating interaction, overcoming social barriers, and encouraging governmental cooperation. Furthermore, the establishment of European and international standards is essential for

enhancing the use of formal protocols, internal guidelines, and improved reporting (Henriques et al., 2021; World Bank, 2021; Norsk Industri, 2019; Goley et al., 2015). These standards can foster a shared approach and mutual understanding among all involved parties. For this matter, it is important to engage in dialogue with parks and study existing cases to ensure that these standards reflect the most effective practices, rather than duplicating previous approaches (World Bank, 2021). Furthermore, financial incentives, support for technological resources and innovation, and training programs for employees at the park level can be crucial for overcoming identified barriers (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021; Fichtner et al., 2005; Madsen et al., 2015; Norsk Industri, 2019; Corsini et al., 2023). Norsk Industri (2019) emphasizes the need for increased long-term research support for projects with longer progression tracks and enhanced support for smaller-scale projects that aim to optimize the utilization of waste and byproducts in existing plants. Other research emphasizes the importance of a corporate culture promoting cooperation and trust, which may be facilitated by an intermediary network (Fichtner et al., 2005; Madsen et al., 2015) and promote collaboration between industries to increase knowledge (Norsk Industri, 2019). Moreover, political measures should focus on facilitating and supporting regional cooperation and networking (Norsk Industri, 2019; Fichtner et al., 2005).

3. Current Environment for Norwegian Industrial Clusters

In this section, we will assess the current environment for Norwegian industrial clusters engaging in industrial symbiosis practices. First, we will provide an overview of the Norwegian process industry in general. Then, we will review European and national strategies Norwegian industrial clusters must align with. Finally, we will present resources available for Norwegian industrial clusters, including funding and collaboration partners, regional facilitators, and research and academic communities.

3.1 The Norwegian Process Industry

The process industry is a collective term that encompasses several industries, including aluminum, ferroalloy, chemical, mineral, fertilizer, refinery, and pulp and paper industries (Norsk Industri, 2016). In Norway, this industry employs 25 000 people and accounts for 18% of the country's total physical exports (Prosess21, 2021). Companies within the process industry are spread out across the country and are typically significant players in their local communities, often serving as cornerstone companies (Norsk Industri, 2016). The process industry is also the largest consumer of Norwegian hydropower, and, thus, an important factor in maintaining the value of the hydropower (Norsk Industri, 2016; Prosess21, 2020). Furthermore, a strength of the Norwegian process industry is its strong collaboration between employees, management, owners, and the government, constituting an important competitive advantage (Prosess21, 2020). However, the process industry is responsible for nearly all of Norway’s onshore industry emissions, accounting for 23% of the country's total emissions in 2020 (Regjeringen.no, 2022). The process industry consists of industries that generate a significant volume of by-products or waste during their operations. The industry is therefore suitable for implementing industrial symbiosis projects, and one proposed solution to reduce the industry’s environmental footprint is to optimize the utilization of these side-streams in a circular manner (Prosess21, 2020).

3.2 European and National Strategies

European strategy

Over the past decade, Norway has implemented a range of policies and initiatives to promote green industrial practices, and the European Union has played a significant role in driving this transition (Regjeringen.no, 2022). The European Green Deal constitutes a set of policy initiatives and is the European Commission's plan for making the European Union climate neutral by 2050 (European Commision, n.d.). According to Prosess 21, The Green Deal constitutes the most comprehensive package of initiatives the Norwegian industry has ever had to adopt (Prosess21, 2021). One of the components of the Green Deal is the Industrial Emissions Directive, which is the primary EU instrument for regulating industrial pollution (European Commission, n.d.). In April 2022, the EU proposed a modified version of this directive, which will cover more relevant pollution sources, increase transparency, and support breakthrough technologies (European Commission, 2022; Regjeringen.no, 2022). Another component is the EUs Circular Economy Action Plan, which will have great implications for the conditions for Norwegian process industry (Prosess21, 2020).

National strategy

On a national level, the Norwegian government has set a main objective: "Norway must be a leading country in the creation of a green, circular economy that better utilizes resources," (Regjeringen, 2019). The government has developed a national circular economy strategy that includes Norway's strategy for making the industry more circular (Regjeringen.no, 2021). Included in these findings is the potential for increased exploitation of by-products and secondary resources, and the importance of clusters and networks to facilitate circular solutions is highlighted. In the report, the government claims that they will acknowledge industrial clusters and cross-sectoral collaboration as an effective tool for increased circularity, facilitate a national cluster collaboration, establish an expert group on sharing of industry data that can develop guidelines for accountability, ownership, and rights of use for sharing of such data, as well as several other proposals. Another initiative introduced by the government is the "Roadmap – The green industrial initiative" which is intended to boost the green industry and states that the government shall create a strategy for the establishment of green industrial parks and regions across the country (Regjeringen.no, 2022). In 2018, the Norwegian Ministry of Trade, Industry, and Fisheries initiated an industrial strategy called Prosess 21, which aims to reduce emissions from the process industry by 2050 (Prosess 21, n.d.). It serves as a valuable

tool for the industry to comprehend the implications of the European Green Deal for the Norwegian process industry (Prosess21, 2021). The strategy also includes a report on how the process industry can become more circular, where green business models and effective utilization of side-streams are key areas of focus.

3.3 Available Resources for Norwegian Industrial Clusters

This subsection aims to provide an overview of the tools that are currently available to support industrial clusters in Norway with guidance, research, and funding to carry out industrial symbiosis projects.

3.3.1 Funding and Collaboration Partners

The Norwegian Innovation Clusters is a publicly financed program for clusters that aims to contribute value creation through sustainable innovation (Innovation Norway, 2023). The program is a collaboration between Innovation Norway, The Industrial Development Corporation of Norway (SIVA), and The Research Council of Norway, with Innovation Norway being primarily responsible for the operations of the program (Siva, n.d.). Competitive clusters in Norway can apply to become part of the program and the services it offers its members include financing, competence services, advisory services, network services, and profiling services (Innovation Norway, 2023). The reports made in correlation with the National Circular Economy Strategy encourage increased support for this program or similar ones (Deloitte, 2020). However, in 2022, the Ministry of Local Government and Regional Development reduced the program's budget by 60 million NOK, or almost 30% (Innovation Norway, 2022). This resulted in the program not being able to accept new members this year and the offer to its existing members was reduced. In addition to the Norwegian Innovation Clusters, Innovation Norway also offers different financing arrangements for companies or clusters seeking to become more circular, including through industrial symbiosis (Innovation Norway, n.d.). Siva also offers a program for business parks (original: Næringshageprogrammet), which aims to provide their members with a network, partners, competence, and facilities, where they can benefit from each other’s experiences and accelerate their own sustainable growth (Siva, n.d.) Other supporting organizations that provide financing for sustainable innovation in Norway include Enova, Skattefunn, and The

Research Council of Norway (Innovation Norway, n.d.). Furthermore, several smaller local funds exist.

3.3.2 Regional Facilitators

An important resource for industrial clusters seeking assistance in implementing industrial symbiosis can come from regional or national facilitators. These facilitators are not restricted to a specific geographical park area, but their members may include individual companies as well as industrial parks or clusters. Two of the most impactful facilitators in Norway are the Arctic Cluster Team and the Norwegian Center of Circular Economy, both of which are members of the Norwegian Innovation Clusters program (Innovation Norway, n.d.) The Arctic Cluster Team is a gathering point for clusters, companies, and research and academic communities in the north of Norway. Their goal is to be at the forefront of sustainable transformation (Arctic Cluster Team, n.d.). The Norwegian Center of Circular Economy is based primarily on the east coast of Norway, but they have members across the country (Norwegian Center of Circular Economy, n.d.). Both regional facilitators strongly focus on collaborations between businesses, research communities, and public authorities (Norwegian Center of Circular Economy, n.d.; Arctic Cluster Team, n.d.). Through the regional facilitators, clusters can receive valuable access to knowledge sharing through innovation projects, workshops, seminars, and excursions, and the facilitators can play an important role in connecting members with relevant partners (Norwegian Center of Circular Economy, n.d.; Arctic Cluster Team, n.d.). Furthermore, the “Hubs for Circularity” is a European resource that targets industrial parks and clusters that was launched in 2021 (Hubs4Circularity, n.d.). The network aims to play a significant role in the European Union's goal of achieving climate neutrality by 2050 by advancing the research and innovation agenda of European industries toward the objectives of the Green Deal (European Commission, 2021). Hubs for Circularity serves as a knowledge-sharing platform for industrial symbiosis, industrial-urban symbiosis, and circular economy closing energy, connecting stakeholders across longer distances (Hubs4Circularity, n.d.).

3.3.3 Research and Academic Communities

Industrial clusters in Norway have access to various research institutions and academic communities for collaboration. Among these, Sintef is one of Europe’s largest research institutes, possessing expertise in technology, natural sciences, and social sciences (Sintef,

n.d.). Their research can prove beneficial to the clusters as they can provide insights into potential resource- or energy streams and how they can enhance their efficiency through collaboration. Sintef, in collaboration with NTNU, has also established HighEFF, a center dedicated to creating a competitive, energy-efficient, and eco-friendly industry for the future (Sintef, n.d.). Moreover, a project conducted by Zero evaluates the climate benefits of closely-located industries in collaboration with Treklyngen, Mo Industrial Park, Herøya Industrial Park, Glomfjord Industrial Park, and Siva (Zero, 2023). Similarly, Norsus is examining the impact of industrial symbiosis in the Øra region (Norsus, n.d.). The findings of both projects will be presented by the end of 2023. Additionally, many clusters are collaborating with local universities, colleges, and high schools.

4. Methodology

In this section, we will discuss the methodological choices of our research. First, we will present our research approach, followed by our choices of research design. Subsequently, we will explain how we have collected and analyzed the data for this study. Then, we will discuss the quality of our conducted research and, finally, we will consider ethical concerns related to this study.

4.1 Research Approach

When deciding upon a research approach, we must take our research question into consideration. As we want to explore how industrial symbiosis can be successfully implemented in Norwegian industrial parks, we find it natural to choose an inductive research approach. This is because the topic is relatively unexplored in the Norwegian context and, thus, we seek to discover the phenomenon by collecting data, finding patterns and themes, and, finally, creating a conceptual framework. Through an inductive approach, we also allow for finding actual effects, and not simply planned and anticipated impacts, which could potentially be the case by choosing a deductive approach (Thomas, 2006). As an inductive approach leaves room for flexibility, generalizes from the specific to the general, and supports the generation of new theories (Saunders et al., 2012), we find it fitting for the purpose of this thesis.

4.2 Research Design

According to Saunders et al. (2012), the research design is the general plan of how we intend on answering our research question, including choice of method, research purpose, time horizon, and research strategy. In accordance with the nature of our research question and our choice of an inductive research approach, we will benefit from a qualitative research method. A qualitative design is typically associated with collecting non-numeric data, e.g., through interviews, in contrast to a quantitative design which analyses numeric data (Saunders et al., 2012). This design is useful when the purpose is to answer questions mainly related to the experience and perspective of participants, and when the data is not suited to be quantified (Hammarberg et al., 2016). Furthermore, qualitative research corresponds well with an

inductive approach, when the purpose is to broaden the existing theoretical understanding (Saunders et al., 2012).

Aligned with the previous choices, our research follows an exploratory purpose. An exploratory research purpose is a valuable way of developing a more nuanced understanding of a problem, by, for instance, asking open questions to gain insights about the respective topic (Saunders et al., 2012). Hence, a customary way of conducting exploratory studies is through interviews with experts on the topic, where it is favorable to keep the interviews somewhat unstructured with open-ended questions. Furthermore, this design is flexible and adaptable to change, which allows for contributions from participants to impact the course of the study (Saunders et al., 2012). Decisively, we find an exploratory design as a suitable research purpose for our study, as we will explore our research question by gaining knowledge from the industrial clusters that have already been successful in implementing industrial symbiosis practices.

When we explore the topic of how industrial symbiosis practices may be successfully implemented in Norwegian industrial clusters, we will answer this according to the current situation, i.e., what barriers Norwegian industrial clusters can expect to face at this point in time. This implies that we are conducting a cross-sectional study, which can be described as a "snapshot" of a particular topic at a particular time (Saunders et al., 2012). This is beneficial due to the limitedness of our study being conducted over only one semester. Furthermore, considering the potential benefits of industrial symbiosis practices for a larger number of industrial clusters, and the lack of published studies in a Norwegian context, we find it beneficial to share our findings promptly.

The research strategy we find most fitting for this study is the Grounded Theory methodology. Grounded theory is viewed as an inductive methodology and refers to the strategy of obtaining a theory grounded in collected, refined, and categorized data (Kolb, 2012). The theory was first introduced by Glaser and Strauss (1967) and aimed to create a systematic approach for analyzing, interpreting, and explaining the meanings that people construct to make sense of their daily life experiences (Saunders et al., 2012). According to Jørgensen (2001), grounded theory can be characterized as a methodology that offers systematic guidelines for collecting, synthesizing, analyzing, and conceptualizing qualitative data with the intention of constructing theory. The literature on grounded theory is largely connected to its method of data collection and analyzing procedures, which involves developing analytical codes through constant

comparisons of the data, followed by a further reorganization of these data into distinct categories (Saunders et al., 2012). This method and how it will be executed in this study will be further explained in Section 4.4.

4.3 Data Collection

In this section, we will outline our data collection methodology, which we have devised to effectively answer our research question. We will begin by discussing the process of selecting our interviewees and include an overview of the selected sample. Then, we will explain our decision to employ semi-structured interviews, where we describe the purpose of our interview guide and provide an overview of how the interviews were conducted.

4.3.1 Sample Selection

To select the appropriate sample to answer our research question, we must first identify and select industrial clusters within the population, and then detect the "expert" within each cluster. As we want to discover how Norwegian industrial clusters can succeed in initiating and implementing industrial symbiosis practices, our population is Norwegian industrial clusters that are practicing industrial symbiosis, to at least some extent, within their cluster. The total population is, thus, hard to identify as several industrial clusters may practice industrial symbiosis activities without explicitly referring to this online. Furthermore, some clusters may practice activities that can be considered industrial symbiosis but have not reflected upon the circularity aspect of these activities, especially if the intentions have been economic or practical. Accordingly, the probability of each case being selected from the total population is unknown, and we must, hence, choose a non-probabilistic sampling technique (Saunders et al., 2012).

In line with the Grounded Theory Method, our sampling approach will be purposive, meaning that we will exercise judgment in selecting clusters that best align with our research question and objectives (Saunders et al., 2012). Furthermore, we will employ heterogeneous, also referred to as maximum variation, sampling, which aims at identifying and describing the central themes that can be observed (Patton, 2002). We then choose cases with sufficiently diverse characteristics to ensure maximum variation in our collected data (Saunders et al., 2012). This sampling method allows us to both find unique and detailed descriptions of each case and also identify shared patterns that cut across cases, despite their variation (Patton,

2002). To achieve this, we will identify key dimensions of variation in advance and use them to guide case selection (Suri, 2011). All cases within the population share the aspect of engaging in industrial symbiosis practices, however, there are variations in the clusters doing this. The key dimensions we will use to select cases to capture the variety of clusters are the following: cluster *size*, measured based on a combination of the number of employees and the number of companies in the cluster; *stage* of implementation of industrial symbiosis; and the *geographical proximity*, which refers to how closely the companies within the clusters are located. The stage of implementation differentiates between the clusters that are in a *development phase* of implementing industrial symbiosis, those that are *experienced* in this process, and those that are also *exploring* more symbiotic opportunities. This heterogeneous approach ensures that our findings apply to various types of clusters and allows for the inclusion of diverse perspectives within our sample. An overview of the clusters including the key dimensions is presented in Table 1 below, while a more detailed description of the selected eleven clusters can be found in Appendix A.

Table 1 - Cluster selection

Industrial cluster	**Size**	**Stage**	**Geographical proximity**
Mongstad Industrial Park	Big	Development phase	Within industrial park
Skogmo Industrial Park	Medium	Experienced	Within industrial park
Thamsklyngen	Medium	Exploring	Within industrial park
Sirkulære Rjukan	Medium	Development phase	Within industrial park
Treklyngen	Medium	Development phase	Within industrial park
Mo Industrial Park	Big	Exploring	Within industrial park
Glomfjord Industrial Park	Medium	Experienced	Within industrial park
Tregruppen	Small	Experienced	Within the same county
Øra Industrial Area	Big	Exploring	Within industrial area
Eyde Cluster	Big	Exploring	Within the same county
Herøya Industrial Park	Big	Exploring	Within industrial park

Furthermore, we needed to identify the individual considered an "expert" on circularity and industrial symbiosis within each cluster. Our aim was to engage with informants who had close involvement with the cluster's industrial symbiosis practices. Given that cluster organization often consists of few employees, we saw it as a sensible approach to reach out to the general managers of the clusters. We then invited the manager to either participate themselves or to refer us to a colleague that would be better suited for the purpose of our research. In accordance with guidelines from the Norwegian Center for Research Data, we have opted to formulate anonymous labels for the informants' positions within the cluster. An overview of the respondents is presented in Table 2 below.

Table 2 - Informant selection

Industrial cluster	**Informant**	**Gender**
Mongstad Industrial Park	Managerial cluster representative	Male
Skogmo Industrial Park	Managerial cluster representative	Male
Thamsklyngen	Managerial cluster representative	Male
Sirkulære Rjukan	Project manager	Male
Treklyngen	Managerial cluster representative	Male
Mo Industrial Park	Business developer	Male
Glomfjord Industrial Park	Managerial cluster representative	Male
Tregruppen	Network facilitator	Male
Øra Industrial Area	Project manager NCCE	Female
Eyde Cluster	Managerial cluster representative	Male
Herøya Industrial Park	Managerial cluster representative	Male

4.3.2 Collecting Data Using Semi-Structured Interviews

Based on our qualitative research method and exploratory purpose we find it fitting to collect data by conducting semi-structured interviews as part of our grounded theory approach. In semi-structured interviews, there are key questions and themes planned for the interviews, however, there is room for adaptation in the flow or structure depending on what seems fitting

for each interview (Saunders et al., 2012). The interview style is suitable for asking open-ended questions, which is favorable for investigating our research objectives. Saunders et al. (2012) further state that semi-structured interviews are beneficial when it is of significance to explore the reasoning behind the research participants' decisions. This is a suitable way for us to gain a deeper understanding of the topic, as it allows for personal contact in a context where the research participants have the possibility to reflect "aloud", as it will likely vary how much the participants have priorly reflected upon the different questions. Furthermore, this allows us to be certain that we are collecting data from the intended person, in contrast to a questionnaire that could potentially be executed by someone else (Saunders et al., 2012).

Creating an interview guide

Aligning with the purpose of semi-structured interviews, we have designed a guide on which we will base all of our interviews, which can be seen in Appendix B. Prior to the interview, we provide the participants with a version of the interview guide, which outlines our areas of interest and enables them to prepare accordingly, thus maximizing the effectiveness of the interview. In this guide, we included a short explanation of what we regard as industrial symbiosis activities, reducing the likelihood of misunderstandings. During the creation of the interview guide, it was important to minimize bias as much as possible. To achieve this goal, our approach was to mainly employ open-ended questions that can be supplemented with probing questions, if required. This allows the participants to respond as they want and encourage them to provide an extensive and developmental response, while the probing questions may seek explanations where the meaning or reasoning of the participant is unclear (Saunders et al., 2012). Furthermore, we have taken care to avoid using leading, lengthy, and compound questions, to ensure unbiased responses and comprehensive answers to all our inquiries (Saunders et al., 2012).

Conducting the interviews

All of our interviews are conducted online, allowing us to transcribe and video-record the interviews, which the interviewees had consented to in advance. Moreover, this secures consistency in the way the interviews are executed and leaves room for us to direct our attention toward the conversation and follow-up questions, rather than transcription. The interviews lasted between 45-70 minutes, were scheduled based on the availability of the participants, and were conducted over a span of approximately three weeks. Each interview is initiated by a short informal conversation, including an introduction of ourselves and our

research, as well as ensuring that the participant has read and agreed to the content of the consent form we sent them in advance. Subsequently, we posed several introductory questions to ensure that all necessary details for mapping the industrial parks and the role of the research participant were included. For the remainder of the interview, we were delving into the key questions of the interview. During the interviews, we provided opportunities for the interviewee to discuss relevant aspects from their perspective. We actively encouraged them to share any additional information they deemed important. Moreover, we employed follow-up questions to further investigate the aspects that the interviewee considered most significant, ensuring a comprehensive exploration of their insights.

4.4 Data Analysis

In this section, we will clarify how we have analyzed our collected data. We will start by describing our transcription process of the interviews, followed by a review of how we have coded our data in line with the Grounded Theory Method.

4.4.1 Transcription

To prepare our collected data for analysis, we performed a thorough transcription of the interviews to ensure that all valuable information is captured. During the interviews, we conducted real-time transcriptions using our chosen online meeting platform, capturing nearly all verbal communication. Additionally, we video-recorded the interviews to facilitate a comprehensive review afterward. This approach allowed us to accurately transcribe the dialogue, while also capturing non-verbal cues such as hesitation, laughter, and gestures, thereby enhancing the richness of the data (Saunders et al., 2012). A recurring challenge we encountered when transcribing the interviews, was interviewees who spoke orally and where it wasn't always clear where one sentence ended and another began. To address this, we exercised caution and discussed the different cases whenever necessary to ensure accurate punctuation and maintain the intended meaning of each sentence. Furthermore, the transcription process was carried out individually, followed by a collaborative review of all interviews to ensure both efficiency and thoroughness.

4.4.2 Coding the Collected Data Through Grounded Theory

After transcribing the interviews, we employed a coding technique to analyze the collected data, following the Grounded Theory Method described in Section 4.2. There are several defined procedures to do so, and the nature of them varies between the sources and sometimes even between editions of the same book (Saunders et al., 2012). While Strauss and Corbin (1998) refer to the stages as open, axial, and selective coding, Charmaz (2006) refers to them as initial and focused coding. There are also other approaches available. In this thesis, we will base the data analysis on the latter coding method, as Charmaz's approach offers more flexibility (Saunders et al., 2012).

Initial coding is the process of identifying concepts and assigning them labels, grouping comparable units of data (Saunders et al., 2012). During this part of the analysis, we will closely study all fragments of the data, including words, lines, and segments (Charmaz, 2006). According to Charmaz (2006), initial coding focuses on comparing data with data, ensuring that the codes are grounded in and closely linked to the data. This process allows us to understand the perspectives of the interviewees and facilitates analytical treatment of the data, revealing significant concepts and themes. As a result, a multitude of codes typically emerges, as one must review all sections of data thoroughly (Saunders et al., 2012). In our case, examples of initial codes identified from the interviews include specific elements that have affected the clusters to initiate industrial symbiosis practices or factors that have been helpful or disadvantageous in the process.

After the initial coding stage, we move on to focused coding, where we examine the data to determine which initial codes should be used to categorize larger data units (Saunders et al., 2012). Charmaz (2006) describes this as selecting paths among the initial codes, focusing on the most significant and/or frequently occurring ones. It is important to choose the initial codes that make the most sense analytically and provide comprehensive categorization of the data, that also considers the insights gained during the analysis process. These focused codes enable coding and comparisons across interviews and observations, as it analyzes and conceptualizes larger segments of data (Charmaz, 2006). The codes might also lead to phenomena that have yet to be conceptualized or lead in unanticipated directions, and it also allows for more analysis. In our thesis, examples of focused codes include potential solutions derived from the data, roles of stakeholders, and specific barriers.

4.5 Research Quality

This section includes an assessment of the research methodologies used, with a focus on evaluating the research's strengths and weaknesses. When assessing the credibility of research, it is common to consider the reliability and validity of the study (Saunders et al., 2012). Validity refers to the extent to which a research study accurately measures the characteristics of the concept (LoBiondo-Wood, 2014), while reliability is whether your data collecting, and analysis methods would yield consistent findings if repeated or duplicated by another researcher (Saunders et al., 2012). The application of validity and reliability in qualitative research is not as direct as in quantitative research, owing to the distinctive characteristics of qualitative research approach (Kitto et al., 2008). Thus, we have chosen to use the method of Guba and Lincoln (1985) for assessing the quality of our research as this method uses new terminology to capture the unique characteristics of qualitative research (Saunders et al., 2012).

Guba and Lincoln (1985) have developed a set of criteria that are related to the conventional quantitative evaluation standards of validity and reliability for qualitative research (Saunders et al., 2012). These standards have played an important part in the establishment of requirements to evaluate the level of qualitative research (Morse et al., 2012) and have also gained extensive employment in quantitative research (Shenton, 2004). In the following, we aim to assess the trustworthiness of our qualitative research through the application of Guba and Lincoln's criteria. These criteria encompass four key dimensions, namely credibility, transferability, dependability, and confirmability.

4.5.1 Credibility

Credibility relates to the trustworthiness of research findings (Korstjens & Moser, 2018). The intent is to establish congruence between the information presented in the research derived from the raw data of the participants and the participants' initial perspectives (Graneheim & Lundman, 2004).

One of the methods for enhancing research credibility is triangulation, which refers to the use of several data sources, investigators, and data collection procedures (Korstjens & Moser, 2018). In our study, we have employed a triangulation approach via data sources, which entails interviewing a wide range of subjects (Shenton, 2004). Specifically, we conducted eleven

interviews with each participant representing a distinct industrial cluster. These clusters were of various sizes, in different developmental stages in their implementation of industrial symbiosis, and the clusters are geographically dispersed throughout the country. This approach enabled us to collect a wide range of viewpoints, compare them with participants from different clusters, and thereby validate individual perspectives. By doing this we get a more nuanced and comprehensive perspective on the topic of research (Shenton, 2004). Moreover, the raw data collected from the participants were analyzed independently by the two resarchers of this study. Subsequently, the findings were debated, and a consensus was reached regarding the outcomes derived from the raw data. The aforementioned method is a type of investigator triangulation (Tracy, 2010), and it is a method that strengthens the credibility of the findings as it makes the analysis more nuanced and complex (Kitto et al., 2008).

Additionally, we have carried out online video interviews utilizing a semi-structured interview approach. This approach allowed us the opportunity to observe nonverbal cue observation, real-time clarification, and follow-up discussions, thereby reducing the risk of inaccuracy in the collected data in regard to the participants' perspectives and experiences. Furthermore, prior to conducting the interviews, a thorough examination of previous research findings was conducted to assess the degree of congruence between the project's findings and those of past studies (Shenton, 2004).

4.5.2 Confirmability

Confirmability pertains to the degree to which the outcomes of research can be verified or supported by external researchers (Korstjens & Moser, 2018). In qualitative research, the concept of confirmability is connected to the objectivity of the researcher, and so confirmability has the aim of maintaining the objectivity of the research findings from the possible effect of the researchers' own biases or opinions (Shenton, 2004; Korstjens & Moser, 2018). The approach used in our study involved an in-depth process for gathering and examining data, with the objective of reducing the likelihood of bias or personal judgment through investigator triangulation elaborated on in subsection 4.5.1. Furthermore, this paper presents a detailed overview of the methods employed for data collection, recording, and analysis, thereby providing an audit trail that contributes to the establishment of confirmability (Korstjens & Moser, 2018).

4.5.3 Transferability

The concept of transferability refers to the extent to which the findings of a research study can be applied to different settings and populations (Korstjens & Moser, 2018). The raw data of each participant is influenced by contextual factors, which in turn affect the research findings (Shenton, 2004), and thus it is imperative to consider contextual variables that could potentially impact the subject matter under investigation (Gomm et al., 2000). In our research we have elaborated on the number of organizations taking part in the study and where they are based, any limitations on participant selection, and the number of participants involved in the fieldwork. In addition to the contextual factors pertaining to the participants, we have also provided details on the frequency and duration of data collection sessions, methods used for collecting data, and the duration of the data collection period. The aforementioned details have been deemed important contextual factors to include in order to enhance the potential for transferability (Shenton, 2004). Lastly, we have a detailed presentation of the findings in our research, including appropriate quotes, which may further enhance transferability (Graneheim & Lundman, 2004).

4.5.4 Dependability

Dependability refers to the stability of the findings (Korstjens & Moser, 2018). Elaborately, dependability is determined by the extent to which data vary over time as well as changes made in the researcher's judgments during the analysis process (Graneheim & Lundman, 2004). We performed the interview over a three-week period and were consistent in examining the same areas of subjects throughout the interview process, employing an interview guide in the form of a structured questionnaire to ensure consistency and uniformity in the interview procedure. These measures were taken to reduce the difference between the inconsistencies in the data. Furthermore, to enhance dependability, it is necessary to offer an in-depth description of the methods used for data collection, recording, and analysis, in the study (Korstjens & Moser, 2018), also known as audit trail, which is discussed in subsection 4.5.2.

4.6 Ethical Concerns

The ethical considerations that are relevant to the research refer to the researcher's proper behaviour toward the individuals who are participating in the study (Saunders et al., 2012). Furthermore, according to Saunders et al. (2012) ethical considerations are likely to emerge

during the course of the research project, with qualitative research being more susceptible to a wider range of ethical concerns as compared to quantitative research. Therefore, it is imperative that we give careful thought to ethical concerns, given the qualitative nature of our research.

In order to maintain ethical standards in our research, we have established procedures that preserve anonymity and regulate the handling of personal information and data in accordance with the directives outlined by the Norwegian Centre for Research Data (NSD). Before conducting interviews, participants were provided with extensive information regarding the study's objectives and primary inquiries. Furthermore, a consent form was created to establish the requirements for the interview and the use of the participant data in the study. Before the interviews, the consent form was distributed to participants, and all subjects provided written consent by signing the form.

We also took additional efforts to protect the participants' anonymity and privacy since we were aware that the interview procedure may potentially yield material that could be considered sensitive. Specifically, we stored all interview data on a university server that was password-protected and carefully sorted into distinct folders with code names for each participant, ensuring that anonymity was maintained throughout the study. In addition, once the interviews were transcribed, we deleted all participant records, as well as the transcripts themselves after the end of the study. By adopting these measures, we were able to ensure that participant data was accessible only to us and existed for no longer than necessary, thereby reducing the risk of privacy or ethical breaches.

5. Findings and analysis

In this chapter, the findings of our study will be presented. The chapter begins by presenting the main findings of our analysis, along with our proposed conceptual framework. Then, we will provide a brief categorization of the clusters and their industrial symbiosis practices. Subsequently, we will discuss the identified internal and external drivers of the initiation of industrial symbiosis practices, as well as the identified barriers to its implementation. We will then present potential solutions to the identified barriers. Moreover, we will present the key identified stakeholders associated with industrial symbiosis initiatives and elaborate on their significance. In the final section, we will summarize our findings. For an overview of the eleven participating clusters, see Appendix A.

The goal of our analysis has been to answer the research question: *"How can industrial symbiosis practices be successfully initiated and implemented in Norwegian industrial clusters?"*. Through our analysis, we have interviewed eleven Norwegian industrial clusters that are engaging in these practices to investigate this research question. To guide us in answering this question, we have identified four research objectives that we have explored through our research. Firstly, we have examined the internal and external drivers for industrial clusters to initiate this process. Secondly, we have identified the key barriers that they face in implementing industrial symbiosis practices. Thirdly, we have investigated the solutions that have been necessary for the clusters to overcome these barriers and what solutions they believe are still needed. Lastly, we have explored the roles of the different stakeholders that are essential for the success of the initiation and implementation of industrial symbiosis practices within industrial clusters.

Based on our research, we have developed a framework that outlines the path to successfully implement industrial symbiosis practices, which is presented in Figure 2. The green layer represents the main identified barriers, which will be presented in section 5.3 The yellow layer represents suggested solutions to solve these barriers and will be expounded upon in section 5.4. The model also connects the barriers with their respective suggested solutions through arrows. As shown in the figure, the different barriers are often connected to several solutions as one must often address multiple aspects in order to effectively overcome them. Furthermore, we have found that the suggested solutions can be encapsulated by four overarching goals. Thus, by reaching these four goals, clusters can have a high chance of succeeding with their implementation of industrial symbiosis. Our suggested solutions function as one way of

reaching them, while other clusters that face a different combination of barriers, may need another combination of solutions. However, our research indicates that if clusters successfully cultivate a collaborative culture, establish trust, cultivate knowledge of industrial symbiosis, and find practical solutions for its implementation, they are likely to achieve success in incorporating industrial symbiosis practices. These four goals will be elaborated upon in section 5.4.8.

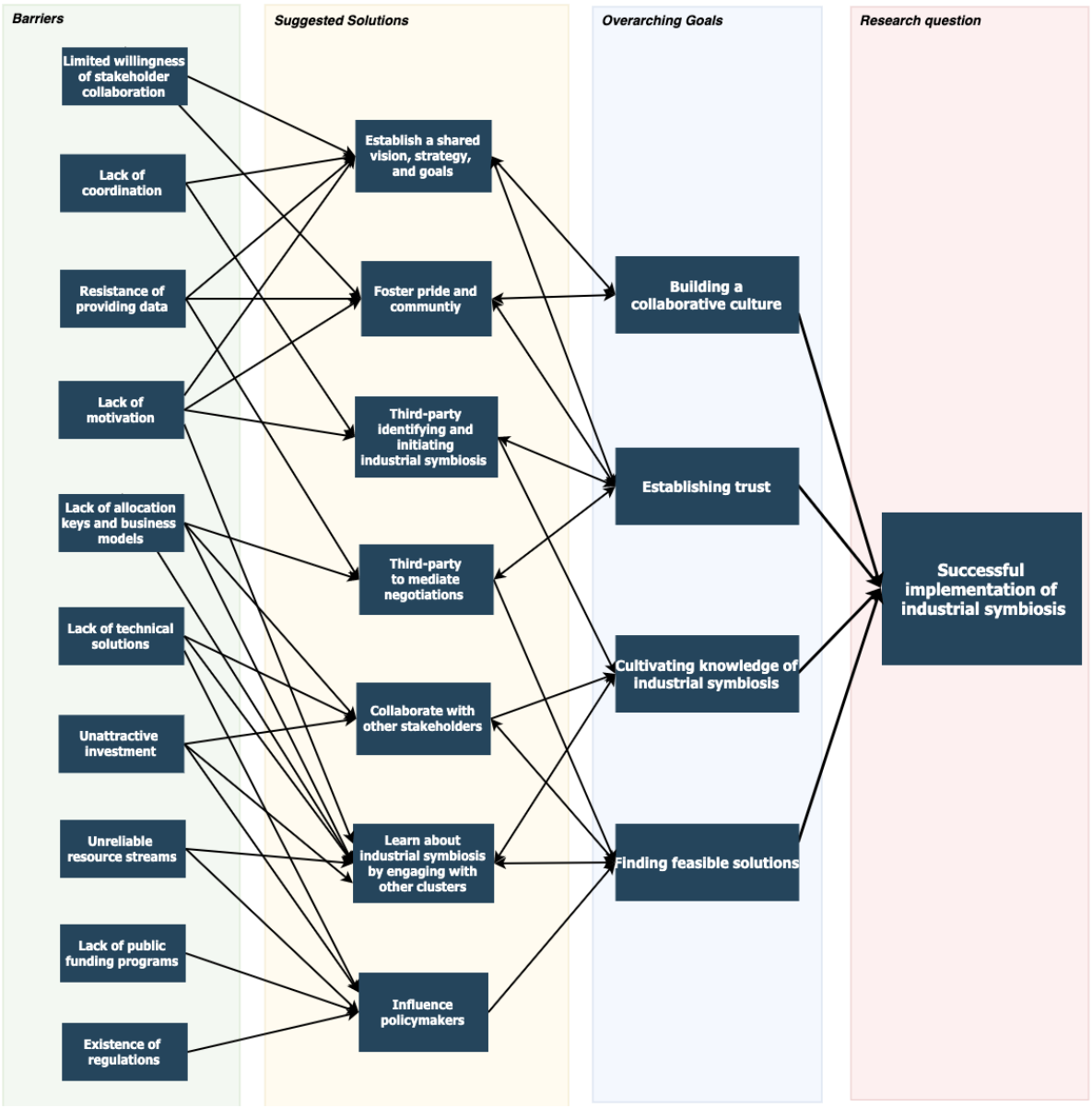

Figure 2 – Conceptual Framework for Implementation of Industrial Symbiosis

5.1 Categorization of Cases

In this section, we will present a categorization of the interviewed clusters. Initially, we will present a classification of the industrial symbiosis practices of the clusters. Subsequently, we will introduce a cluster categorization predicated on whether the industrial symbiotic relationship was established as a part of a sustainability strategy.

Types of industrial symbiosis

This section will look at the various industrial symbiosis practices that the participants have initiated or are currently engaged in. Our findings have led to the categorization of industrial symbiosis practices into four separate categories, which are sharing and exchanging of infrastructure and/or services, sharing of excess water, sharing of excess energy, and exchange of by-products and/or waste. The diagram presented in Figure 3 illustrates the percentage of the clusters that have initiated industrial symbiosis across each of the categories. The diagram illustrates the current industrial symbiosis practices being undertaken by the participants, as well as practices that are currently in the developmental and planning stages.

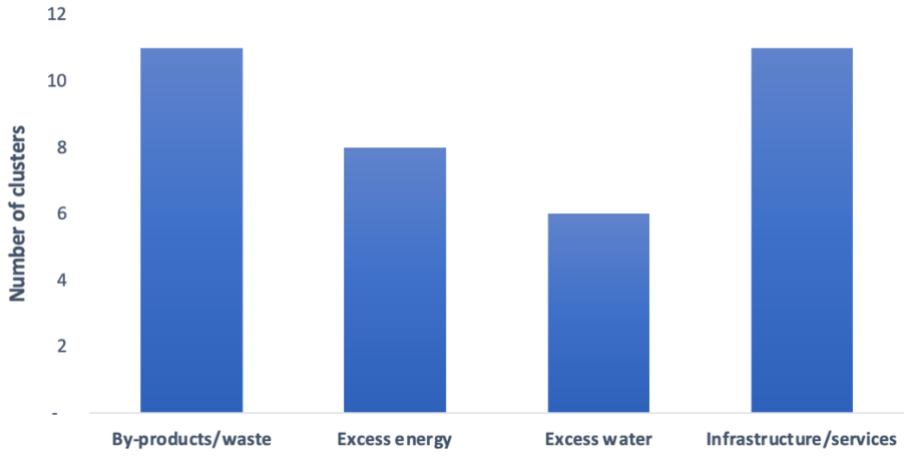

Figure 3 –Types of industrial symbiosis in the clusters

Initiation of industrial symbioses

It is varying when the industrial clusters initiated their industrial symbiosis projects. For some of them, this has been a gradual process over many years, while for others the implementation has been a more sudden or target move. As it is not necessarily easy to pinpoint the time the symbiosis projects were initiated, we are classifying the clusters based on whether the resource exchanges have been present in the clusters for a long time or if they were initiated along with a sustainability strategy. This classification is illustrated in Figure 4. We find that nearly half

of the clusters have engaged in industrial symbiosis activities for a longer period, while six of the clusters have initiated industrial symbiosis practices along with a broader sustainability strategy.

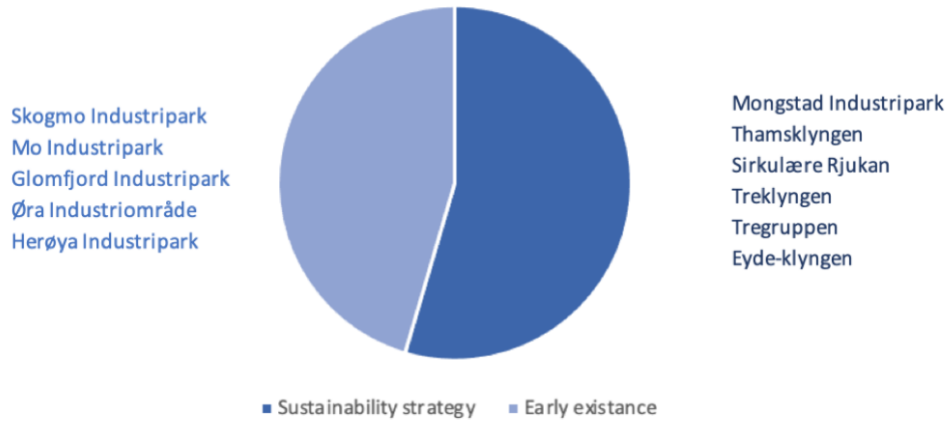

Figure 4 – Initiation of industrial symbiosis

5.2 Drivers of Industrial Symbiosis

This section addresses the first research objective: Identify internal and external drivers for Norwegian industrial clusters to implement industrial symbiosis practices. Our research suggests the internal drivers for initiating industrial symbiosis practices are tied to economic benefits and climate responsibility. In addition, we detected the existence of stakeholder pressure on climate responsibility, and financial and regulatory drivers for clusters to participate in industrial symbiosis activities. In the following subsections, we will begin by examining the internal drivers for clusters to initiate industrial symbiosis practices, followed by the external drivers that encourage these activities.

5.2.1 Internal Drivers of Industrial Symbiosis

Economic benefits

Although the environmental and social impacts of industrial symbiosis projects are principal, it is important to recognize the economic benefits the activities may offer to companies. In fact, this aspect is likely central to furthering the development of industrial symbiosis. Our research indicates that without perceived long-term financial viability, clusters would be unlikely to initiate such projects. Additionally, facilitators find it easier to motivate the

companies to participate in an industrial symbiosis when they can highlight tangible economic benefits from the projects. These economic benefits may emerge in various ways, sometimes more directly than others.

The majority of the respondents highlighted economic benefits as a motivating factor for industrial symbiosis, either related to cost reduction, new revenue streams, or both. For instance, the creation of synergies through collaboration often implies cost reductions due to production efficiencies, reduced transportation costs, or reduced waste generation. Treklyngen elucidates the positive economic impacts of industrial symbiosis through the following quote:

> *"First of all, it is financially rational to create synergies. That the synergies create a competitive edge and attractiveness so that we have the economic income and muscles to further develop the synergies, infrastructure, and park facilities, while also being left with a positive return for our owners" – Treklyngen*

Furthermore, companies can generate additional revenue outside of their core business by selling by-products that they have formerly regarded as waste. In addition, some respondents indicated that initiating industrial symbiosis projects could boost innovation and value creation, resulting in financial benefits for the enterprise, and thus constituted a portion of their motivation. Lastly, the perception that industrial symbiosis could provide a competitive advantage over businesses outside the cluster was also a factor in these businesses' decisions to participate in industrial symbiotic initiatives.

Environmental responsibility

Our study indicates that many industrial symbiosis initiatives were motivated by the companies' and clusters' environmental considerations. Notably, six of the respondents indicated that the initiation of industrial symbiosis activities was consistent with a broader sustainability strategy for their respective clusters. However, it is important to note that the focus on environmental responsibility as the motivation for these activities has been becoming more prevalent in recent years. Firstly, we find that most of the industrial symbiosis initiatives that have been implemented in combination with a larger sustainability policy have only been in place for a few years. Secondly, when examining long-standing instances of industrial symbiosis, it was discovered that the main motivation was often of an economic nature, whereas in recent industrial symbiosis projects, greater emphasis was placed on environmental

responsibility. For instance, while initially being primarily economically motivated, Mo Industrial Park has in more recent years formulated a broader sustainability strategy for their clusters, emphasizing the promotion of sustainable initiatives and the advancement of circular solutions.

Moreover, according to our research, the facilitator was frequently motivated by the pursuit of sustainable practices when initiating industrial symbiosis endeavors. However, the promotion of sustainability as a rationale for participation in industrial symbiosis initiatives varied significantly among companies within certain clusters. Extensively, some businesses within the cluster exhibited a stronger commitment to industrial symbiosis and inclination toward environmental sustainability, whereas others required additional incentives to adopt these practices. In instances where companies were less motivated by environmental responsibility, facilitators frequently served as the primary driver of overall environmental responsibility.

5.2.2 External Drivers of Industrial Symbiosis

Stakeholder pressure on sustainable practices

As noted in the previous subsection, there has been a rise in the motivation for participating in industrial symbiosis initiatives linked to inherent environmental responsibility. Nonetheless, it was also observed that pressure from stakeholders impacted the drive of clusters to prioritize the environmental implications of their activities. Accordingly, the deployment of industrial symbiosis approaches might not exclusively be motivated by the clusters' inherent environmental responsibility, but also by the increased sustainability requirements that firms face from their stakeholders. The following statement issued by Herøya conveys the sense of pressure experienced by its shareholders.

> *"Taking care of sustainability is, in other words, an aspect that has become increasingly emphasized and on which these multinational corporations are experiencing greater pressure from their shareholders." - Herøya Industrial Park*

Furthermore, our analysis indicates that the participants have identified pressure from a varied range of stakeholders, with only a few respondents recognizing the same stakeholders. Thamsklyngen explains that the motivation behind the embrace of sustainable practices can be attributed, in part, to the growing consumer demand for environmentally friendly alternatives. Skogmo Industrial Park places emphasis on the circular economy as a means of

attracting prospective employees, recognizing the increasing relevance of this subject matter for the workforce of tomorrow. Furthermore, it was discovered that Mongstad Industrial Park's initiation of industrial symbiosis projects was primarily influenced by the changing dynamics of the global market. The anticipated fall in demand for traditional fossil fuels has prompted the cluster to rethink its production and investigate other options to maintain long-term viability.

Regulatory restrictions

The findings of our analysis revealed that the implementation of industrial symbiosis practices in clusters was also influenced by laws and regulations. Our findings indicate that the focus on forthcoming regulations was perceived as a stronger motivator for taking on industrial symbiosis initiatives in comparison to current regulations. Elaborately, while one respondent mentioned the influence of existing regulations on the initiation industrial symbiosis practices, the majority of respondents viewed upcoming legislation and regulations as an essential factor for the initiation of industrial symbiosis practices.

Additionally, when the participants mentioned these approaching regulations, they primarily referred to those resulting from the ratification of the European Union's Green Deal. These upcoming regulations serve as a motivation for several clusters, as several customers of the cluster companies will be required to adhere to these regulations, which necessitates that the cluster also stay up to date with these policies. However, the motive for initiating industrial symbiosis practices in response to upcoming regulations arose largely from a strategic perspective among the cluster's participants. Specifically, the companies and facilitators wished to avoid falling behind their industrial counterparts in the transition to sustainability practices, given the anticipated regulatory support for environmentally conscious business practices. The majority of participants saw the upcoming regulations as an opportunity for proactive preparation and as a means to gain a competitive advantage. The following declaration provided by Skogmo Industrial Park elucidates the push that the impending regulation exerts on corporations.

> *"Many environmental requirements will be imposed. Then you have the option of either waiting for some new rules and requirements to come in and then begin implementing them or starting training right away to get better. So that when they come, you're already at, or nearly at, the finish line." – Skogmo Industrial Park*

5.3 Identified Barriers to Implementing Industrial Symbiosis

In this section, we will address the second research objective: Identify the key barriers Norwegian industrial parks are facing when implementing industrial symbiosis practices. Through our research, we have found that key barriers Norwegian industrial clusters face when implementing industrial symbiosis practices can be sorted into five main categories, namely, technical, organizational, social, economic, and institutional. In this section, we will go through all identified barriers and present our findings and analysis. These barriers are also presented in the green box in Figure 2.

5.3.1 Technical Barriers

Unreliable resource streams

Through our research, we have uncovered that the primary barrier encountered by the industrial clusters is the lack of continuity and consistent quality in the resource streams. As the nature of industrial symbiosis relationships involves one company providing excess resources to another company that lacks them, challenges related to this flow of resources are likely to arise (Johansen & Haavik, 2019). While the relationship is a mutually beneficial arrangement, the risk connected to the continuity of the flow may be heightened, for instance, if the receiving company depends on a continuous sufficient flow or quality of the resource, or if the providing company is dependent on continuously disposing of the resource. This risk may arise because the involved companies will primarily focus on their core operations and prioritize this above ensuring that there are no disruptions in the resource flow (Bansal and Mcknight, 2009). Conversely, if the resource is sourced as the primary product and not through industrial symbiosis, the seller is likely to be more concerned with delivering high-quality products. As disruptions in the resource flow may affect the rest of the production, it is crucial to address this obstacle.

Several of the industrial clusters specifically address this heightened risk related to the dependency on the resource flow, however, the clusters are facing different aspects of this risk. Some brought up the issue of vulnerability that arises from a key provider company potentially relocating or going bankrupt and thus disrupting the flow of their resources. Furthermore, if the provider company is struggling with a technical problem affecting the resource flow, or due to other reasons needs to make temporary changes to the flow, this may negatively affect the production of the receiving company. For instance, if one of the companies at Glomfjord

Industrial Park needs to halt the processes in its factory, this will imply changes in the temperature of the excess heat. As this excess heat is utilized for smolt production in another company, it is imperative to coordinate any changes gradually to prevent harm to the fish. Another challenge stemming from this dependency is related to the planning of industrial symbiosis, as internal changes in the plans of one company can have significant implications for the feasibility of a project. For example, Treklyngen points to the possibility of companies wanting to save energy on their internal process suddenly having less excess flow to offer, and Herøya Industrial Park refers to a scenario where a shared resource becomes more valuable which may affect the terms of the arrangement. Furthermore, an issue Thamsklyngen drew attention to is that lack of consistency in the quality of biological products can be a restrictive factor for industrial symbiosis projects. This applies especially to the exchange of waste products, as it is hard to ensure a standardized quality, which is necessary to operate a well-functioning market.

> *"There is a difference between biological material and biological material. This makes it hard for a company to go on a website to buy, i.e., 80 tonnes of biological material. In reality they need to negotiate with each individual provider with the quality they can deliver." - Thamsklyngen*

Finally, as Eyde Cluster has pointed out, this heightened risk related to uncertainty in the resource flows, contributes to making the industrial symbiosis projects riskier for investors, as there are no existing policies that can guarantee the flow of resources.

Lack of technical solutions

Moreover, numerous clusters address that they have encountered various technical challenges when dealing with industrial symbiosis projects. Some clusters have reported that their previously effective solutions are becoming obsolete due to changes in factors like the volume or quality of the resource. Skogmo Industripark emphasizes the significance of finding optimal solutions for both the technical and material aspects of the project for it to succeed. In addition, some clusters have encountered difficulties in discovering new symbiotic projects, primarily in terms of identifying circular ways to utilize waste or finding the appropriate technical solutions to ensure the project's feasibility. However, Herøya Industrial Park maintains that technical obstacles are transient and that if the companies can reach a consensus on pricing and continuity, there will always be feasible solutions to the technical aspects of the projects. In general, the type of technical difficulties may vary significantly between the different

clusters and projects, as available resources, research facilities, and technical knowledge will differ between the clusters.

5.3.2 Organizational Barriers

Lack of appropriate allocation keys and existing business models

Another main barrier identified is related to the lack of appropriate allocation keys and existing business models. Several of the industrial clusters have addressed that the companies involved in the industrial symbiosis projects often struggle to find reasonable ways to allocate the relevant costs, that all parties can agree to. The nature of industrial symbiosis collaborations among firms can vary significantly from one project to another, depending on factors such as the resources being transferred, their availability, and the transportation requirements. Therefore, the terms and cost allocation involved in such collaborations tend to differ on a case-by-case basis. Additionally, facilitators have observed that companies with more experience in such negotiations approach them differently than those who are new to the process. Typically, the latter group tends to be more skeptical, due to their lack of knowledge and experience in such collaborations. For many companies, engaging in industrial symbiosis collaborations represents a new way of doing business, which often requires a fresh mindset and innovative business models. Several clusters experience that it can be challenging to devise these business models and seek to adopt pre-existing ones, which is not always feasible.

Determining the value of the resource being exchanged can pose a significant challenge, regardless of one's level of experience, due to various factors. Encountered examples include the lack of an alternative market, the lack of prior sales record, or a low or uncertain value of the resource. The latter is particularly prominent in the context of exchanging waste products (Henriques et al., 2021). For instance, one cluster notes that the profit margin on selling waste is typically minimal, and in some cases, it may even cost more to share it than to dispose of it. Another example, from Herøya Industrial Park, pertains to the alternative utilization of the resource. The recipient company contends that they are doing the provider company a favor by utilizing the resource, as the latter would likely have to dispose of it as waste if not given to them. Conversely, the provider company maintains that the resource has an alternative cost, and its price should reflect this. Often, there will not be a definite right or wrong solution, and the project is dependent on the companies' ability to reach a mutually agreeable decision for it to take place.

> *"The provider company will want to put the price as close to the alternative energy sources as possible, while the receiver company will argue that this is basically waste. […]. It is obvious that, when these two extremes are your starting point, there is quite a distance to go" – Herøya Industrial Park*

Lack of coordination

Industrial symbiosis projects involve multiple parties and coordinating their actions can be a challenging aspect of the process, according to our research. These projects demand effective logistical solutions and depend on the contributions and timeliness of all parties involved (Huang et al., 2019), and a lack of coordination may hinder progress or prevent the project from success.

> *"The possibly most difficult factor is to facilitate a coordination in this kind of project. Like, it does not help to build a gas power plant or a fish feed pellet factory if you cannot access the raw material." - Thamsklyngen*

Additionally, such projects may necessitate changes in the operations of the participating companies, that are necessary to be implemented within a specified timeframe, according to Eyde Cluster. While most companies tend to prioritize their internal processes, it is crucial to dedicate sufficient attention to the by-products or side-streams in line with the other parties, to ensure the viability of the project. They further emphasize that for this to happen, many factors need to fit together including the right partnership, and the right time and place.

5.3.3 Social Barriers

Lack of motivation

Some of the facilitators have noted that there have been instances where it is challenging to motivate all the relevant companies to put in the necessary effort for industrial symbiosis projects to be executed. Our research indicates that one of the main reasons for this is that these companies are often preoccupied with their day-to-day operations and their primary productions. If the companies are already working at their full capacity, it may seem excessive to take on additional projects. Thamsklyngen emphasizes that, in such instances, companies may find it more convenient to opt for less complex projects than industrial symbiosis.

> *«Big, hard projects like circular economy projects might remain in the drawer, even though they have the greatest impact on the environment and access to raw materials. Because it is easier to carry out more symbolic projects like "Biking to work"." - Thamsklyngen*

Another reason that has been pointed out is that a lack of a joint vision or goal within the industrial park or the collaborating companies may lead to the companies not seeing the point of the collaboration. Mongstad Industripark asserts that this has been one of their main challenges for the collaboration among the park members and that this is something that they need to have a lot of focus on.

Resistance of providing data

In industrial symbiosis projects, companies must disclose information about their resource streams and data that they would want to keep confidential, due to, for instance, sensitivity issues (Neves et al., 2019). However, sharing this information is often necessary to determine if collaborations are possible and to identify which projects can be initiated based on available resources.

> *"Sharing of information is super important and critical really. Because the more open you are, the easier it is to find collaboration partners, but the riskier it gets too. But by sharing as little as possible, you will never find any partners." – Eyde Cluster*

While a few facilitators have faced difficulties in this regard, the clusters we examined have managed to overcome this barrier relatively swiftly. However, projects that were unable to overcome this barrier did not progress to being executed. Moreover, after having successfully obtained data, Eyde Cluster emphasizes the importance of ensuring that the shared data does not exceed its intended recipients, in order to maintain the trust of the companies.

Limited willingness of stakeholder collaboration

We have identified limited willingness of the management in the involved companies to collaborate as a barrier to implementing industrial symbiosis practices, as some facilitators have encountered this challenge. Our research indicates that there have been instances where the involved companies' management did not recognize the value of collaboration and new solutions, resulting in project stagnation. For example, in one cluster, employees have demonstrated effective teamwork and recognized the benefits of collaboration, while the

distant management remains hesitant and slows the project's progress. Another facilitator asserts that if the management of a company fails to see the value of collaboration, that company cannot continue being involved with the project. Furthermore, facilitators have observed issues with international owners who prefer to adhere to their accustomed practices, which are often characterized by a lower level of trust than is customary in Norway. This has caused a backlash in collaboration at some clusters.

5.3.4 Economic Barriers

Unattractive investment

One of the challenges faced by all clusters when embarking on industrial symbiosis projects is securing the necessary financing. This applies both to the launch of the first projects and to the pursuit of new ones. Our research indicates that private investors are essential, either from companies within the cluster or from an outsider. However, we have identified several reasons why investing in these projects is not yet attractive to all investors.

Firstly, the projects often require significant upfront costs, particularly when the construction of infrastructure, factories, or plants is necessary. In such cases, it may take a considerable amount of time before an investor can expect to see positive returns (Hiete et al., 2012), and as the payback time extends, the higher the likelihood of the investment failing to generate profits (Ramsheva et al., 2019). Furthermore, the inherent risk associated with unreliable resource streams may also deter potential investment. This concern becomes particularly pronounced when there is heavy reliance on a single company (Zhu & Ruth, 2013), a scenario that applies to several of the projects within the clusters we have researched. For instance, companies cannot be assured a continuous future supply of a resource stream or a consistent quality of the resource, and the value of the resource might change, which adds uncertainty to the collaboration. This risk, commonly referred to as economic or vendor lock-in, becomes even more disadvantageous when the exploration of alternative options proves to be costly (Zhu & Ruth, 2013; Ramsheva et al., 2019).

> *"And when you also have that uncertainty related to the availability of the resource, like, I can have it available today, fine, but what will it look like in the future? Will it be available then?" – Eyde Cluster*

Another aspect is related to the challenge of creating fitting contracts between the involved parties as described in section 5.3.2, as the complex context of industrial symbiosis and the

occasional need for process adaptions increase the likelihood of overlooking potential risks in the contract (Carpenter et al., 2009). Moreover, some of the clusters find that many investors lack knowledge of industrial symbiosis practices or fail to see the value of such projects and that the investors find other types of projects more attractive (World Bank, 2021; Madsen et al., 2015). Ultimately, these aspects likely contribute to investors being hesitant to invest in industrial symbiosis projects.

5.3.5 Institutional Barriers

Lack of public funding programs

While there exist several funding arrangements for industrial symbiosis projects and national strategies encourage such initiatives (see Chapter 3), several clusters experience a notable shortage of available funding options. For instance, the budget cuts of the Norwegian Innovation Clusters program (Innovation Norway, 2022) impacted a few of our researched clusters. These clusters have considered these cuts to be a disadvantage, as they have experienced positive outcomes from the program. Moreover, some of the clusters express that they miss the availability of consistent and predictable funding programs for long-term investments. They find that the existing public funding landscape exhibits too much volatility, which discourages clusters from relying on it for their larger-scale projects.

While companies acknowledge that projects cannot be reliant on public funding programs to be viable, public funding can have great impacts on the initial faces of industrial symbiosis (Yu, 2015). The funding often goes to the mapping of potential resource exchanges, initial research on the feasibility of a project, or as a means to get started. The lack of funding programs may prevent industrial symbiosis projects from being initiated, as companies may not be aware of the available possibilities. Furthermore, without adequate funding for initial research, a project may struggle to showcase potentially positive outcomes, which can hinder its ability to attract further investment and support. As a consequence, promising ideas run the risk of being unrealized and remaining unexecuted.

Existence of regulations

Some of the clusters have identified existing regulations that impose limitations on the incentives for certain industrial symbiosis projects. For instance, Mo Industrial Park highlights the absence of incentives for reusing excess CO2 derived from fossil carbon, as opposed to CO2 derived from biological material, as there are differences in how the two types are being

accounted. As a result, the projects become very expensive due to high CO2 prices, even though they are environmentally beneficial. Moreover, Herøya Industrial Park explains how companies in their cluster belong to different regimes in Europe, posing challenges in pricing the CO2. Øra Industrial Area has also encountered regulatory frameworks that hinder the continuation of one of their industrial symbiosis projects. The challenge is related to a company within the cluster that produces energy through waste incineration but faces regulatory challenges that require them to pay additional fees for delivering the energy to the industry, as opposed to getting paid by delivering it to households. This makes it less profitable for the company to share its excess energy with industries, despite the significantly greater environmental and societal benefits. As a result, the company is uncertain about the feasibility of continuing to share energy with the industry due to the high costs imposed by existing regulations.

> *"They have taken the costs over many years, waiting for the policy to get fixed. […]. Soon they must either cut the delivery to the industry and only deliver to households, or they must find another way to make the necessary changes" – Øra Industrial Area*

5.4 Potential Solutions to Identified Barriers

In this section, we will address the third research objective: Investigate possible solutions to overcome the identified barriers. In our research, we have found seven distinct solutions that have been essential for the success of the researched clusters on implementing industrial symbiosis. These seven are the following: foster pride and community; establish a shared vision, strategy, and goals; have a third-party to identify and initiate industrial symbioses; have a third-party to mediate negotiations; learn about industrial symbiosis by engaging with other clusters; collaborate with other stakeholders; and influence policymakers. These solutions are illustrated in Figure 2 and will be discussed in detail in the following paragraphs.

5.4.1 Foster Pride and Community

While it may vary what kind of relationship the companies in the cluster have had prior to the initiation of industrial symbiosis activities, it is key to foster pride and community within the cluster to succeed with these activities. By doing so, the companies are more likely to act in a way that benefits the cluster (Ireland & Webb, 2007). In some of the clusters, including Mo

Industrial Park, Øra Industrial Area, and Herøya Industrial Park, there have been traditions for collaboration for a long time. These parks acknowledge this as an advantage for them in the process of establishing industrial symbioses, which is also supported by literature (Ramsheva et al., 2019).

> *"Altogether, there is so much that comes naturally from the history. That it has been natural to share or buy products internally creates a symbiosis that has been there since the park was first built." – Mo Industrial Park*

For clusters where the participating companies did not have pre-existing relationships before the collaboration, this aspect will be particularly important to prioritize. This is to ensure motivation to collaborate, trust between the companies, and willingness to take upon additional responsibility (Ramsheva et al., 2019). For Eyde Cluster, the culture of collaboration that they have established in the cluster has been instrumental in fostering trust and information-sharing among the companies, as they are not physically located within the same industrial area and did not have any prior relations. For the initiation of industrial symbiosis projects in 2016, Eyde Cluster had the following to say about how they were able to get the companies to share the necessary data of their resource streams:

> *"And of course, the fact that we have existed since 2007 and built up a culture for collaboration. Had we tried this in 2007, it would probably not have worked." – Eyde Cluster*

Several of the clusters have emphasized the importance of ensuring that all parties involved take pride in their work and feel like they are part of a positive change. Thamsklyngen specifically highlights the positive feedback loop that occurs when companies are proud of the positive outcomes resulting from the collaboration. This creates a sense of trust and motivates the companies to contribute more to the projects. Other clusters assert that fostering pride and community within the cluster contributes to an inner motivation of the employees to participate in industrial symbiosis, which may further lead to enhanced workplace satisfaction, improved reputation, and potentially increased profitability (Cho & Perry, 2012).

5.4.2 Establish a Shared Vision, Strategy, and Goals

Our research indicates that creating and maintaining a shared direction for the companies involved in the industrial symbioses including, vision, strategy, and goals is crucial for

overcoming several of the barriers previously identified. One of these barriers is linked to how companies in an industrial cluster often focus solely on their daily operations and tend to think as a single entity when creating plans and strategies. To overcome this barrier, several clusters have emphasized the importance of facilitating a shared direction, enabling them to recognize their potential within a broader context. Another barrier to the success of projects that have been identified is the need to coordinate the actions of the involved companies and ensure that they are prepared and ready at the right time. This coordination must be facilitated, and the companies must integrate the shared strategy into their own plans so that all parties can be aligned. To do so, several facilitators point to the importance of being united toward the same goals, that all parties can understand and work towards, which can further contribute to developing trust within the cluster (Mayer et al., 1995; Ramsheva et al., 2019).

> *"We need to have the same goal. That is why I say: This is what we need, folks, and if we succeed, it will be more business for you and more business for you. But for that to happen, we need to pull on the same jersey and collaborate." – Mongstad Industrial Park*

Moreover, the success of the collaboration relies heavily on the motivation of the involved companies and their management. Without proper motivation, the collaboration is unlikely to succeed (Henriques et al., 2021; World Bank, 2021). Therefore, it is crucial to ensure that all parties involved are motivated and share the same vision for the project's direction. While hosting meetings to provide information and allow for discussion is an important step to achieving this goal, other measures are often needed as well. Therefore, the clusters have found different additional ways of unifying the collaborating companies. For instance, several clusters have created a slogan or symbol that can be easily understood and related to on a daily basis, rather than just a collection of bullet points and visionary sayings in a meeting, which may contribute to establishing a shared identity (Ramsheva et al., 2019).

> *"We refer to these solutions in our park as "don't waste" [original: "itj sløs!"]. It may not be the textbook terminology, but we call it this because people understand what it means." - Skogmo Industrial Park*

Furthermore, Skogmo Industrial Park promotes the use of training programs to ensure a common understanding of industrial symbiosis and a shared vision for the future. Sirkulære Rjukan emphasizes the importance of early clarification on the project's "what, how, and

whys" to prevent future challenges. By presenting the collaboration terms upfront, companies can decide for themselves whether to enter the collaboration, reducing the risk of disagreements later on. Other clusters emphasize the importance of recruitment in achieving successful collaboration, by ensuring that new managers in the involved companies understand the value of industrial symbiosis and integrate the shared direction into their own company's strategies.

5.4.3 Have a Third-Party to Identify and Initiate Industrial Symbiosis

According to our research, the involvement of a third-party facilitator is central in identifying potential industrial symbiosis projects that may not have been recognized otherwise. Most of the companies within the cluster will not have the knowledge of potential symbiosis projects that could be initiated, and most of them will, either way, be focused on their day-to-day operations. However, a third-party with insight into the entire cluster can identify available resources that can be utilized in symbiosis. To successfully facilitate industrial symbiosis projects, several clusters emphasize the importance of the third-party establishing their credibility among the companies and demonstrating experience, particularly for clusters where the companies may not have prior relationships. It is essential that the companies trust the third-party and feel confident in their ability to propose beneficial projects and coordinate collaboration between them (Ingstrup, 2010). Additionally, a third-party who is familiar with all of the companies in the cluster can connect the right companies with each other, thus ensuring the successful initiation of projects. Øra Industrial Area, emphasizes that the companies themselves need to find the solutions, but for this to take place it is valuable that workshops, meetings, and gathering points are being facilitated.

> *"We tend to say that we have a very strong referral expertise. We know everybody and see whom we should place at the same table to make [the collaborations] happen." – Øra Industrial Area*

5.4.4 Have a Third-Party to Mediate Negotiations

While it in most clusters is up to the companies themselves to reach specific solutions for collaborations, our research indicates that many encounter challenges related to the negotiation process, including finding appropriate allocation keys, business models, and solutions that all parties can agree on. Typical instances may be that the companies lose track of the

negotiations, the discussions may become heated, and the involved companies may be skeptical or lack trust in each other. To address these issues, the vast majority of clusters emphasize the importance of having a third-party, typically a representative from the cluster administration, to mediate negotiations.

> *"So my role is also a lot about being a kind of broker and a facilitator to get them to sit down by the table and find win-win solutions, where it originally would be most to earn by just grabbing everything themselves." – Thamsklyngen*

This third-party can use their experience with such projects to provide insight into practices that have worked elsewhere and help guide the negotiation process. Herøya Industrial Park highlights that this role is particularly significant when the involved companies are not experienced in these types of projects but can be valuable for more experienced companies as well. Moreover, several clusters emphasize that to do this successfully, it is important to have established credibility through experience and fostering relationships with the involved parties. This way, it is more likely for the participating companies to trust the third party's ability to effectively lead the negotiation process (Ingstrup, 2010).

5.4.5 Learn About Industrial Symbiosis by Engaging with Other Clusters

Many of the interviewed clusters emphasize the value of learning from clusters that have already implemented industrial symbiosis activities, to learn from their experiences. They express that engaging in open dialogues with other clusters can provide insights into what has worked for them and what challenges they have faced. We find that several of the clusters have established collaborations with different established Nordic clusters. According to Eyde Cluster, these collaborations are sensible as there are numerous cultural and societal similarities among the Nordic countries, particularly when it comes to shared values, such as trust and openness (Beilmann & Lilleoja, 2015). These similarities make it easier to transfer experiences and knowledge between clusters.

This interaction can be valuable at different stages of the process, however, it may be particularly important in the initial phase of implementing industrial symbiosis, especially for the clusters that have not had existing relationships between the firms. Several of the representatives from the interviewed clusters assert that they have visited other clusters in

Norway, Sweden, Denmark, and Finland to learn from their experiences, in the initial faces of the process. After these trips, many participants realized that the practices observed were not significantly different from those employed in their own clusters. As a result, they became motivated and inspired, and all found the trips to be highly valuable. Furthermore, some clusters have also invited representatives from experienced clusters to meetings or conferences with the companies who will be involved in symbiosis, for them to gain knowledge on these activities. As a result, engaging with other clusters during the initial phase can be decisive in moving from an idea to action.

> *"One of these meetings does not have great impact, but when we do this time after time, the knowledge of the industrial symbioses increase, and more companies see the potential of it." - Thamsklyngen.*

However, our research indicates that maintaining these relationships beyond the initial phase can also be valuable as there will most likely be more challenges that need to be overcome. Having sound relationships with other clusters can be an effective way to share experiences and receive information, and both parties typically find these relationships valuable.

5.4.6 Collaborate with Other Stakeholders

Several clusters emphasize the importance of collaboration with research communities and academic institutions. This involves partnerships with organizations such as Sintef, Norsus, Zero, and various academic institutions. As a dynamic field, industrial symbiosis requires up-to-date theoretical knowledge to discover innovative solutions to current challenges. Contributions from research communities can be critical in this regard. Herøya, for instance, credits its success and continued collaboration after Hydro's split to its research community, which features 400 researchers.

> *"These processes are not something that operators on the floor can simply figure out. It's not because they lack the intelligence, but because they aren't specifically trained for it. You need a specialized education for that." – Herøya Industrial Park*

In addition, certain clusters highlight the benefits of working together with regional industrial symbiosis facilitators such as Arctic Cluster Team, Innovation Norway, and Siva. These facilitators can assist with securing research funding and support the establishment of new

resource collaborations. They can also promote collaboration across the region, not just limited to industrial parks, and help remove biases towards companies in neighboring areas. Finally, by maintaining a close dialogue with these regional facilitators, clusters can receive assistance in finding effective solutions that may have worked for others.

5.4.7 Influence Policymakers

Our research suggests that certain barriers to initiating or implementing industrial symbiosis need to be solved by changes in existing policies. Clusters can therefore work towards influencing policymakers to make the changes that are necessary for more clusters to initiate industrial symbiosis projects and to make the process smoother for those attempting to implement it. The clusters we studied have identified several solutions as essential to overcoming these barriers. For instance, increased support for funding programs for research has been suggested by several of the clusters as a means of assessing the viability of the project and providing the necessary financial push. The Eyde Cluster, among others, emphasizes the need for a solution to the issue of continuity of flow and uncertainty of profitability, which can be achieved through governmental guarantee programs that share some of the risks related to the projects. Additionally, current regulations that hinder industrial symbiosis should be removed or changed, and positive incentives should be introduced to encourage its integration. Finally, clusters should support the work of standardization authorities, as this can be beneficial for finding appropriate allocation keys and suitable business models.

5.4.8 The Overarching Goals of Implementing Industrial Symbiosis

As illustrated in Figure 2, we have identified four overarching goals to succeed in implementing industrial symbiosis practices, namely building a collaborative culture, establishing trust, cultivating knowledge of industrial symbiosis, and finding feasible solutions for its implementation. The figure further highlights the connections between these goals, the suggested solutions, and the identified barriers, represented by arrows. For example, building a collaborative culture is essential for solving barriers related to lack of motivation, limited willingness to collaborate, lack of coordination, and resistance of providing data, while establishing a shared vision, strategy, and goals, and fostering pride and community represents specific means of doing so. Furthermore, these arrows show that the four goals are linked to several different suggested solutions, while the solutions are further linked to various barriers, as the process of successfully implementing industrial symbiosis is complex and intertwined.

For instance, cultivating knowledge of industrial symbiosis can be important for motivating companies to participate in symbiotic activities which can be solved by learning from other clusters, moreover, it can be important for finding appropriate business models and allocating costs which may be done through collaboration with other stakeholders. Finding feasible solutions may be achieved by influencing policymakers to invest more in research on industrial symbiosis projects which may contribute to solving technical barriers. There will also likely be additional indirect connections between the different elements of the model, but we will be focusing on the ones we have found to be the most direct. We further find that several of the connections are represented by double-headed arrows. For instance, having a third-party to mediate negotiations may increase trust between the companies, while the establishment of trust may further simplify the process of facilitating negotiations. Ultimately, the connections within this system are closely intertwined. However, this also implies that the suggested solutions, when implemented collectively, hold the potential for synergistic effects. This furthers the objective of achieving success in industrial symbiosis while also reflecting the inherent nature of industrial symbiosis itself.

5.5 Key Stakeholders of Industrial Symbiosis

In this section, we will address the fourth research objective: Explore the significance of the key stakeholders in the process of implementing industrial symbiosis practices in Norwegian industrial clusters. Through our research, we have observed that there are four groups that have influenced the initiation and implementation of industrial symbiosis projects and can therefore be categorized as important stakeholders. These four are significant companies and individuals, cluster facilitators, research communities and academic institutions, and governmental actors, which will be elaborated on respectively in the following subsections.

5.5.1 Significant Companies and Individuals

Through our research, we find that the role of certain individuals and companies within the park was important in enabling industrial symbiosis projects. A common characteristic among these stakeholders has been that they typically represented an anchor company or were individuals holding authoritative positions within large companies. According to some of the clusters, the significance of these stakeholders came from their ability to influence other community members and companies, allowing them to effectively promote industrial

symbiosis initiatives. It was especially two ways these stakeholders impacted the initiation of industrial symbiosis projects, namely through securing financial support or being at the forefront of adapting sustainable practices within the cluster. In our analysis, we found that the large corporations within clusters frequently took the initiative to alter their current practices and initiate industrial symbiosis projects. Furthermore, these companies often had a sustainable motivation behind these initiatives. Sirkulære Rjukan, for instance, noted that there were three prominent companies in the cluster that exhibited a green-thinking mentality in all facets of their operations, thereby playing a pivotal role in advancing circular initiatives within the cluster. We also found that such proactive steps seem to positively influence the behavior of other companies in adapting to these practices. In the following statement, Tregruppen emphasizes the significance of the cluster's large companies pursuing social responsibility and initiating industrial symbiosis projects.

> *"The largest company must take on more responsibility in terms of resources, people, and capital. It will not function if the larger firms do not participate to collaborate and accept social responsibility." – Treguppen*

Concerning the stakeholder engagement in funding such projects, they contributed either through direct investment in these practices or indirectly by investing in more sustainable practices that are in line with industrial symbiosis activities. Some participants mentioned that these stakeholders typically had a long-term outlook on investments and thus did not just focus on short-term gains, and viewed this outlook as essential for investing in such projects. The significance of a foresight investor in enabling industrial symbiosis initiatives can be illustrated by the following statement by Thamsklyngen.

> *"He has nearly limitless resources to carry out a variety of investment initiatives, and when he chose to establish a network based on sustainability, things began to move. It would have been difficult to come as far as we have now without such a foresight investor." – Thamsklyngen*

5.5.2 Cluster Facilitators

Our research indicates that the facilitators of the cluster networks play a vital role when it comes to establishing industrial symbiosis between companies within the clusters. Some participants even asserted that the companies would not have participated in this practice if

the facilitator had not been present. However, in certain industrial clusters, the practice of industrial symbiosis had been initiated by companies prior to the establishment of a third-party facilitator. In these instances, the involved entities originated from the same corporation, with the exception of Øra Industrial Area. Nevertheless, even in such instances, the facilitator was perceived as a crucial stakeholder in promoting the development of new industrial symbiosis practices. According to several clusters, the significance of the facilitator often lies in their ability to bring firms together for collaboration, a task that was described to be difficult as companies have limited resources to explore innovative production methods outside their usual operations. The significance of facilitators in bridging this gap is illustrated in the following statement made by Øra Industrial Area.

> *"When it comes to the administration and protection of industrial symbiosis, a third party is often required because the companies themselves have enough to manage." – Øra Industrial Area*

Our research indicates that the facilitator play an important role in establishing opportunities for companies to gather and engage in conversation, thereby facilitating the exchange of information and ideas. Without the assistance of third-party facilitators, participants noted that it would have been difficult for these companies to find a common direction, given that they frequently operated in distinct sectors, which made collaboration and information sharing challenging. Furthermore, a few facilitators have been dedicated to providing a shared platform for communication and collaboration among firms within the cluster. Elaborately, some facilitators took the initiative to invite relevant experts to give presentations on sustainability-related topics or to coordinate excursions to locations where industrial symbiosis practices were already being implemented successfully. Others have arranged conferences or skill seminars on the topic of industrial symbiosis. The objective of these activities has been to inspire and educate the companies in the cluster so that they would embrace the concept of industrial symbiosis.

The facilitators have also played an essential role in building a culture of collaboration between the enterprises. For instance, in clusters where disagreements have arisen during negotiations of the collaboration, the facilitator has acted as a mediator to resolve the disputes. Moreover, several of the clusters also explained that they have attempted to establish trust and set a vision for the entire cluster in order to facilitate collaboration between the companies. The study's participants emphasized that the implementation of joint goals and strategies

assisted in the synchronization of member companies' interests and fostered a collective outlook for the cluster. Elaborately, the facilitators' establishment of a common vision has enabled effective communication and collaboration among the involved companies and helped in the development of joint projects and initiatives that supported industrial symbiosis practices. Moreover, clusters in the initial phases of industrial symbiosis have particularly placed emphasis on the facilitator's role in motivating industrial symbiosis projects and enabling a shared vision for the cluster companies. Thamsklyngen explains the significance of a facilitator in fostering trust and outlining an overall goal through the following statement.

> *"There must be a significant amount of visionary management, so we [the facilitator] must frequently build trust among these actors so that they can cross the infamous threshold and feel comfortable implementing sustainability projects." – Thamsklyngen*

5.5.3 Research Communities and Academic Institutions

Our analysis further emphasizes the importance of collaborating with research communities and academic institutions to acquire a more comprehensive knowledge of industrial symbiosis practices. Moreover, it was found essential to engage with these institutions, regardless of the level of advancement or the number of industrial symbiosis processes implemented in the cluster. For instance, Herøya Industrial Park, with a current circularity rate ranging from 85 to 90 percent, also emphasized the necessity of collaboration with scientists for such projects. Moreover, the clusters elucidate that such collaborations served as an opportunity for them to acquire knowledge and new research on challenges related to industrial symbiosis that may not be accessible within the cluster. Elaborately, the collaborations often served as a strategy to overcome technical challenges related to the implementation or exploration of industrial symbiosis projects. In the following statement, Herøya Industrial Park elaborates on how the stakeholders play a pivotal role in the development of industrial symbiosis practices.

> *"We have these serious scientists with a long education who like to initiate problems that no one else recognizes. The fact that they are there is critical for these types of operations." – Herøya Industrial Park*

In addition to the significance of collaborating with universities and research institutions, a number of the clusters emphasized the importance of cultivating necessary competencies and

skills through partnerships between companies and local schools. These collaborations frequently involve the implementation of apprenticeship agreements or the incorporation of relevant curricula into local schools. The objective of these collaborations was to foster the development of the skills and knowledge necessary for businesses, giving them the possibility of recruiting future employees with the competencies they deemed essential. These initiatives were not necessarily solely aimed at industrial symbiosis, but also other industrial knowledge. However, Sirkulære Rjukan identifies initiatives that are specifically directed at working towards integrating circular economy principles into the educational programs of local schools.

5.5.4 Governmental Actors

According to our research, the involvement of the local government can play an influential role in supporting industrial symbiosis projects. Our findings suggest that governmental actors have played a particularly valuable role in driving and facilitating the initiation and development of new industrial symbiosis projects. Consequently, the significance of this stakeholder group was frequently highlighted particularly in clusters where the implementation of industrial symbiosis was in an early stage of development. Specifically, some clusters emphasized the importance of municipal support for industrial symbiosis activities through the provision of infrastructure and by being at the forefront of granting land access to facilitate the expansion of industries within the region. The allocation of land and facilitation of infrastructure was regarded as an indirect enabler for the initiation of new industrial symbiosis initiatives, as this helped the clusters to broaden their scope of operations and integrate new industrial symbiotic practices.

A number of clusters have also emphasized the proactive involvement of local government entities in promoting environmentally sustainable initiatives as opposed to solely facilitating traditional industrial operations. The commitment of municipalities to promoting sustainability in their region served as a catalyst for the implementation of environmentally conscious production methods in the cluster, leading to an embrace of industrial symbiosis practices. The significance of the municipality in enhancing the region’s orientation towards environmentally sustainable initiatives can be exemplified by the subsequent declaration from Treklyngen.

> *"The municipality of Ringerike has a rather active energy and environment manager. As a result, the municipality wishes to be pioneering in terms of assisting industry and facilitating sustainable industry. So it is one of the most prominent stakeholders, and it has been a catalyst for us to focus on [industrial symbiose] here." – Treklyngen*

Moreover, there have also been occurrences where the municipality's engagement with industrial symbiosis endeavors has been more direct. For instance, in the case of Tregruppen, it was the county municipality that took the initiative to establish the cluster and provided financial support to facilitate its formation. Additionally, the municipality and county municipality played a proactive role in supporting the cluster's participation in a visit to another cluster that had successfully implemented industrial symbiosis practices.

5.6 Summary of Findings

In this chapter, we have investigated how clusters within the Norwegian process industry can successfully initiate and implement industrial symbiosis practices. Through thorough analysis, we have explored the internal and external drivers of the clusters to initiate these initiatives. Furthermore, we have identified which barriers the clusters have faced during their implementation of industrial symbiosis, as well as possible solutions for overcoming the barriers. Finally, we have analyzed the roles and contributions of the key stakeholders in the initiation and implementation of industrial symbiosis. In this section, we will summarize the findings from our analysis.

Our research suggests that the main internal drivers for actors to participate in industrial symbiosis are economic benefits and environmental responsibility. We have observed a shift in the trend of internal drivers, whereas earlier initiatives were predominantly driven by economic benefits while more recent projects more dominantly include sustainability considerations. According to our research, the main external drivers of initiating industrial symbiosis are stakeholder pressure on environmental production practices and upcoming international regulations. Furthermore, through our analysis, we have identified ten barriers that Norwegian industrial clusters may face in their implementation of industrial symbiosis, related to either technical, organizational, social, economic, or institutional dimensions. Most dominant is the risk associated with unreliable resource streams, followed by the difficulties in creating appropriate contracts due to a lack of appropriate allocation keys and existing

business models. These, and other aspects, further contribute to making the investment in industrial symbiosis less attractive, which becomes a barrier to its implementation due to lacking investments. We have also identified several social barriers clusters need to overcome and highlighted institutional barriers clusters are currently facing. We find that these identified barriers might be overcome through seven suggested solutions: fostering pride and community; establishing a shared vision, strategy, and goals; having a third-party to identify and initiate industrial symbiosis; having a third-party to mediate negotiations; learning about industrial symbiosis by engaging with other clusters; collaborating with other stakeholders; and influencing policymakers. Furthermore, we also relate these potential solutions to four overarching goals, namely building a collaborative culture, establishing trust, cultivating knowledge of industrial symbiosis, and finding feasible solutions. The connections between the identified barriers, potential solutions, and overreaching goals are summarized and illustrated in Figure 2. In the subsequent chapter of our research, we will elaborate upon aspects related to the connections of this model, as well as other relevant aspects of our analysis.

Finally, our study finds that the initiation and implementation of industrial symbiosis initiatives involve various key stakeholders, including significant companies and individuals, cluster facilitators, research institutions, and governmental actors. Prominent companies and individuals were found to play a crucial role in providing financial support and initiating these initiatives, whereas municipalities and county municipalities play an important role in providing infrastructure and granting land areas, as well as promoting sustainability in the region. Moreover, we find that cluster facilitators help with establishing a shared platform for companies to meet and collaborate, coordinate activities, and foster a shared vision and trust among the cluster's participating companies. Lastly, the collaborations with research communities were found to contribute to overcoming technical barriers and identifying new industrial symbiosis activities through knowledge sharing.

6. Discussion of Findings

This chapter will provide a discussion of the main finding of the analysis. We have categorized the discussions based on five dimensions, namely technical, organizational, social, institutional, and economic aspects.

6.1 Technical Aspects

6.1.1 Managing the Risk of Dependence

The unreliability of shared resource streams stands out as one of the most significant and challenging barriers to initiating and implementing industrial symbiosis. As discussed in the analysis, clusters may face either temporary or permanent disruptions, variations in the quality of the byproducts, or variations in accessibility throughout the year. The implications of such uncertainties range from threatening daily operations to economic unviability, as these collaborations enforce dependencies and risks for the involved companies (Johansen & Haavik, 2019). The potential exit or bankruptcy of a highly resource-rich player from the industrial symbiosis network poses a notably high risk for the involved companies. Several clusters expressed concerns regarding this risk as the departure of an anchor company can have a significant impact on the network's resource flow, supply, productivity, and coordination of activities, and can be decisive for minor networks (Walls & Paquin, 2015).

To address the operational challenges, the participating companies and facilitators can take measures to become more resilient and better at adapting to changes. According to Johansen & Haavik (2019), actions that improve resilience include optimizing production rhythms and maintenance stops, formalizing priority contracts in the event of disruptions, and establishing a shared vision and mindset between the companies. They further argue that trust relations and a shared vision in the network are significant contributors to the adaptability of the companies to change on short notice. By working on their ability to pursue alternative input materials and treatment or recycling channels for their waste streams, the involved companies can drastically reduce the risk related to permanent disruptions in the resource streams (Domenech & Davis, 2011). Moreover, by having a diverse network of companies within the cluster, facilitators can reduce the risk associated with the departure of an anchor firm (Korhonen, 2005), and creating contractual agreements for controlling such dependencies (Williams & Meyer, 2012; Fichtner et al., 2015), can help to further mitigate the impact of such issues.

According to our research, these uncertainties not only pose challenges for operating such projects but also hinder the willingness of companies to participate or invest in them. In regard to the initiation of the projects, the situation today is that companies have to bear the entire risk themselves. However, if this risk could be partially shared with governmental institutions, industrial symbiosis projects could become significantly less uncertain and more attractive for both companies and investors. A cluster from our research highlighted that this is a pressing issue, and despite multiple attempts to address it, complete certainty cannot be guaranteed, as providing companies may shut down, move, change their resources or the quality of it, or face technical disruptions in the stream. The cluster argues that the only stakeholder capable of addressing this issue is the government and suggests that risk-sharing initiatives would be very beneficial for industrial symbiosis projects.

In conclusion, the unreliability of shared resource streams remains one of the most significant barriers to initiating and implementing industrial symbiosis, and there is currently no clear solution in place. While companies and facilitators can take some actions to mitigate these uncertainties, governmental support could be essential in allowing for more reliable and attractive projects.

6.1.2 Ensuring Dynamic Knowledge of Industrial Symbiosis

Through our research, we have identified several participants who have encountered technical difficulties during the implementation of industrial symbiosis practices and the exploration of new industrial symbiosis projects. These barriers can be attributed to the lack of appropriate technology or technical knowledge, which aligns with findings from previous studies (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021). Our research indicates that some of the challenges faced when implementing industrial symbiosis relate to the divergence between these activities and traditional operational practices. For instance, we find that some of the actors operating within the clusters presently exhibit a lack of the required abilities to embrace these new production processes. To address these challenges, we found that collaboration with research institutions plays a crucial role in bridging this gap. This collaborative effort facilitates the generation and dissemination of knowledge to the industrial sector, thereby enabling the consolidation of initiatives related to industrial symbiosis (Mortensen & Kørnøv, 2019; Spekkink, 2013).

Moreover, further adoption of industrial symbiosis practices calls for radical innovations that require the development of technologies demanding a fundamental shift from the current business practices, knowledge, principles, and ideas (Prosess21, 2021). Consequently, insufficient allocation of funds towards research and development activities has been recognized as a notable technical obstacle impeding the effective execution of industrial symbiosis initiatives (Henriques et al., 2021). This disparity in funding is evident in the Norwegian context, and thus there is a need for increased investments in circular economy-related business research and innovation (Prosess21, 2020). Consequently, businesses must play a more active role in investing in and capitalizing on such research initiatives for enabling new industrial symbiosis endeavors (Norsk Industri, 2019).

According to a report by Prosess21 (2021) the transition to a more circular process industry requires new knowledge and skills at all levels of the workforce. Consequently, it is essential to empower the upcoming labour force with these skills and knowledge (Prosess21, 2021). Thus, Prosess21 (2021) emphasizes the importance of incorporating circular economy principles into school curricula and highlights the importance of the industry to collaborate with the educational institutions and the authorities to ensure this development of skills. Through our research, we found that although many companies had partnerships with local schools, proactive efforts to prepare the future workforce for circularity were lacking. As incorporating circular production into collaborative initiatives with educational institutions could prove advantageous in mitigating upcoming technical challenges in industrial symbiosis endeavours, clusters should make greater use of these collaborations to increase circularity-promoting initiatives. Given that several of the analysed clusters have already had success with establishing effective partnerships with local schools, we argue that more cluster should establish these collaborations.

To summarize, in compliance with international research we find that collaboration with research intuitions is important in enabling industrial symbiosis practices (Mortensen & Kørnøv, 2019; Henriques et al., 2021). However, there is a lack of investment in research projects that support circular solutions, necessitating a greater need for businesses to invest in such programs. Moreover, we argue that it is important for clusters to incorporate knowledge of industrial symbiosis in their collaborations with local schools.

6.2 Organizational Aspects

6.2.1 Finding Mutually Beneficial Solutions for All Involved Parties

The literature surrounding implementing industrial symbiosis highlights a recurring issue, namely the lack of guidelines and protocols for both facilitators and companies, combined with a lack of formal agreements between the companies and indicators for development (Henriques et al., 2021; World Bank, 2021; Norsk Industri, 2019; Madsen et al., 2015). Our own research confirms this observation and identifies the lack of guidelines and indicators as a significant barrier for Norwegian clusters in identifying appropriate allocation keys and structures for collaboration projects, which complicates the process of finding a mutually beneficial solution for all parties involved.

To address this issue, we propose a dual approach. Firstly, there is a pressing need for standardization and best practices frameworks. Nevertheless, given the unique nature of many projects, it is essential to establish a foundation of trust and willingness to collaborate among the companies, and to have a third-party intermediary to facilitate negotiations where necessary. When it comes to standardization, ISO has established a technical committee working on developing standards for circular economy. Included in this is the ISO 59010 "Circular Economy — Guidance on the transition of business models and value networks", which encompasses industrial symbiosis projects (ISO, n.d.). This standard will also be implemented by Norway upon publication (Standard Norge, n.d.). Until then, best practices and guidelines can be found by learning from other industrial clusters or drawing inspiration from resources such as HighEFF's handbook for resource and energy collaborations (HighEFF, 2021). In cases where best practices might not suffice, it is essential to establish a shared culture and values among the involved companies and ensure their willingness and motivation to collaborate. Alignment of goals and strategy is also crucial as it is necessary for the involved companies to integrate the projects into their own business models, as timing and alignment are key for the feasibility of the project (Ramsheva et al., 2019).

In summary, the absence of established guidelines, protocols, and formal agreements for actors engaging in industrial symbiosis initiatives presents a barrier to the practical implementation of such endeavors. We propose that increased use of standardization tools, accompanied by the establishment of shared culture and values to increase companies' motivation to collaborate, may enable the companies to find mutually beneficial solutions.

6.2.2 Pre-Existing Structural Enablers

Through our research, we were able to identify certain enablers possessed by some of the clusters that aided them in their progress of implementing industrial symbiosis, including ownership structure and company mix.

While the structuring of land areas in the industrial parks we have researched varies, those that are owned by the park management or an owner organization have consistently identified this as an advantage, compared to individual company ownership. Øra Industrial Area is an example of how separate ownership can work, as collaborations there have developed organically without the need for a third-party facilitator. However, the representative of Øra Industrial Area, the Norwegian Center of Circular Economy, has experienced that having a single owner who rents out sites to park members instead of selling them is the preferred approach. This approach has therefore been chosen in the development of Viken Park, an eco-industrial greenfield park. The advantages the clusters emphasize are linked to the simplified selection of suitable companies for symbiosis, especially when there are still free land areas. In contrast, in cases where companies have separate ownership, they may not have to interact with other cluster members in the same manner. This can also lead to an "every man for himself" culture, which is not ideal for creating synergies. Generally, when the companies are more embedded, it is easier to implement industrial symbiosis projects, and having a single owner can facilitate this integration (Zhu et al., 2015; Paquin & Howard-Grenville, 2012).

Moreover, our research highlights the significance of having a well-balanced mix of companies in order to successfully initiate and implement industrial symbiosis practices. In the literature, conflicts of interest among the companies within the cluster are viewed as a significant barrier to this (Henriques et al., 2021; Madsen et al., 2015). However, several clusters that we have analyzed have reported that the absence of conflicts of interest has made the process smoother. In cases where some competition existed between cluster members, it was effectively managed, and we did not come across any cases where direct industrial symbiosis projects were pursued between such companies. This is possibly due to how such projects are more commonly found in cross-industrial collaborations, wherein a company having an excess resource offers it as a by-product to a company in a different industry (Neves et al., 2020). Thus, having a diverse range of companies with varying industries and types of side-streams may function as a pre-existing enabler for industrial symbiosis.

6.2.3 The Advantage of Having a Third-Party Cluster Facilitator

According to our analysis, the involvement of a cluster facilitator plays an important role in initiating and implementing industrial symbiosis. Their presence brings about a significant advantage by accelerating the process and by enabling industrial symbiosis where it may not have occurred otherwise. While there are instances in our researched clusters where industrial symbiosis has naturally arisen without the intervention of a third-party facilitator, these cases have typically involved clusters derived from a single company's division and have benefitted from pre-existing routines and knowledge. Øra Industrial Area stands as an exception, as the companies there proactively initiated collaboration due to the economic benefits and waste reduction potential.

However, for clusters that are yet to initiate the process of implementing industrial symbiosis, having a facilitator becomes instrumental in accelerating this process (Fichtner et al., 2015). Organic synergies take time to develop, and if they have not emerged naturally yet, there is a likelihood that they may not do so in the near future either, particularly when the symbiosis consists of multiple resource streams involving more than two businesses. For such clusters, industrial symbiosis represents a new way of conducting business, requiring adaptation and time. A facilitator can contribute to this process and help manage the network of symbiotic relationships, particularly when numerous resource streams span across multiple companies.

Furthermore, the success of industrial symbiosis also relies on cooperation among all key stakeholders, and a third-party facilitator proves to be valuable in managing these interactions (Mortensen & Kørnøv, 2019). Given the Norwegian government's commitment to achieving climate goals and the industry's alignment with this objective (Regjeringen, 2019, Prosess21, 2021), industrial symbiosis can play a vital role in the process, with facilitators significantly contributing to accelerate the necessary changes. As highlighted in our conceptual framework, as depicted in Figure 2, it is indeed feasible to accomplish the four overarching goals without relying on a facilitator. While our proposed solutions do not present a definitive answer, adhering to these suggested solutions to attain the four goals serves to streamline and expedite the process, and to succeed with this, the presence of a facilitator becomes key.

Conclusively, to witness the success of implementing industrial symbiosis across a greater number of industrial clusters and accelerate the pace of progress, it is vital to dedicate efforts towards supporting third-party cluster facilitators.

6.2.4 Need for an Inclusion of Multiple Stakeholders

The results of our study emphasize the importance of involving a variety of stakeholders who are not directly involved in the industrial symbiosis projects, to effectively initiate and execute these projects. The need for collaboration with key stakeholders in enabling industrial symbiosis projects has also been found in international research (Henriques et al., 2021), as well as in the Norwegian context (Process21, 2021). Moreover, consistent with the findings of Baltasarre et al. (2016), the key stakeholders contribute specific knowledge and resources that benefit the clusters' overall business models. Essentially, in our research, we find that these stakeholders fulfill specific areas of expertise and responsibilities that are not taken on by the symbiotic partners but are essential to the completion of such initiatives. For instance, we find that research institutions contribute to knowledge and expertise that is not available within the cluster, and that facilitators frequently create a space for companies to engage in conversation, which the companies within the cluster found difficult.

Furthermore, in line with past studies, we find that stakeholders involved in the development and execution of clusters frequently take on different roles (Mortensen & Kørnøv, 2019). This can be exemplified by the identified tasks of the facilitator and the research institutions as expounded upon previously. Nonetheless, in our research we also observe that multiple stakeholders adopt the role of motivator in the context of industrial symbiosis, including the facilitator, prominent companies and individuals, or governmental actors, indicating that this role is not exclusively executed by a facilitator. Moreover, our findings indicate that the significance of the role stakeholders play in industrial symbiosis can differ based on the cluster's level of maturity. For instance, in clusters where industrial symbiosis is more developed, we observe that stakeholder efforts to motivate industrial symbiosis projects are given less consideration. Mortensen and Kørnøv (2019) have identified a similar trend wherein stakeholders engaged in the execution of industrial symbiosis practices undergo distinct phases that entail a shift in their respective areas of expertise and responsibilities. This suggests that in different phases of industrial symbiosis, the significance of certain stakeholders' roles might differ due to a shift in the roles necessitated. This is something that we observed in regard to the municipality's function in our research. Elaborately, in clusters where industrial symbiosis practices were more developed, there was less emphasis on this stakeholder, which may be due to this stakeholder typically serving as a motivator for industrial symbiosis practices.

In conclusion, it is highly important to involve stakeholders that are not directly involved in industrial symbiosis practices. Understanding the roles of stakeholders and their suitability for resolving specific challenges at various phases of industrial symbiosis initiatives can be of great benefit to the industrial clusters.

6.3 Social Aspects

6.3.1 The Benefits of Trust

In Chapter 2, a lack of trust was identified as an essential barrier to initiating and implementing industrial symbiosis. Literature has shown that a lack of trust can lead to reluctance to collaborate or share data, and it also impacts motivation (Neves et al., 2019; Fichtner et al., 2005; Goley et al., 2015; Corsini et al., 2023). However, we did not find this to be a significant issue for the Norwegian clusters included in this research. Part of the explanation for this, as several clusters point to, may be the high level of trust in Norwegian society. For instance, trust in government in Norway was 77% in 2021, which was the highest compared to other OECD countries (OECD, 2022). Additionally, 73,7% of people agree with the statement that most people can be trusted, which was the highest among the 108 countries surveyed (Ortiz-Ospina & Roser, 2016). High social trust in Norway promotes better collaboration among people (DFØ, 2022). Although many clusters acknowledged this as an advantage, they also emphasized that trust needs to be earned over time.

The other part of the explanation is related to the establishment of a culture of trust and collaboration in the clusters. For industrial clusters where companies have been neighbors for a long time and perhaps have had shared infrastructure, services, or knowledge of each other, trust has been built up over a longer period (Lewicki et al., 2006; Boons and Howard-Grenville, 2009). In our research, the majority of the clusters had a pre-existing relationship before engaging in industrial symbiosis projects. Furthermore, we find that a trust-based relationship enables companies to enter long-term investments with longer payment periods than they would have done otherwise. As this drastically lower depreciation costs, the risk of the investment also becomes reduced. For clusters without prior relationships, the need for a third-party facilitator and to establish a shared direction for the cluster is greater, as this may accelerate the trust relationships which have been built up over years or decades in other clusters (Mortensen & Kørnøv, 2019). The facilitator contributed to this by ensuring that the

interests of all parties are taken care of and by uniting the goals of the involved companies. However, in these cases, the facilitator must have credibility and respect among the companies through experience with the cluster or the industry, and they need to have good knowledge of the core operations of the involved companies (Ingstrup, 2010).

In conclusion, our research indicates that high levels of trust in society, combined with the establishment of a culture of trust either through long relationships or a facilitator, have been one of the key advantages of the Norwegian industrial clusters.

6.3.2 Increasing Motivation and Knowledge of Industrial Symbiosis

In our analysis, we identified lacking motivation and low willingness to join industrial symbiosis projects as barriers to their implementation, and the underlying cause for these barriers can vary widely from company to company. Our analysis indicates that factors such as preoccupation with daily operations, a lack of shared cultural foundation or strategy, or management and ownership that fail to see the value in industrial symbiosis may contribute to this issue. However, our research also suggests that fostering a sense of pride and community and aligning companies with a shared direction and vision can be impactful in addressing this problem.

Furthermore, as observed in the literature, lack of knowledge often poses a noteworthy barrier to the initiation of industrial symbiosis projects (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021; Goley et al., 2015; Madsen et al., 2015; Fichtner et al., 2005). Although this barrier was not prominent among our interviewees, as all of them had already initiated industrial symbiosis projects, we did find that a lack of knowledge about industrial symbiosis contributed to the reluctance of stakeholders to participate in such projects. Several clusters have taken measures to spread awareness and knowledge of industrial symbiosis and emphasize the importance of involving all key stakeholders in this process. This work includes hosting conferences, workshops, seminars, and other events aimed at interested companies and relevant actors in the local governments, research communities, and academic institutions. Eyde Cluster, for instance, emphasizes that successful industrial symbiosis projects revolve around collaboration between all involved parties, which further requires everybody to have access to the same information, a good understanding of the concept, and a shared direction and vision for the projects. By cultivating knowledge of industrial symbiosis, motivation for

participation may rise, as the involved parties can increasingly recognize its value (Fichtner et al., 2015; Madsen et al., 2015).

In conclusion, we propose that the lack of motivation to engage in industrial symbiosis can be tackled by increasing the knowledge of industrial symbiosis practices and their potential benefits.

6.4 Institutional Aspects

6.4.1 Impact of the European Union's Green Deal

In our research, we observed an increasing motivation among industry actors to pursue industrial symbiosis initiatives for environmental reasons, driven by legislation from the European Union's Green Deal. This is consistent with a report on the circular economy by Process21 (2021) which expresses that the Europeans Union's Green Deal will have a significant impact on the conditions for industrial activity in Norway. This will primarily be observed by factors such as access to capital, access to EU programs and instruments as well as the future design of state aid regulations (Prosess21, 2021). Appropriate regulations are essential for the success of a circular economy (Prosess21, 2021), and given the far-reaching impact of these regulations on the industry, it is crucial to ensure that they are designed in a manner that supports and enhances industrial symbiosis practices in a Norwegian context (Norsk Industri, 2019). This is particularly important as the Norwegian process industry has a large element of non-ferrous metals such as aluminum and ferroalloys production (Regjeringen.no, 2001), which is unique in the European context (Prosess21, 2021). Moreover, the intricacy of the political packages also necessitates heightened monitoring and effort to evaluate the risk of unexpected outcomes (Prosess21, 2021). Consequently, it is highly important for the Norwegian authorities to collaborate with the process industry to participate in the development of instruments at the European Union level and collaborate to protect Norwegian interests regarding industrial symbiosis practices (Norsk Industri, 2019).

In conclusion, forthcoming regulations from the European Union are expected to have a significant impact on the process industry. Given the unique nature of the Norwegian process industry within the European context, it is imperative that the government collaborates closely with the industry to ensure that their interests are met in the development of new European legislation.

6.4.2 Incentivizing All Industrial Clusters to Implement Industrial Symbiosis

Consistent with prior academic research, we find that a key driver of industrial symbiosis initiatives for companies is the pursuit of economic benefits and to improve the environmental sustainability of their operations (Chertow, 2007; Henriques et al., 2021). However, we have also observed a significant variation among clusters and individual companies regarding the extent to which the pursuit of circularity serves as a driver for their involvement in industrial symbiosis projects. While some clusters and companies are actively leading the way toward a circular transition, others are lagging behind in their efforts. Additionally, regardless of the sustainability motivations of the companies involved, the projects themselves must be economically viable (Henriques et al., 2021; Neves et al., 2019). Nevertheless, several firms may encounter difficulties in this regard as a considerable number of viable industrial symbiosis initiatives have already been executed, and thus many of the remaining industrial symbiosis endeavors are unprofitable (Norsk Industri, 2019). Consequently, lowering the profitability threshold of a project becomes essential in order to incentivize clusters and companies that have not yet engaged in industrial symbiosis to do so (Prosess21, 2020; Norsk Industri, 2019).

The provision of financial support for circular incentives by national governments can serve as an incentive for the implementation of industrial symbiosis (Henriques et al., 2021; Neves et al., 2019; World Bank, 2021). A possible approach for the Norwegian government to promote industrial symbiosis initiatives could entail enhancing its support for the industrial implementation and commercialization of environmental technology (Prosess21, 2021). Furthermore, the establishment of risk mitigation funds to support investments that are specifically geared towards facilitating new circular solutions (Norsk Industri, 2019; Prosess21, 2021). The implementation of such measures can potentially mitigate or decrease the associated risks that arise from exploring new markets and undertaking initiatives with uncertain prospects. This, in turn, can significantly encourage companies to actively participate in industrial symbiosis initiatives (Norsk Industri, 2019). Lastly, since developing process improvements and solutions for industrial symbiosis practices frequently requires long-term projects and commitment over time, extending the funding period for such research projects is an option that can serve as an incentive for businesses to engage in industrial symbiosis practices (Prosess21, 2020).

6.5 Economic Aspects

6.5.1 Increasing the Attractiveness of Investment in Industrial Symbiosis

As outlined in the analysis, there are various factors that diminish the appeal of investing in industrial symbiosis. Addressing this barrier requires comprehensive analyses to understand the underlying reasons behind investor hesitation. Investing in industrial symbiosis entails inherent risks, as is the case with any project, however, a range of proactive measures can be employed to mitigate these risks and uncertainties, as elucidated in preceding sections. One such measure involves addressing the challenge of unreliable resource streams by implementing effective measures to reduce uncertainty. Additionally, establishing robust contracts and arrangements for the collaborations that should address potential disruptions and outline contingency plans in case of unforeseen circumstances. Furthermore, having a diverse mix of companies involved in the symbiotic ecosystem can contribute to risk reduction. Finally, providing more evidence of the positive impacts of industrial symbiosis may enhance investment prospects by demonstrating the benefits and value of such initiatives. In general, as the prominent barriers are gradually overcome, and awareness of industrial symbiosis spreads while project risks decrease, the attractiveness of investments in industrial symbiosis will inevitably increase. The market is currently undergoing a maturation process, and as more evidence emerges regarding the positive impacts of symbiotic relationships, the market will continue to mature and evolve.

7. Conclusion

This chapter provides a conclusive summary of the research conducted in this thesis. In section 7.1, we discuss the theoretical implications that examine how our research addresses significant gaps in the existing literature on industrial symbiosis. In section 7.2, we address the practical implications, which encompass how our research can be implemented in practice. Section 7.3 discusses the limitations of the study, whereas section 7.4 provides suggestions for future research.

In this thesis, we have conducted an exploratory study of how Norwegian industrial clusters can successfully initiate and implement industrial symbiosis practices. To answer this research question, we have identified four research objectives that we have explored through our analysis. Specifically, we have identified existing internal and external drivers of the initiation of industrial symbiosis, as well as key barriers to its implementation. We have also provided potential solutions to overcome these barriers and explored the significance of key stakeholders when engaging in industrial symbiosis activities.

In conclusion, our analysis has revealed that Norwegian industrial clusters exhibit a promising outlook for successfully initiating and implementing industrial symbiosis practices. Through our research, we have identified cluster facilitators as a central stakeholder in this regard. First, they may identify and initiate the projects by bringing the right actors together. However, it is important that the involved companies are motivated to engage in the collaboration. Our findings indicate that internal factors such as economic benefits and environmental responsibility typically serve as the primary drivers for companies to join such initiatives. Furthermore, facilitators can actively work towards fostering a sense of pride and community and establishing a shared vision, strategy, and goals. This approach may serve to secure motivation, and willingness to collaborate and share data, as well as to coordinate the actions of the involved companies. Further in the process, facilitators may engage in mediating negotiations, learning from other industrial clusters, and collaborating with other stakeholders, as these actions are aimed at resolving barriers encountered by the companies, such as unreliable resource streams, lack of appropriate allocation keys or business models, and technical challenges. Moreover, to provide external incentives for companies to engage in industrial symbiosis practices, policymakers must enact changes in existing policies and provide improved conditions for industrial clusters pursuing such initiatives. In summary, our research indicates that if clusters successfully build a collaborative culture, establish trust,

cultivate knowledge of industrial symbiosis, and find feasible solutions to its implementation, they are likely to succeed in implementing industrial symbiosis.

7.1 Theoretical Implication

Our research provides support to the existing literature on industrial symbiosis and its implementation in eco-industrial parks while also adding the perspective of Norwegian industrial clusters on the topic. Currently, there has been limited research on the implementation of industrial symbiosis in Norwegian industrial clusters, especially when it comes to researching the topic across different clusters. Therefore, there is limited knowledge regarding the distinctive nature of barriers in Norwegian clusters compared to barriers observed worldwide. Our study addresses this research gap and contributes to the literature by providing insight into the topic within the Norwegian context.

Certain aspects of industrial symbiosis will be globally applicable, as certain challenges will emerge regardless of the geographic location. This includes barriers related to the unreliability of the resource streams, both considering flow and quality, the need to coordinate actions, and economic and technical challenges. However, our findings suggest some differences applying to the Norwegian context. For instance, the presence of trust in society and the fact that it is more natural to collaborate, function as an enabling factor for the implementation of industrial symbiosis in Norwegian clusters. Moreover, we find low levels of resistance of sharing data, conflict of interest, and unwillingness of stakeholder collaboration, which also contributes to simplifying the process. We also find that Norwegian clusters are actively dealing with lacking knowledge and expertise on industrial symbiosis by learning from other actors, often at a Nordic level. Our findings suggest that the main tasks of a cluster are to build a collaborative culture, establish trust, cultivate knowledge of industrial symbiosis, and find feasible solutions to its implementation, which align with prior literature and add to it by including the Norwegian perspective.

7.2 Practical Implications

We consider our findings to be valuable for industrial clusters currently engaged in or planning to implement industrial symbiosis practices, by having identified potential barriers they may face and offer strategies for overcoming them. Moreover, our thesis explores the driving

factors behind industrial symbiosis and identifies the incentives that are currently lacking, which may contribute to guiding stakeholders who are committed to fostering more practice of industrial symbiosis in Norway.

Our findings may provide valuable insight for clusters at varying stages of industrial symbiosis, including those that are considering, currently in the process of, or already engaged in such practices. We have addressed barriers faced by clusters in different stages of implementation, making our findings applicable to a wide range of clusters. Additionally, as industrial symbiosis is a dynamic process with evolving challenges, our analysis may also be relevant for clusters that have already successfully implemented some industrial symbiosis projects. Furthermore, we have suggested solutions that may be adapted by clusters in order to overcome these challenges. Our proposed model, presented in Figure 2, may also guide clusters in finding the most appropriate solutions based on the specific barriers they encounter. While clusters may employ alternate approaches, our model may help guide them toward the overarching goal they must reach, enabling them to find their own solutions accordingly. Moreover, our research may be beneficial for clusters that aspire to engage in industrial symbiosis but have not yet done so. By leveraging our findings, these clusters can proactively anticipate potential challenges and position themselves one step ahead. Furthermore, our research sheds light on the roles and significance of various stakeholders that clusters may collaborate with, which may enable them to foster effective partnerships and maximize the benefits of industrial symbiosis.

Additionally, our findings may contribute to guiding governmental actors in supporting the industrial actors in the solutions they are trying to employ. Our findings suggest that increased financial support for research projects, working together with the industry to find suitable incentives to implement and make changes in outdated regulations, as well as supporting standardization authorities will be impactful actions.

7.3 Limitations

As discussed in Chapter 4, we found that an exploratory, qualitative study, utilizing data collected from eleven semi-structured interviews and analysed through the Grounded Theory method, was a suitable approach to answer our research question and explore the research objectives. However, our chosen methodical approach also has several limitations, which we will discuss in this section.

One aspect we must address is that the study was limited to conducting only eleven interviews due to time constraints. By conducting additional interviews, we could be more certain that our findings could be generalized to other clusters (Saunders et al., 2012). Another aspect that was impacted by time constraints, was that we were not able to fully adhere to the constant comparison aspect of the grounded theory method, especially in terms of sample selection. Grounded theory is commonly associated with theoretical sampling, which involves selecting subsequent samples based on emerging theories and evolving storylines (Saunders et al., 2012). However, due to our constraints, we were limited to working with our initial sample.

Furthermore, limiting the investigation to interviewing only one actor involved in the symbiotic collaborations, namely the cluster facilitator, may have limited our ability to achieve a complete understanding of the topic due to potential variances in perspectives and information. This limitation is especially notable in the context of industrial symbiosis activities, where multiple actors are involved, each with distinct perspectives and knowledge on the subject. By limiting data collection to a single individual per collaboration, it is possible that certain perspectives were not adequately represented, or that crucial information was overlooked. Furthermore, as industrial symbiosis typically encompasses multiple projects that, for some clusters, have been established for a longer period, the cluster representative may not possess a complete overview of all key aspects of industrial symbiosis practices. However, we have attempted to mitigate this limitation by selecting the most suitable representative available.

Another limitation pertains to the study being conducted at a specific point in time. Industrial symbiosis is a dynamic and evolving concept, making it difficult for researchers to capture its temporal dimension and changes over time. Conducting a study at a specific point in time may offer a limited perspective on the challenges and motivators encountered by stakeholders during the implementation process and may not capture contextual nuances that influence these.

7.4 Suggestions for Future Research

The extent of academic research into industrial symbiosis practices in Norway is notably restricted, with little focus devoted to the examination and comparison of the practices of multiple clusters. Future research should further investigate Norwegian clusters, either with an even larger sample size or more comprehensively, to obtain a more thorough knowledge of

the contextual elements that impact industrial symbiosis practices and potential enablers. Furthermore, future research should also adopt a longitudinal perspective to capture the evolving barriers, drivers, and complexities associated with implementing and sustaining industrial symbiosis, as well as the contextual factors that influence these.

In order to gain a better understanding of how clusters can successfully initiate and implement industrial symbiosis, we would also encourage future research to investigate the relationships between the mentioned barriers, potential solutions, and far-reaching objectives that we outline in our framework. In addition, it would be advantageous to conduct additional research into the relationship between the functions of various stakeholders and the obstacles they assist in overcoming during the execution of industrial symbiosis projects, as this would allow for a more thorough understanding of the stakeholders required for successful implementation.

While we have identified key drivers and barriers faced by Norwegian industrial clusters, it would be valuable to explore the environmental and economic impacts of industrial symbiosis, including methods for quantification. For instance, it would be interesting to investigate potential indicators of resilience or risk within industrial symbiosis collaborations. Moreover, through this research, we have encountered the aspect of regional and national facilitators, as several clusters have highlighted these as being valuable. Future research could further examine the role and importance of these facilitators, as they may be valuable for scaling the number of clusters and companies engaging in industrial symbiosis.

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Appendices

Appendix A: Presentation of Cases

Mongstad Industrial Park

Mongstad Industrial Park is one of Norway's largest industrial areas located close to Bergen in Vestland county. The park employs over 2700 people and accommodates 59 companies, the biggest being Equinor. There is a wide variety of industries connected to the park and the area has functioned as an industrial park since 1975. In 2021, the project "Greenspot Mongstad" was initiated, aiming to ensure a diverse industrial mix, increase green investments, and encourage circular industrial processes, including industrial symbiosis. Currently, the park has several internal resource exchanges and shared infrastructure and services, however, substantial changes toward resource and energy exchanges are being planned and soon ready to be initiated. Therefore, we classify the park as being in a development stage of industrial symbiosis.

Skogmo Industrial Park

Skogmo Industrial Park is located in Overhalla in Trøndalag county and hosts 54 companies and 850 employees. Today the park consists mostly of the construction and infrastructure industry and has a goal of becoming climate neutral within 2040. There has been a wood-related industry at Skogmo for over 100 years, while the cluster network was initiated in 2006, after the wish of the industrial actors to engage in more collaboration. Existing industrial symbiosis at Skogmo is mostly related to the exchange of excess resources, and most actors in the park are involved with symbiotic projects. In addition, the park has shared infrastructure and services and several synergies with the local municipality.

Thamsklyngen

Thamsklyngen is an industrial cluster comprising 36 member-owned companies located in the southern region of Trondheim. Thamsklyngen was founded in the year 2018 and serves as a collaborative platform for prominent stakeholders from diverse industries such as food, offshore, process, and electronics. The cluster aims to spearhead the transition towards sustainable practices among the industrial entities operating within the park. Presently, the cluster companies are actively involved in collaborative endeavors that revolve around the utilization of waste heat for energy and the facilitation of byproduct exchange. Thamsklyngen

is also actively engaged in the exploration of new possibilities pertaining to industrial symbiosis projects.

Sirkulære Rjukan

Sirkulære Rjukan is a collaborative network consisting of 25 member companies located at Rjukan in Vestfold og Telemark county and involves xxx employees. The participating companies operate in industries including hydrogen production, aquaculture, process industry, and data centers. The industrial history of Rjukan is over 100 years old, and multiple of the members of Sirkulære Rjukan has been located there for several decades. However, until the initiation of this network in 2022, there had been limited cooperation between the companies. The network is based on circular economy collaborations between companies across industries and the activities are aimed at increasing the exploitation and exchange of the resources within the network. Sirkulære Rjukan is still in the development stage of implementing industrial symbiosis but is far in the negotiations and planning of the projects, which will include the exchange of by-products, heat, and water, as well as sharing of infrastructure and services.

Treklyngen

Tryklyngen is an industrial estate located in Hønefoss in Viken county, consisting of 30 companies and around 100 people having their daily work in the park. There has been industry on the site for over 150 years, while Treklyngen industrial park was established in 2012 when Viken Skog SA invested in the clearing and clean-up of the industrial area. Gradually over the last decade, Treklyngen has had the strategy to facilitate the accommodation of energy-intensive industries within wood processing, biomass, renewable energy, and circular economy. They are currently in the development stage of the process of implementing several industrial symbiosis projects, which will primarily revolve around the exchange of excess heat and by-products. Furthermore, they are providing shared infrastructure and services for the companies and offer several synergies toward the local community.

Mo Industrial Park

Mo Industrial Park is located in Mo i Rana in Nordland county and consists of 110 companies and 2500 employees. There has been mineral industry located in the area for over 120 years and after the second world war, the site became an ironwork which was present for over 40 years. Then, Mo Industrial Park was established and the park currently accommodates various industries such as process and mineral industry, aquaculture, energy, and recycling. Due to its history, the park has long traditions of collaboration between the companies, and almost all of

their companies are involved in some sort of industrial symbiosis. These include the exchange of by-products, waste, and excess heat and water, as well as shared infrastructure and services, and synergies toward the local community. The park has a vision of becoming a world-class green industrial park and is committed to putting substantial efforts toward sustainability, including through research collaborations.

Glomfjord Industrial Park

Glomfjord Industrial Park, located in Nordland county, accommodates a group of 26 companies and provides jobs for around 450 individuals. The park has a longstanding history of industrial operations, dating back to the year 1912. The Glomfjord industrial park was founded in 2003 and currently accommodates firms belonging to diverse sectors, including the process industry, chemical industry, and aquaculture industry. The origins of industrial symbiosis in Glomfjord can be dated back to 1986, when companies begun the practice of exchanging surplus water. In addition to its internal collaborations, the Glomfjord industrial park fosters synergistic relationships with the surrounding community. At present, the park is actively involved in industrial symbiosis initiatives, with a particular emphasis on the exchange of surplus water.

Tregruppen

Tregruppen is a collaborative initiative that emerged in 2016 as a result of the joint efforts of the participating companies and the Trøndelag County Council. At present, Tregruppen comprises seven distinct firms, collectively employing a workforce of 125 individuals. Tregruppen operates as a commercial cluster and serves as a regional hub for the forestry industry. Prior to this establishment of Tregregruppen, the efforts were informally organized within the community. Since around 2016, the cluster has begun to engage in resource collaboration and is currently fostering industrial symbiosis primarily through the exchange of by-products and waste, as well as shared services.

Øra Industrial Area

Øra industrial area is located in Fredrikstad, within the county of Viken, and its industrial history stretches back to the early twentieth century. Øra industrial area is home to 145 businesses with approximately 2 430 employees. Companies in the region have practiced industrial symbiosis for years, with a concerted effort to promote such initiatives beginning roughly 20 years ago. Presently, industrial symbiosis efforts in Øra entail the exchange of by-products and waste materials, as well as the sharing of excess energy. Additionally, the industrial territory contributes to synergies with other regions throughout the nation. Moreover, the companies within the park are still looking for new industrial symbiosis projects.

Eyde Cluster

Eyde Cluster is an industrial cluster located in Agder county, comprising 80 companies and a workforce of around 5 000 employees. The member companies predominantly belong to the process industry and are geographically dispersed throughout the county. The creation of the Eyde Cluster dates back to 2007 and was initiated by the companies in the area. In 2016 the cluster began to also prioritize industrial symbiosis initiatives between the companies as a strategy for the companies to become more environmentally friendly. The companies that are part of the cluster are actively involved in the implementation of industrial symbiosis practices, which involve the sharing of surplus energy and the exchange of by-products and waste. Moreover, the Eyde cluster is actively pursuing new prospects for industrial symbiosis.

Herøya Industrial Park

Herøya Industrial Park is located in Telemark County and is home to 80 businesses employing around 2 500 people. The region has had an industrial presence since 1928, and Herøya Industrial Park was founded in 2003, shortly after the separation of Hydro, which formerly inhabited the whole area. Prior to the creation of Herøya Industrial Park, the many manufacturing facilities within Hydro were already engaged in industrial symbiosis through sharing energy. The necessity for a coordinated approach to industrial symbiosis practices among the new companies, on the other hand, resulted in the development of Herøya Industrial Park. The park now has a circularity rate of 85 to 95 percent, with participating enterprises actively engaged in industrial symbiotic activities such as sharing excess energy and water, as well as exchanging by-products and waste, and Herøya Industrial Park is still exploring new potential for industrial symbiosis practices.

Appendix B: Interview Guide

Intervjuguide

Gjennomføring av intervjuet

Vi vil starte intervjuet med å gi en kort introduksjon av oss selv og om oppgaven. Deretter vil vi stille noen *innledende spørsmål* som vi vil bruke til å kunne kartlegge ulike aspekter ved industriparken og intervjuobjektet. Vi håper også at du vil ha mulighet til å kunne se på *hovedspørsmålene* i forkant slik at intervjuet kan gjennomføres best mulig. Vi ønsker også å stille oppfølgingsspørsmål underveis i prosessen der det måtte bli relevant.

Hva vi mener med industriell symbiose?

Når vi refererer til begrepet industriell symbiose mener vi samarbeid om bruk av ressurser på tvers av bedrifter. Dette kan for eksempel være ressurser knyttet til materialer, råvarer, energi, vann, biprodukter eller lignende. Industrielle symbioses kan altså forekomme på veldig mange forskjellige måter og vil ofte gi økonomiske og/eller bærekraftige synergieffekter. Vi vil i dette intervjuet i hovedsak referere til begrepet som «ressurssamarbeid».

<u>Introduksjon</u>

- Takke for intervju
- Referere til samtykkeerklæring – vi vil ta videoopptak og transkribere intervjuet
- Presentere oss selv og oppgaven

<u>Innledende spørsmål</u>

- Kort introduksjon av industriparken, inkludert:
    - Hvilke(n) bransje(r) består industriparken av
    - Antall bedrifter i industriparken
    - Antall ansatte i industriparken
    - Om det foreligger større geografisk avstand mellom bedriftene i industriparken
    - Når ble industriparken opprettet

- Hva er din stillingstittel og rolle i industriparken?
- Hva er din tilknytning til sirkularitet og ressurssamarbeid innad industriparken?

Hovedspørsmål:

1. Hva slags ressurssamarbeid (industrielle symbioser) gjennomføres i dag og hvordan?
2. Hvor mange bedrifter i industriparken er involvert i ressurssamarbeid?
3. Hva er status på ressurssamarbeidet i dag? Er prosjektet/prosjektene for eksempel under utvikling, stabilt eller i vekst?
4. Når ble ressurssamarbeidet initiert/startet?
5. Hvem initierte dette? For eksempel bedrifter innad parken, ledelse av industriparken, et overordnet nettverk eller en kombinasjon?
6. Er det noen parter som du mener har vært spesielt viktige for denne prosessen?
7. Hva var motivasjonen bak å igangsette dette?
8. Forelå det noen regulatoriske, finansielle eller andre insentiver for å igangsette dette?
9. Hva har vært vanskelig i forbindelse med denne prosessen? Hvilke utfordringer er støtt på?
10. Hvordan har dere eventuelt løst disse utfordringene?
11. Hva var relasjonen mellom bedriftene innad industriparken før ressursdeling ble introdusert og fantes det et felles nettverk for industriparken?

Avslutningsspørsmål:

Basert på det vi har snakket om i dag, er det noen andre innspill eller tanker du tenker kan være relevant å dele?

Appendix C: Information Letter and Consent Form

Informasjonsskriv om deltagelse i masterutredning ved NHH

I forbindelse med vår mastergrad ved Norges Handelshøyskole (NHH) skal vi skrive en avsluttende masteroppgave innenfor fagområdet økonomisk styring. Etter avtale på mail har du takket ja til å delta i vårt forskningsprosjekt om sirkularitet og samarbeid om bruk av ressurser innad i norske industriparker (industriell symbiose). I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Formålet med denne masteroppgaven er å studere hva som skal til for å lykkes med innføring av ressurssamarbeid på tvers av bedrifter (industriell symbiose) i norske industriparker. Studien vil utforske hva som motiverer industriparker til å igangsette slike prosjekter og hvilke insentiver som foreligger. Videre vil vi undersøke hvilke utfordringer industriparker møter på i forbindelse med dette arbeidet og hvordan disse utfordringene potensielt kan løses. Vi ønsker å intervjue norske industriparker som har innført ulike former for ressurssamarbeid for å kunne bruke deres erfaring til å analysere vår problemstilling.

Hvem er ansvarlig for forskningsprosjektet?

Norges Handelshøyskole er ansvarlig for prosjektet. Masterutredningen skrives av Kaisa Havem og Sofie Karlsen, med professor Marcus Selart som veileder.

Hva innebærer det for deg å delta?

Vi ønsker å gjennomføre semi-strukturerte intervjuer for å sikre en åpen tilnærming til problemstillingen. Det er viktig at intervjuobjektet skal kunne snakke fritt og at egne synspunkter og erfaringer kan komme tydelig frem. Intervjuet vil vare mellom 45-60 minutter og vil gjennomføres digitalt.

Vi ønsker å transkribere og ta videoopptak av intervjuet slik at dataene som innsamles vil være mest mulig pålitelige. Intervjuobjektet velger selv om de ønsker å ha på kamera eller ikke og kan få tilsendt en ferdig transkripsjon av intervjuet dersom dette er ønskelig. Oppgaven vil gjengi navnet på industriparken, men vil ikke nevne intervjuobjekter med navn eller stillingstittelen i organisasjonen. Vi vil i stedet referere til intervjuobjekt som, for eksempel,

«relevant person i ledelsen av industriparken». Når den endelige masterutredningen publiseres vil du som deltaker derfor ikke kunne identifiseres.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

Det er kun forskere og veileder som vil ha tilgang til materialet. Etter intervjuet vil datamaterialet gjennomgås og anonymiseres, og kandidater kan be om sitatsjekk. Filene med videoopptak vil lagres adskilt fra øvrige data med anonymiserte titler og vil slettes når intervjuet er ferdig transkribert.

Prosjektet vil avsluttes når oppgaven er levert, noe er senest 01.06.2023. All datamaterialet og persondata vil slettes etter oppgaven er levert.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra NHH har Sikt – Kunnskapssektorens tjenesteleverandør vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg

- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

- NHH ved Marcus Selart: (marcus.selart@nhh.no), 55959695
- Vårt personvernombud: personvernombud@nhh.no

Hvis du har spørsmål knyttet til vurderingen som er gjort av personverntjenestene fra Sikt, kan du ta kontakt via:

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

Med vennlig hilsen,
Kaisa Havem og Sofie Karlsen

Samtykkeerklæring

Samtykkeerklæring i forbindelse med intervju om «Industriell symbiose i norske industriparker».

Ved signatur av dette dokumentet bekrefter jeg (intervjuobjekt) å ha mottatt og lest informasjonsskrivet tilsendt fra Kaisa Havem og Sofie Karlsen. Jeg gir med dette mitt samtykke til innsamling av data i forbindelse med masterutredning ved Norges Handelshøyskole (NHH). Dette inkluderer:

- Digitalt opptak av intervju
- Transkribering av intervju
- Forskernes og veileders tillatelse til bruk av transkripsjon etter transkribering
- Anledning til å lese gjennom transkribert intervju før publisering av masterutredning
- Sitering i anonymisert form i masterutredningen
- At transkripsjonene fra intervjuene slettes ved avslutning av forskningsprosjektet 01.06.23

Intervjuet vil bli gjennomført av Kaisa Havem og Sofie Karlsen. Jeg (intervjuobjekt) bekrefter med dette min frivillige deltakelse i studien. Samtidig bekrefter jeg at jeg har blitt informert

om egne rettigheter overfor mine personopplysninger, og at jeg kan trekke meg fra deltakelse av fri vilje.

Sted og dato: Signatur prosjektdeltaker:

_____ _____

Appendix D: NSD Approval

Vurdering av behandling av personopplysninger

Referansenummer
969719

Vurderingstype
Automatisk

Dato
30.03.2023

Prosjekttittel
Masterutredning ved NHH

Behandlingsansvarlig institusjon
Norges Handelshøyskole / Institutt for strategi og ledelse

Prosjektansvarlig
Marcus Selart

Student
Sofie Karlsen

Prosjektperiode
09.01.2023 - 01.06.2023

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 01.06.2023.

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.