QUALITATIVE EVALUATION OF INDUSTRIAL SYMBIOSIS IN A CIRCULAR ECONOMY CONTEXT

Case Study – The Kymenlaakso Industrial Cluster in Finland

Lappeenranta–Lahti University of Technology LUT

Master's Programme in Circular Economy, Master's Thesis

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ABSTRACT

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Circular Economy

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Qualitative Evaluation Industrial Symbiosis in a Circular Economy Context: Case Study – The Kymenlaakso Industrial Cluster in Finland

Master's thesis

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Keywords: industrial symbiosis, circular economy, sustainability, resource management

This Master's thesis studies industrial symbiosis as a promotor of circular economy, particularly within the Kymenlaakso industrial cluster in Finland. Industrial symbiosis aims to advance collaborative resource and by-product exchange among industrial operators. The goal is to reduce waste and harmful environmental impacts and increase resource efficiency: to create a closed-loop system – an operating environment resembling a natural ecosystem, in which waste from one activity becomes a useful resource for another.

The study examines industrial symbiosis in a global and regional circular economy context. Mainly two methodologies, document analysis and a regional survey, are used to map the present-day situation and to address the perceptions, primary material flows, opportunities and threats related to the concept. The research covers an introduction to the principles of circular economy and industrial symbiosis and presents multiple examples of international and Finnish industrial symbiosis -related units and incentives. The Kymenlaakso industrial cluster is the subject of a more profound case study and an online survey targeted at local business representatives. A comparative response analysis is presented, mirroring the answers to research findings and general perceptions.

In the introduction and implementation of industrial symbiosis, the findings bring forth both benefits – such as lower greenhouse emissions, increased resource efficiency and competitiveness, job creation and new business prospects – and challenges, such as the need for support measures and technical adjustments, increasing cooperation and transparency. The study indicates local and global variance in industrial symbiosis -related practices and background knowledge among operators. The results also reveal a clear need for more fiscal support and training. The relevance of the thesis findings is discussed in the study. The thesis ends by emphasizing the importance of industrial symbiosis in achieving the goals of a circular economy and by providing policy and strategy -related recommendations – such as more effective digitalization of information systems – for the Kymenlaakso industrial cluster and other sustainable development -focused areas.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

LUT Energiajärjestelmät

Kiertotalous

Minna-Liisa Keränen

Teollisen symbioosin kvalitatiivinen arviointi kiertotalouskontekstissa: Tapaustutkimus – Kymenlaakson teollisuusklusteri Suomessa

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Avainsanat: teollinen symbioosi, kiertotalous, kestävä kehitys, resurssienhallinta

Tässä diplomityössä tutkitaan teollista symbioosia kiertotalouden edistäjänä erityisesti Kymenlaakson teollisuusklusterissa Suomessa. Teollisen symbioosin tavoitteena on edistää teollisuuden toimijoiden välistä resurssien ja sivutuotteiden vaihtoa. Pyrkimys on vähentää jätettä ja haitallisia ympäristövaikutuksia ja lisätä resurssitehokkuutta: luoda suljetun kierron järjestelmä – toimintaympäristö, joka muistuttaa luonnollista ekosysteemiä, jossa yhden toiminnan jätteestä tulee hyödyllinen resurssi toiselle.

Tutkimus tarkastelee teollista symbioosia globaalissa ja alueellisessa kiertotalouskontekstissa. Nykytilanteen kartoittamiseen ja konseptiin liittyvien käsitysten, ensisijaisten materiaalivirtojen, mahdollisuuksien ja uhkien kartoittamiseen käytetään pääasiassa kahta metodologiaa, dokumenttianalyysiä ja kyselytutkimusta. Tutkimus kattaa johdannon kiertotalouden ja teollisen symbioosin periaatteisiin ja esittelee useita esimerkkejä kansainvälisistä ja suomalaisista teollisen symbioosin yksiköistä ja kannustimista. Kymenlaakson teollisuusklusteri on perusteellisemman tapaustutkimuksen ja paikallisyritysten edustajille suunnatun kyselytutkimuksen kohteena. Vastauksille tehdään vertailuanalyysi, joka heijastaa niitä tutkimustuloksiin ja yleisiin käsityksiin.

Teollisen symbioosin käyttöönotossa ja toteutuksessa tulokset tuovat esiin etuja, kuten kasvihuonepäästöjen vähenemisen, resurssitehokkuuden ja kilpailukyvyn kasvun, työpaikkojen lisääntymisen ja uudet liiketoimintanäkymät – ja haasteita, kuten tarpeen tukitoimenpiteille ja teknisille muutoksille sekä yhteistyön ja läpinäkyvyyden lisäämiselle. Tutkimus paljastaa paikallista ja globaalia vaihtelua teollisen symbioosin käytännöissä ja toimijoiden taustatiedoissa. Tulokset osoittavat myös, että verotuille ja koulutukselle on selkeä tarve. Diplomityössä käsitellään opinnäytetyön tulosten relevanssia. Työ päättyy korostamalla teollisen symbioosin merkitystä kiertotalouden tavoitteiden saavuttamisessa ja antamalla polittisiin käytäntöihin ja strategiaan liittyviä suosituksia – kuten tietojärjestelmien tehokkaampi digitalisointi – Kymenlaakson teollisuusklusterille ja muille kestävän kehityksen painopistealueille.

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1 Introduction

Throughout history, the predominant global economic model has followed a linear path, starting with extracting resources, then manufacturing, followed by consumption and finally disposing of waste. This "take-make-dispose" approach has significantly burdened our limited resources, leading to increased environmental harm and promoting a growth model that is not sustainable (Benedetti 2017). In response, forward-thinking individuals are recognizing the flaws of this linear system and are advocating for a transition to a more sustainable, circular economy. This alternative model emphasizes reducing waste, extending product lifespans and being mindful of resource use. The circular economy stands as a promising solution, aiming to address the environmental and social challenges posed by current economic practices (Ellen MacArthur Foundation n.d.).

The idea of industrial symbiosis entered in this field, proving crucial in realizing the goals of a circular economy. The concept of industrial symbiosis involves a cooperative exchange of resources and by-products between various businesses. Its clear but significant aim is to minimize waste and environmental effects while enhancing resource efficiency. Similar to the balanced ecosystems in nature, industrial symbiosis seeks to create a fluent system where one company's waste transforms into valuable resources for another (Mirata & Emtairah 2005; Sitra n.d.).

Despite the significant potential of industrial symbiosis to align with the principles of a circular economy, its adoption is still sporadic across different regions and industries (Haq, Välisuo & Niemi 2021). The Kymenlaakso industrial cluster, a diverse industrial hub located strategically between Helsinki and St. Petersburg (Appendix 1), presents an ideal setting for exploring industrial symbiosis. This research aims to navigate this complex area, seeking to uncover the possibilities that industrial symbiosis offers within the circular economy framework. It will concentrate on pinpointing obstacles, influential factors and key strategies necessary for effective implementation.

This study aims to explore the important role of industrial symbiosis in enhancing resource efficiency and environmental sustainability (Henriques et al. 2021). It seeks to inform leaders in politics, industry and academia, all of whom are actively pursuing sustainable practices and effective resource management, both in Kymenlaakso and elsewhere. The upcoming sections will focus on identifying gaps in existing research, setting out the study's goals, formulating key questions and presenting the structure of the thesis.

1.1 Research Gap

The concept of industrial symbiosis has been known for decades (Chertow 2007). During the implementation of industrial symbiosis, the principal operations have remained the same: collaboration of companies and organizations, resource savings through sharing, sustainable and optimized material procurement, beneficial reuse or recycling of waste and deployment of new technology (FISS 2023; European Commission 2019). Industrial symbiosis was established in response to the need to change the world. At present, the environmental state of the planet is alarming; in a state of rapid transformation, threatened by e.g., toxic waste, climate change and overpopulation. The depletion of natural resources, loss of biodiversity and continuous geopolitical turbulence are other worrisome factors. In the midst of these changes, the habits, attitudes, technological and operational methods are constantly evolving. Due to the ongoing fluctuation in the operational field, it is crucial to repeatedly – and at regular intervals – study the general perceptions, technical and industrial development, resource flows, material procurement and the functionality of industrial symbiosis at both a regional and global level. Recent developments in industrial symbiosis and its importance in the circular economy have attracted significant interest. However, there is still a gap in knowledge regarding its implementation in various geographical areas and industrial sectors (Benedetti 2017). When considering the case of the Kymenlaakso industrial cluster in Finland, it can be noticed that despite collaborative initiatives by e.g., the Finnish Industrial Symbiosis System platform (FISS 2023), Motiva Oy (2023), Syke (2023) and Sitra (n.d.), there is a noticeable lack of comprehensive academic research focused on this particular region.

Looking back at previous studies, such as those by Sokka, Lehtoranta & Melanen (2011), there's a noticeable focus mainly on the timber industry. The comprehensive regional

research by Savikko et al. (2019), conducted by the Regional Council of Kymenlaakso and Ramboll Finland, centers on data like emissions and resource flows for the Carbon Neutral Kymenlaakso Region 2040 project. Yet, considering Kymenlaakso's diverse industrial landscape, which includes sectors like chemicals, timber and logistics (Finder 2023a; Kymenlaakson liitto 2023c), a more expansive approach is required. There's a clear need for a thorough investigation into the practical industrial activities and collaborations in the region, including an analysis of knowledge, opinions, resource flow dynamics, existing synergies and the rate of implementing symbiotic practices. Such an in-depth study could reveal new opportunities for resource efficiency and sustainable methods in Kymenlaakso (Mallawaarachchi et al. 2020).

Addressing this gap in academic research can provide valuable knowledge for both scholarly purposes and real-world applications. This information could be crucial for policymakers and industry experts and contribute to broader discussions on sustainable development practices in Finland and worldwide (Benedetti 2017). In light of this, the following parts of this thesis will thoroughly explore industrial symbiosis, focusing specifically on the Kymenlaakso industrial cluster.

1.2 Objectives and Research Questions

This research delves into the realms of circular economy and industrial symbiosis, aiming to dissect their fundamental principles, evaluate their benefits and drawbacks and showcase worldwide examples of their transformative impact on industries. Focusing on Kymenlaakso, the study investigates its suitability for industrial symbiosis, taking a look at core industrial players and resource flows and the feasibility of implementing symbiotic approaches in this industrial area. It is essential to consider the environmental, economic and social consequences. Therefore, this study examines these aspects in Kymenlaakso, drawing from quantitative data, detailed qualitative insights and responses from an online survey of company representatives in the region. By navigating through this diverse range of information, the study seeks to identify solutions to potential challenges and provide practical recommendations for policymakers and industry leaders.

This research is driven by a deep interest in exploring the intersection of industrial symbiosis and the circular economy. Its aim is to provide insights that extend beyond the Kymenlaakso region, serving as a model for various industries and countries. This quest for understanding leads to the formulation of the following research questions:

A. How does the Kymenlaakso industrial sector manage its resource flows, collaborations and symbiotic interactions?
B. What attracts and what discourages Kymenlaakso when considering industrial symbiosis?
C. Beyond the immediate, what are the causes and effects - both environmental and economic - of industrial symbiosis in the Kymenlaakso region?
D. In operational industrial symbiosis, what are the driving forces and obstacles in Kymenlaakso?

1.3 Significance of the Study

This study seeks to understand the core of industrial symbiosis and its crucial role in the circular economy, especially in the context of Kymenlaakso in southern Finland. The findings of this research are intended to act as a guide for other areas and industrial centers in their pursuit of sustainable practices within a challenging global landscape. The research is expected to uncover valuable insights beneficial to various stakeholders. The thesis pinpoints the integration of industrial symbiosis within Kymenlaakso's industrial framework. This effort contributes to the existing body of knowledge on regional industrial symbiosis and lays the groundwork for further scholarly exploration in this field. The findings are anticipated to identify both the drivers and obstacles in effectively incorporating industrial symbiosis into Kymenlaakso's industrial context. The study is enriched by an online survey, gathering firsthand perspectives from company representatives in the region. These insights, together with strategic recommandations, are invaluable for industry professionals considering the adoption of symbiotic practices and for leaders aiming to foster a circular economy.

1.4 Structure of the Thesis

This section delves into the composition of the study, unfolding the key concepts of the seven chapters.

Chapter 1. Introduction. This chapter sets the stage for the research, outlining the background, driving questions, significance and structure of the study.

Chapter 2. Methodology and Considerations. This part provides a look at the data collection and analysis methods. The chapter describes the primarily qualitative methods used, explains the formulation of the survey, presents a visual timeline of the thesis process and addresses ethical considerations.

Chapter 3. Circular Economy and Industrial Symbiosis Concepts and Cases. This section reviews existing literature on circular economy and industrial symbiosis and discusses their key aspects, benefits and challenges while exploring their real-world applications in Finland and elsewhere.

Chapter 4. Case Study. The Kymenlaakso Industrial Cluster. The fourth chapter provides examination of the Kymenlaakso region, focusing on resource dynamics, industrial connections and the environmental and economic impacts of industrial symbiosis. The chapter includes a comparison of the case study region and case areas introduced in the previous chapter.

Chapter 5. Results. This chapter compiles the main findings of the study, discusses the survey outcomes and relates the content to the research questions.

Chapter 6. Discussion and Recommendations. This section engages in a discussion, comparing Kymenlaakso's experiences with broader academic perspectives on industrial symbiosis and circular economy, addressing the results of the research and offering practical suggestions, recommendations and policy strategies. The chapter concludes by evaluating the limitations of the study and offering recommendations for further research.

Chapter 7. Conclusion. The final chapter summarizes the study's structure and key findings, discussing their wider implications. It highlights the importance of industrial symbiosis in achieving sustainable development and encourages global stakeholders to embrace this approach in line with evolving circular economy principles.

2 Methodology and Considerations

This part of the thesis delves deeper into the research methods used. It discusses the outlines of the research approach, evaluates the significance of the study, evaluates potential limitations and addresses ethical considerations related to the study. Each of these subjects is covered in its own dedicated section.

2.1 Research Design

This study adopts a qualitative case study approach, focusing on the Kymenlaakso industrial cluster in Finland, a region of economic significance located between Helsinki and St. Petersburg. This methodology provides a detailed understanding of the complex aspects of industrial symbiosis in specific industrial settings. It serves as a tool to uncover opportunities, challenges and key factors essential for success in this area. The qualitative nature of the research enables an in-depth examination, gathering the views, stories and experiences of various stakeholders within the Kymenlaakso industrial environment. This approach goes beyond quantitative data, capturing personal narratives and identifying patterns that might not be immediately apparent.

The data for this study is gathered from current literature, statements from organizations and companies, academic papers, various documents related to the Kymenlaakso industrial area and the wider topic of industrial symbiosis and a survey conducted with companies in the Kymenlaakso industrial cluster. The aim is to understand the current state of industrial symbiosis in the cluster and explore potential improvements. Upcoming sections will detail the data collection methods. This data will be analyzed thematically, a qualitative method effective in identifying, examining and explaining recurring themes. This approach allows for the discovery of significant patterns and trends, providing a detailed picture of industrial symbiosis in Kymenlaakso. Using triangulation enhances the reliability of the findings, confirming insights and general perceptions through various data sources or methods. This study combines literary research with insights from different industrial symbiosis case studies and the perspectives of business representatives, offering a comprehensive view.

This research aims to provide clear, well-structured insights that respond directly to the main research questions, offering a detailed view of industrial symbiosis in the Kymenlaakso area. It delves into analyzing factors that either support or hinder the effective integration of industrial symbiosis, along with outlining possible opportunities and challenges. The methodology selected for this study is designed to enhance the academic understanding of industrial symbiosis, contributing to its role as a key component in advancing the circular economy.

2.1.1 Data Collection

This study primarily utilizes a qualitative case study approach, focusing on document analysis and regional perceptions on industrial symbiosis. The research centers on the Kymenlaakso industrial cluster, using existing sources for an in-depth perspective and various industrial symbiosis -focused industrial parks for comparison, complemented by a regional survey. This survey, conducted anonymously with scale-based responses from company representatives in the region, supplies current and pertinent additional data.

The research examines e.g., scholarly articles, research papers, news articles, company websites, statistics and insights from environmental studies to build a comprehensive understanding of industrial symbiosis, the circular economy and the specifics of the Kymenlaakso industrial cluster. This document analysis not only lays the groundwork for the study but also uncovers the subtleties of possible opportunities and challenges in the adoption of industrial symbiosis.

To gather up to date, practical insights on industrial symbiosis within the Kymenlaakso region, a survey targeting specific companies was conducted by the author. The survey was anonymous and directed at chosen representatives from various companies in the Kymenlaakso industrial cluster. The final percentage shares of each response option are presented in Figure 9 (p. 46). The benchmarking and general analysis of the results are presented in Chapter 5. A thorough analysis of question-specific answers and their relation to general perceptions is presented in Appendices 2 and 3.

2.1.2 Industry and Employee Selections for the Survey

In the Kymenlaakso region, key industrial sectors identified by Kymenlaakson liitto (2023a) include pulp and paper, chemicals, energy and construction, with the latter being one of the largest employers in the region, featuring numerous small businesses and a major glazing company, Lumon (2023). The survey encompassed these industries, along with transport and waste management due to their roles in material transfer and processing.

The survey targeted companies selected based on data from Kymenlaakson liitto (2023a-c), Yle (2022) and Finder (2023a-b), considering accessibility and practical factors. The survey aimed for a manageable size, focusing on six industrial fields with five companies each and one key employee per company. The goal was to receive up to 15 responses, as typically less than half of survey recipients respond (Vehkalahti 2014). Eventually, 18 participants finished the questionnaire, which is a successful participation rate.

Given the qualitative nature of the survey and potential overlaps in industrial fields and personnel roles, the correlation between variables and factors remained indeterminate. The survey seeked to capture subjective estimates of general perceptions, existing industrial interconnections and symbiotic networks in Kymenlaakso. For quantitative data and future projections, readers can turn to a comprehensive study by the Regional Council of Kymenlaakso and Ramboll Finland (Savikko et al. 2019).

Despite the integration of industrial symbiosis in Finnish companies, specific professions related to it are limited, mainly including scholars, statisticians, managers and engineers focusing on industrial symbiosis in national or large-scale organizations like Sitra (n.d.), FISS (2023) and Neste (2014). Selecting appropriate personnel for the survey within the Kymenlaakso region presented a challenge, primarily due to the diverse nature of company directories and a commitment to gender balance. The variability in the detail and accessibility of multinational company directories added to the complexity of pinpointing individuals linked to industrial symbiosis activities. To refine the selection, extensive reviews of various company websites and publications were conducted. The goal was to achieve a balanced representation of male and female participants. Preliminary contacts with

some companies were made to gather specific information about their personnel, contact details and job roles.

The final list of survey participants was carefully curated, focusing mainly on individuals in leadership roles across different industrial sectors. This choice was driven by the understanding that those in managerial positions are likely to have a comprehensive view of industrial symbiosis, including its concept, the regional industrial landscape and existing or potential collaborative networks. The selected recipients are listed below.

- In the forest, pulp and paper industry: EHS (environmental, health & safety) specialist, environment and quality manager, environmental manager, corporate customer advisor and managing director.
- Within the chemistry industry: project manager, CEO, general manager, HSEQ (health, safety, environment & quality) manager and refinery manager.
- For the energy industry: production manager, energy service manager, technical services manager, construction manager and procurement specialist.
- In the construction industry: CEO, construction engineer, chief building inspector and sales manager.
- In the transport sector: sustainability and development manager, sales manager, general manager, managing director and project manager.
- In the waste management sector: responsibility manager, environmental engineer, CEO, corporate governance operator and processing manager.

The emphasis on leadership roles was based on the assumption that these individuals are more likely to be involved in making broad policies related to industrial symbiosis. They are expected to have a clearer understanding of the concept, the industrial and market landscape of the area, the HR field and employee levels and actions within the company and the dynamics of cooperation networks. Operational-level employees, often more meritorious in specific jobs and directly engaged in material flows, technical issues, transport or everyday industrial processes, generally interact with the management or middle management regularly and contribute information about the practical aspects of resource exchange and industrial cooperation for those in corporate decision-making positions.

2.1.3 Formulation of the Questionnaire

The questionnaire was presented in Finnish and structured for online completion, ensuring that each question was on a separate page for clarity. The survey was hosted on Kyselynetti from December 3, 2023 to January 14, 2024 (Kyselynetti 2024). The questionnaire included a brief introduction, 25 questions with scale-based response options (0; 1-5) and an opportunity to add comments (a 3000 px text field). The respondents were asked to rate each question on a scale from 1 to 5, with 0 indicating “no response”. Each question had to be answered in order to proceed to the following questions and complete the questionnaire. A scale-based approach was chosen for its simplicity and effectiveness in capturing variable degrees of agreement or awareness. The questions are listed in Figure 8 (p. 46).

The questions were designed to collectively encompass the essence of the research topics, mirroring the interconnected nature of industrial symbiosis. Rather than targeting each research question directly, the survey aimed to weave a tapestry of overlapping thoughts and insights. This approach was chosen to enrich the study with practical, region-specific knowledge and exploratory insights, contributing to a deeper understanding of industrial symbiosis within the local context. The goal was to capture a snapshot of regional industrial perspectives, facilitating a comparison between local, national and international perceptions of industrial symbiosis, including its potential challenges and benefits.

Conducting the survey online was a strategic decision aimed at maintaining respondent anonymity and streamlining the process of distribution, completion and analysis. This method facilitated the efficient handling of the questionnaire, from its dispatch to the eventual deletion post-publication of the thesis. The results of the survey are presented in Chapter 5. In Appendices 2 and 3, the survey questions (Figure 8, p. 46) are analyzed one by one. Exploring these materials uncovers the dynamics of industrial symbiosis in the Kymenlaakso cluster. It reveals the current state of affairs, indicating areas that could benefit from improvement. The study also extends its scope, incorporating lessons from past experiences in industrial symbiosis. This broader perspective situates the Kymenlaakso findings within a larger context, identifying common patterns, obstacles and successes relevant to various industrial settings. By weaving together these different aspects of research, the study aims to present a comprehensive picture of industrial symbiosis in the

Kymenlaakso cluster. This detailed overview not only spotlights areas ripe for development but also sheds light on potential challenges that could shape its future trajectory.

2.1.4 Data Analysis Methods

This study focuses on two primary methodologies: document analysis and a regional survey. Based on the literary sources, document analysis, case study findings and the survey results, the data in this study will be subject to qualitative analysis. Wide-ranging qualitative analysis will reveal subtle patterns, emerging themes and crucial insights, enhancing the understanding of industrial symbiosis in the Kymenlaakso industrial cluster and supplementing the statistical, more quantitative research findings of e.g., Savikko et al. (2019). The qualitative research methodology is guided by the techniques outlined by Humble and Mozelius (2022). The focus on thematic analysis allows for an in-depth and structured examination of the qualitative data. This process involves several steps: familiarizing with the data, generating initial codes, identifying key themes, refining these themes, labeling them accurately and integrating them into a comprehensive report. This thorough and holistic approach is key to uncovering insights essential to the dynamics of industrial symbiosis in Kymenlaakso. It also helps identify potential opportunities, challenges and important factors for its effective implementation.

Moving forward, content analysis serves as a key qualitative tool. It examines textual data and identifies and interprets patterns in an objective manner. This method is particularly effective in understanding the content of documents and various information sources related to the Kymenlaakso industrial cluster and its integration with industrial symbiosis. Content analysis reveals the delicate, sometimes complex patterns and connections, highlighting the dynamics of industrial symbiosis in the cluster and suggesting areas for improvement. Using a comparative approach, as detailed in Chapter 4.5, the study compares findings from Kymenlaakso with those from other industrial symbiosis cases. This comparison helps identify commonalities and differences, deepening the understanding and drawing lessons applicable to Kymenlaakso.

Using the aforesaid qualitative methods and perspective thinking within the two primary methodologies: data analysis and online survey, the research aims to create a comprehensive

picture of industrial symbiosis in the Kymenlaakso cluster. This effort goes beyond answering the main research questions; it also contributes significantly to academic knowledge, highlighting the crucial importance of industrial symbiosis in fostering a circular economy.

2.2 Timeline of the Thesis

This section includes a visual timeline (Figure 1) that outlines the key stages of the thesis process, beginning with the initial planning in autumn 2023 and culminating in the publication in the spring of 2024. In reality, some work phases overlapped and required revisiting for proactive refinement, particularly in collecting topic-specific data and adjusting the structure and text: summarizing, removing repetitions, correcting the phrasing and spelling mistakes etc. The analysis of the online survey required review of previous findings and their comparison with the survey results. Supervision of the work was more frequent than shown in the timeline, as the kind and professional thesis supervisors offered guidance and support whenever necessary.

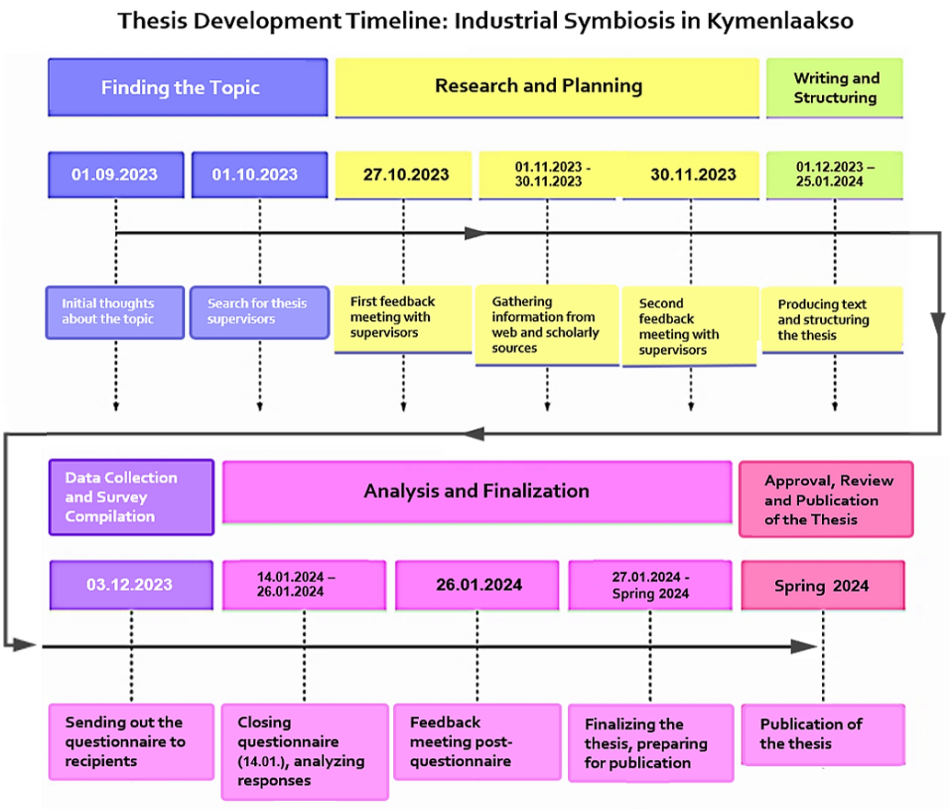

Figure 1. Visual Timeline of the Thesis Process (2023-2024)

2.3 Ethical Considerations

Maintaining the integrity and trustworthiness of this research is rooted in strictly following ethical standards and guidelines. Although the study primarily relies on secondary data, minimizing direct human interaction, it consequently lessens the focus on certain ethical principles like informed consent and privacy protection. However, there will be a strong commitment to properly credit all information sources, respecting the intellectual property of authors and their affiliated institutions. Throughout the research process, from data gathering to analysis, there is a continuous emphasis on transparency and impartiality. The aim is to minimize biases and strengthen the credibility of the findings. This thoroughness involves a detailed description of the research framework, data collection methods and analytical techniques used, while also highlighting possible limitations and sources of bias.

To enhance the trustworthiness and authenticity of this research, the study utilizes a solid research framework and thorough data examination methods, comparing information from a variety of data sources. Guided by the principle of non-maleficence, the study is committed to avoiding harm to individuals, organizations and the environment. This includes a strict policy against sharing misleading information and a strong commitment to maintaining the confidentiality of entities within the Kymenlaakso industrial cluster. Adhering firmly to these ethical guidelines, the study aims to contribute to the discussion on industrial symbiosis in Kymenlaakso with both responsibility and clarity. This approach not only strengthens the credibility of the research but also acts as a guiding light for those dedicated to advancing the circular economy.

3 Circular Economy and Industrial Symbiosis Concepts and Cases

Shifting from the conventional "take-make-dispose" model of economics, the circular economy introduces a different approach to resource management. This model is grounded in a crucial philosophy: using resources wisely to not only prolong their lifespan but also significantly minimize waste. Additionally, it emphasizes the importance of reclaiming and reintegrating used materials into the production and usage cycles, rather than discarding them. This strategy represents a commitment to sustainable practices that prioritize long-term advantages for both the economy and the environment over immediate profits. (Ellen McArthur Foundation, n.d.)

3.1 Circular Economy

Exploring the circular economy involves understanding key concepts that combine academic theory with practical applications.

- Closed-loop system: Central to the circular economy is the closed-loop system, mirroring natural ecosystems (European Commission 2020). It envisions a continuous cycle of materials within the economy, where one entity's waste becomes another's resource, promoting ecological conservation. (Kara et al. 2022.)
- Resource efficiency: A core principle of the circular economy is the efficient use of resources, aiming to reduce consumption. This involves not just minimizing waste but also avoiding the use of untapped resources. Achieving this efficiency requires improved designs, manufacturing processes and a culture of repair and refurbishment. (IGES 2023.)
- Waste as a resource: The circular economy transforms waste into valuable assets (Ellen McArthur Foundation n.a.). Through innovative technologies and business models, waste materials are repurposed into new products, reducing the need for new resources and lessening environmental impact (EPA 2023).
- Design for circularity: Design plays a crucial role in the circular economy, focusing on creating durable and recyclable products. This approach considers the entire lifecycle of

a product, aiming to reduce environmental impact while maintaining economic value. (Ellen McArthur Foundation n.d.)

- Business model innovation: Shifting to a circular economy requires creative business strategies that focus on reducing waste, enhancing economic sustainability and promoting conservation. Examples include product-as-a-service and shared platforms (Pieroni, McAloone & Pigosso 2019). These innovative models not only transform industries but also foster resilience and environmental awareness.
- Collaboration and stakeholder involvement: A successful circular transition involves collaboration across industries, governments and consumers (Nobre & Tavares 2021). These partnerships are crucial for shaping supportive legislation, infrastructure and market conditions. While the definition of a 'circular economy' can be ambiguous, leading to misunderstandings and superficial implementations (Ventura, Bortolini & Galicia 2023), its importance in combating climate change, biodiversity loss and pollution is clear, emphasizing the need for preservation and recycling (Ellen McArthur Foundation n.d.).

As this discussion unfolds, the circular economy is revealed as a beacon of optimism in the face of growing global challenges, guiding economic development towards sustainability. The following sections will focus on the intricacies of industrial symbiosis, a crucial element in the broader framework of the circular economy.

3.2 Industrial Symbiosis

Exploring the circular economy reveals a key concept: industrial symbiosis (Mirata & Emtairah 2005; Sitra n.d.). Similar to the exchange processes in natural ecosystems, it encourages collaboration among different businesses, seeking to transform one company's waste into a valuable resource for another, creating a complex network of resource sharing (Mallawaarachchi et al. 2020; Sitra n.d.). This thesis will delve into the workings and advantages of industrial symbiosis, highlighting its crucial role in the machinery of the circular economy.

In line with the principles of industrial symbiosis, the efficient use of resources is key (Ellen McArthur Foundation, n.d.). This approach enables organizations to exchange essentials like materials, energy or water, reducing the need for new resources and lessening environmental impact (Haq, Välisuo & Niemi 2021). Industrial symbiosis is more than a concept; it actualizes the idea of waste being repurposed, fitting perfectly with the circular economy's principles (European Commission 2020). From an economic perspective, it's not only about environmental benefits. Adopting these interconnected systems can lead to significant cost savings, improving a company's competitive position and financial stability (Henriques et al. 2021; Haq, Välisuo & Niemi 2021).

The path to achieving industrial symbiosis is filled with continuous innovation and technological advancements (Ventura et al. 2023). It calls for the development of cutting-edge technologies, fueling innovation and driving technical progress in various sectors (Ellen McArthur Foundation n.d.). This journey goes beyond technology, potentially creating new job opportunities, boosting economic growth and invigorating industries (Kwinana Industries Council 2023). At its heart, industrial symbiosis relies on collaboration between different industries, combining their strengths to enhance the circular economy model (Kalundborg Symbiosis 2023). Industrial symbiosis is more than a mere strategy: it is essential for shaping a circular economy, integrating efficient resource use with waste transformation, economic insight, innovative breakthroughs and strong partnerships. Focusing on the Kymenlaakso industrial area, adopting industrial symbiosis could be crucial in improving the region's environmental impact and competitive edge.

3.3 Material Exchange in Industrial Symbiosis

In industrial symbiosis, material exchange involves industries collaboratively sharing and reusing materials to enhance efficiency and reduce waste. This approach transforms by-products from one business into valuable resources for another, improving resource use and environmental sustainability (Somoza-Tornos, Graells & Espua 2017; Sitra n.d.). By exchanging waste, energy and raw materials, industrial symbiosis saves resources, cuts costs and reduces greenhouse gas emissions (Haq, Välisuo & Niemi 2017). It embodies the principles of circular economy, where resources are continually reused, maximizing their value and fostering a more sustainable, integrated industrial system (Somoza-Tornos,

Graells, & Espua 2017). In a recent study by Haq, Välisuo & Niemi (2021) a visual representation (Figure 2) showing the material exchange between a power plant, a combined heat and power plant and a biogas plant within an industrial symbiosis network, along with relevant formulas and calculations, is provided.

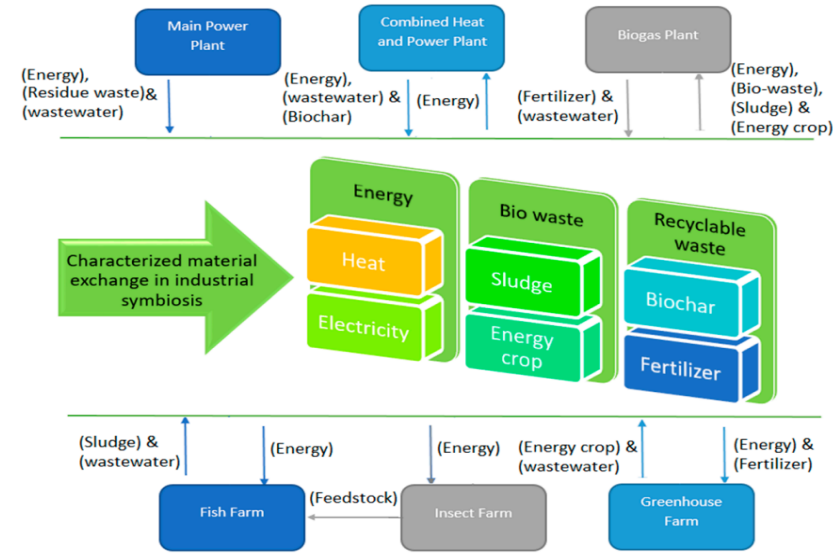

Figure 2. Material Exchange Identification in Industrial Symbiosis Network. (Haq, Välisuo & Niemi 2021)

The data in this study is organized by business sector, functional units and system boundaries, incorporating a cradle-to-gate approach. The model identifies and quantifies material exchanges and industrial symbiosis activities. For the industries involved, formulas are provided to calculate key factors like energy, water, raw materials, products, emissions, wastewater and solid waste. Economic assessments cover life cycle costs of materials, products and waste management, along with production costs, discount rates and unit costs. Environmental evaluations include estimating emissions of carbon dioxide, methane and nitrous oxide. Haq, Välisuo & Niemi (2021) also explore optimization strategies, focusing on waste heat recovery and reducing environmental impacts for cost efficiency. In industrial symbiosis, the life cycle costs related to production (LCC_{IS}) can be calculated using the following formula (Haq, Välisuo & Niemi 2021):

$$LCC_{IS} = \sum_{t=1}^{T} \sum_{a=1}^{n} \left(C_p (1+e)^{-1} \right)$$

, where Cp represents manufacturing costs, e is the discount rate (1.5%) and n is the number of participating industries. Production costs encompass expenses for input fuel, energy,

feedstock, raw materials and labor (Haq, Välisuo & Niemi 2021). Material exchange in industrial symbiosis not only leads to financial savings but also enhances environmental sustainability, making it a vital approach for businesses in the Kymenlaakso region and elsewhere.

3.4 Benefits, Challenges and Success Factors Within Industrial Symbiosis

In the context of the circular economy, industrial symbiosis stands out as a beneficial approach for businesses and their surrounding areas (European Commission 2020). However, this path is not without its challenges. This section explores the advantages, obstacles and critical factors that contribute to the success of industrial symbiosis.

Industrial symbiosis stands as a significant solution for environmental improvement. This approach greatly reduces the negative impact of industrial activities, especially in areas like waste reduction, greenhouse gas emission control and efficient use of vital resources such as water and energy (European Commission 2020; Ellen McArthur Foundation n.d.; Interreg 2020). Financially, it's not just about cost savings. By efficiently managing resources and recycling waste, companies improve their profitability, strengthen their market position and discover new growth opportunities (Kotkan Energia 2023; City of Kwinana 2023). This economic vitality extends to the broader regional economy, contributing to its resilience and development (Kymenlaakson liitto 2023b). Moreover, industrial symbiosis positively impacts society by creating jobs, enhancing skills and fostering community involvement. These benefits improve the quality of life and foster a sense of unity in areas that adopt industrial symbiosis (Benedetti 2017; City of Kawasaki 2023). These diverse advantages highlight the crucial role of industrial symbiosis in the journey towards sustainability. Economically, IS offers advantages such as cost reductions, increased resource efficiency and new business opportunities. Resource sharing among different sectors can lower infrastructure costs and strengthen market positions (Haq, Välisuo & Niemi 2021). A survey conducted by the author explores IS-related topics in the local corporate sector, aiming to provide insights into some of the potential benefits especially for the case study area.

The journey towards industrial symbiosis is like navigating a landscape filled with complex challenges. Central to these challenges is transforming waste into valuable resources, which

often requires cutting-edge technologies, new methods and strong infrastructure (Mallawaarachchi et al. 2020). The scale of this task can be overwhelming. Adding to the complexity are regulatory hurdles. Sometimes, existing waste management regulations can inadvertently hinder industrial symbiosis efforts (European Commission 2020). Overcoming these regulatory barriers is crucial for the successful implementation of symbiotic practices. However, the core of industrial symbiosis lies in human relationships. It thrives on collaboration and trust among a diverse group of stakeholders, including businesses, regulators and local communities. Establishing these connections, especially in the early stages, can be challenging (Henriques et al. 2021), but it is essential for the long-term success of these ventures.

For industrial symbiosis to reach its full potential, several key factors must align. Fundamental to this is a supportive policy environment that encourages resource efficiency, waste reduction and inter-industry collaboration (European Commission 2020; Ventura et al. 2023). However, policies alone are not enough. The exchange and accessibility of information are critical. Effective industrial symbiosis relies on stakeholders having access to information about resource flows, technological innovations and best practices (Haq, Välisuo, & Niemi 2021).

Local and regional networks play a vital role in this process. These connections facilitate not only the exchange of resources and knowledge but also build trust among the various participants in industrial symbiosis (Kymenlaakson liitto 2023b). Additionally, the leadership of ´champion organizations´ is crucial. Their commitment and vision can turn challenges into opportunities, driving the momentum of industrial symbiosis (Mirata & Emtairah 2005).

In summary, successfully navigating the complexities of industrial symbiosis requires a comprehensive approach. It involves recognizing its environmental, economic and social benefits, addressing technical and legal challenges and activating the drivers of success. For its part, this study aims to serve as a guide for successful industrial symbiosis implementation and initiatives within Kymenlaakso and other regions, seeking to find and present valuable information and tools of success while promoting resource efficiency, waste reduction and regional cooperation.

3.5 Industrial Symbiosis Case Examples

This chapter presents a series of Finnish and international industrial symbiosis cases, highlighting their key aspects, outcomes and insights. These examples illustrate the potential benefits, challenges and driving forces of industrial symbiosis in various settings, emphasizing its role in shaping a circular economy. They also illuminate the factors contributing to success in different environments. These stories could inform the development of industrial symbiosis initiatives in the Kymenlaakso industrial area, potentially enhancing the region's ecological balance and competitive strength.

3.5.1 Raahe, Finland

In 2019, Raahe, a town in northern Finland, witnessed a pioneering symbiotic project between SSAB's steel mill and a nearby cement factory. This collaboration led to significant energy savings and reduced greenhouse gas emissions by incorporating blast furnace slag from the steel mill into the cement factory's production process. This case from Raahe highlights how symbiotic agreements can significantly reduce energy use and carbon emissions - and demonstrates the benefits of repurposing industrial waste (Raahen Seutu 2019).

3.5.2 Nivalan Teollisuuskylä Oy, Finland

Nivalan Teollisuuskylä (Figure 3, p. 28), near Oulu in northern Finland, is an industrial park that exemplifies industrial symbiosis. Here, a steel fabricator supplies scrap metal to an on-site metal recycler. The park has established a platform for businesses to exchange resources, leading to substantial resource conservation and waste reduction. Collaborative groups like the FMT research group, Tera, Hybridi and ARVO are centered around Nivalan Teollisuuskylä, fostering sustainable and resilient innovations across sectors. This case underscores the effectiveness of well-organized industrial parks and resource-sharing platforms in promoting symbiosis (Nivalan Teollisuuskylä 2021).

3.5.3 Kalundborg Symbiosis, Denmark

Denmark's Kalundborg Symbiosis is a prime example of industrial symbiosis involving a power plant, refinery, pharmaceutical company and gypsum board mill. Their resource-sharing practices, including steam, water and waste products, have led to economic benefits and a reduced environmental footprint, marked by lower energy use and waste generation. This model shows that trust and long-term relationships, along with local advocacy, are crucial for such networks (Kalundborg Symbiosis 2023).

3.5.4 Kawasaki Eco-Town, Japan

Kawasaki Eco-Town in Japan aims to transform Kawasaki into an ecological hub, uniting businesses, research institutions and government bodies. Its focus on minimizing waste, enhancing recycling and promoting resource-sharing has yielded significant ecological and economic benefits. This initiative highlights the importance of supportive regulations and incentives and a holistic approach that integrates ecological, economic and social objectives (Kawasaki City 2023; Government of Japan 2020).

3.5.5 Landskrona Industrial Symbiosis Network, Sweden

In Sweden's Landskrona region, a diverse group of companies from various sectors participates in resource-sharing initiatives, including utilities and materials. This collaboration has led to efficient resource use, cost savings and improved environmental outcomes. Insights from Landskrona emphasize the contributions of SMEs (small and medium-sized companies) and the importance of regional networks and platforms for information exchange and collaboration (Benedetti 2017; Mirata & Emtairah 2005).

3.5.6 Kwinana Industrial Area (KIA), Western Australia

In Australia's Kwinana Industrial Area (Figure 4, p. 28), the Kwinana Industries Council launched the Kwinana Waste Initiative (KIWI), embracing circular economy principles. KIWI promotes waste resource repurposing and by-product exchanges among industrial giants, leading to environmental and economic benefits, including waste redirection,

greenhouse gas reduction and new commercial opportunities. Key takeaways include the importance of industrial collaboration, local government support and commitment to the circular economy (Kwinana City Council 2023; Kwinana Industries Council 2023).

3.5.7 The Baltic Industrial Symbiosis (BIS) Project

From 2019 to 2021, the BIS Project, supported by the ERDF (The European Regional Development Fund), aimed to promote industrial symbiosis, connecting over 150 businesses from the Baltic Sea region. The project involved resource allocation studies, matchmaking events, training sessions and tools for resource management. It raised awareness about industrial symbiosis and strengthened support structures, highlighting the value of industrial parks with symbiotic principles, public-private partnerships and supportive policies (Interreg 2020; Dansk Symbiosezentrum 2021).

3.5.8 Summary of Industrial Symbiosis Case Examples

This section featured a collection of different case studies on industrial symbiosis efforts, ranging from small-scale industrial parks to multinational cooperation platforms, concentrating on contexts ranging from Finland to other countries across the world. These examples are helpful references for eventual comparison with the primary case study region, the industrial cluster in Kymenlaakso. The comparison will be conducted in subchapter 4.8.

Two case example areas, Nivalan Teollisuuskylä in Finland and the Kwinana Industrial Area in Australia are depicted as aerial views on the following page (Figures 3 & 4).

Figure 3. Kurunpuhto area in Nivalan Teollisuuskylä. (NIHAK n.d.)

Figure 4. Kwinana Green Hydrogen Hub. (bp Australia/RenewEconomy 2020)

4 Case Study: The Kymenlaakso Industrial Cluster

This chapter focuses on Kymenlaakso, providing a comprehensive look at the region. It examines Kymenlaakso's economic structure and industrial setup to assess its compatibility with industrial symbiosis principles. The analysis includes resource flow dynamics, integrated processes and current technological trends in the region's industries, highlighting the potential for symbiosis. However, this potential is tempered by challenges and key factors crucial for practical implementation. The examination considers the regional industrial landscape, comparisons with other successful symbiosis models and specific challenges faced by Kymenlaakso. Additionally, the impact of geopolitical changes on the region's potential for industrial symbiosis is evaluated. The chapter concludes with a survey conducted in the case study area on industrial symbiosis-related topics, offering insights and interpretations of the results. This discussion aims to provide valuable perspectives and recommendations for enhancing sustainable and resource-efficient practices within the Kymenlaakso industrial cluster.

4.1 The Kymenlaakso Province

Kymenlaakso, located in southern Finland, is home to key cities like Kouvola and Kotka, as reported by Statistics Finland (2023a). The region, known for its economic strength in transportation and timber, spans from northern wilderness to southern archipelagos. Its strategic location between Helsinki and St. Petersburg, along with robust industrial and port facilities, drives its growth (Kymenlaakson liitto 2023b-d). For a detailed geographical overview, see Appendix 1. Kymenlaakso's significance extends beyond its size, with a population of 161 391 in 2021 and 59 628 job openings in 2020 (Statistics Finland 2023a). The region's strategic position, infrastructure and skilled workforce make it a key industrial hub in Finland (Kymenlaakson liitto 2023a).

Recent geopolitical turmoil, including the Russia-Ukraine conflict, has impacted the region. Local businesses have faced economic challenges in 2023, as reported by Yle (2023a). Finland's alignment with NATO and sanctions on Russia have further complicated the situation, leading to a 40.1% drop in Finnish exports to Russia in the first three quarters of

2022 (Kymenlaakson liitto 2023e). These changes have forced regional companies to reassess their Russian ties.

4.2 Kymenlaakso in Terms of Industry and Business Operations

Kymenlaakso's industrial landscape features key sectors like forestry, which thrives on Finland's timber resources (Finder 2023a). The pulp and paper industry, derived from wood, has been a historical economic pillar (Suomen Pakkausyhdistys 2022). The region also hosts several paper mills and chemical producers (Business Kotka-Hamina 2023). Renewable energy sources, including hydropower (Pohjolan Voima 2023) and bioenergy from timber activities (Metsäkeskus 2023), contribute to Finland's energy mix. Kymenlaakso's geographical advantage has also made it a logistics hub (Kymenlaakson liitto 2023d).

A 2022 study by Kinno focused on the business climate in Kymenlaakso, particularly in Kotka. The study revealed concerns about the Ukraine war's impact, labor shortages, rising energy costs and financial challenges despite reasonably healthy order books. (Kouvola Innovation Oy 2022.) These factors, along with recent geopolitical and economic changes, may influence the region's industrial symbiosis prospects, as successful symbiosis relies on stable supply chains and trade collaborations (Henriques et al. 2021).

4.2.1 Forest Industry and Pulp & Paper Sector

In the Kymenlaakso industrial cluster, the forest industry and pulp and paper sector are still prominent despite recent difficulties, featuring major companies like UPM Kymi, Kotkamills, Stora Enso – which shut down its second paper mill in Anjalankoski due to unprofitability in November 2023 (Yle 2023c) and is also closing down its pulp mill in Sunila, Kotka (Yle 2023f) – and Versowood. These companies are significant consumers of resources, especially wood fiber, water and energy. They are also dedicated to minimizing their environmental footprint, employing advanced technologies in their operations. The region has a long-standing history, over 150 years, in fiber-based product manufacturing, which is currently evolving with a focus on higher-value products such as cardboard (Suomen Pakkausyhdistys ry 2022). The Ukraine crisis has raised concerns about gas supply disruptions, affecting key manufacturing processes in the region. Despite these challenges,

there are ongoing efforts to enhance operational efficiency. For instance, Metsähallitus, a state-owned enterprise, is actively exploring ways to reduce emissions from timber transportation, considering alternative methods like traditional timber rafting or log floating (Helsingin Sanomat 2023; Tekniikka ja Talous 2023).

4.2.2 Chemical Industry

Kymenlaakso's chemical industry comprises a range of companies producing diverse products from fertilizers to specialized chemicals. Key players, such as Teollisuuskemia Oy Ab and Kemira Chemicals Oy, play a vital role in the region's economic landscape (Finder 2023; Kotka-Hamina Business 2023). These companies extensively use energy, water and raw materials in their operations, leading to the production of considerable solid and liquid waste which is often not suitable as a raw material for further production or for recycling, but requires careful management and considerable post-processing, thus hindering the implementation of industrial symbiosis practices (Yang et al. 2022). However, it's important to highlight that the sector is actively implementing modern practices. These include closed-loop systems, the use of sustainable energy and waste recovery methods, all aimed at enhancing resource efficiency and reducing environmental impact (Kemira 2016; IEA 2023).

4.2.3 Energy Sector

Kymenlaakso's energy sector is diverse, featuring a range of power generation facilities that utilize hydropower, biomass and natural gas, among other sources. The region's energy landscape includes prominent companies like Neste Oyj (2014). These extensive energy operations require significant amounts of resources, particularly fuels and water, leading to by-products such as ash and flue gas emissions. However, these companies are committed to using advanced methods like combined heat and power systems and integrating sustainable energy technologies. These practices aim to improve output efficiency and reduce environmental impact (Kotkan Energia 2023; Kymenlaakson liitto 2023c; Pohjolan Voima 2023). Figure 5 presents the CO2 emissions of Kymin Voima from 2018 to 2022. The recent increase in emissions may be linked to the post-pandemic period and a rise in

electricity consumption. While household electricity use has decreased, the overall demand has increased, driven by higher industrial needs and public space heating (Elomaa 2022).

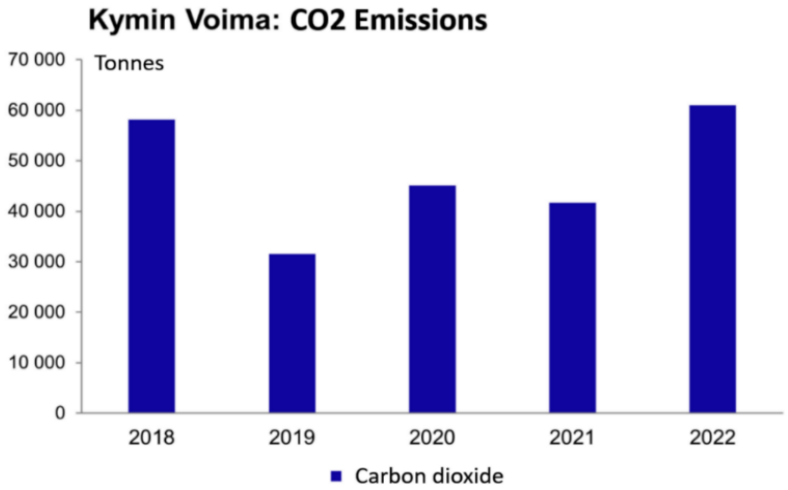

Figure 5. Carbon Dioxide Emissions of Kymin Voima in 2018-2022. (Pohjolan Voima 2023)

4.2.4 Logistics and Transport

Kymenlaakso is well-equipped in logistics and transport, featuring key infrastructures like the Port of HaminaKotka and Kouvola's railway hub. The logistics and transport sector in the region employs around 5 000 people, as reported by Kymenlaakson liitto (2023d). Leading companies in this field, including Steveco (n.d.) and CMA CGM Finland (2023), significantly contribute to the local economy. The operations of this sector require substantial use of resources, especially fuel and energy, which results in emissions and waste. However, there is a growing commitment within the sector to adopt more sustainable practices. Innovations such as intelligent transportation systems and fuel-efficient vehicles are being implemented to enhance operational efficiency and reduce environmental impact (Kymenlaakson liitto 2023d). Figure 6 (p. 33) shows and aerial view of the Port of HaminaKotka on Mussalo island in Kymenlaakso. Most of Finland's export and transit containers are processed in this container terminal. The port has an annual capacity of 1,5 million TEU units (20 ft containers), giving numerous opportunities for the introduction of industrial symbiosis principles in e.g., various stages of procurement or joint procurement, processing, goods transport and waste management (Port of HaminaKotka 2024).

Figure 6. Port of HaminaKotka. (Logistiikan Maailma 2024)

4.2.5 Construction Industry

Kymenlaakson liitto (2023d) states that the construction industry employs about 4 000 people in the target area. This industrial sector is firmly tied to economic cycles. A 1-3% growth was predicted for 2022 and a decrease for 2023. Repair construction was set to grow steadily by a few percent in the coming years, while land and water construction was predicted to show slight increase in 2022, followed by a decrease. According to Statistics Finland (2023b), the number of construction permits rose slightly in Kymenlaakso in 2023 despite a general 17% decrease in the national construction market figures. Challenges include raw material costs and availability, with potential for increased repair construction due to EU regulations. (Kymenlaakson liitto 2023d).

The REUSE project, led by South-Eastern Finland University of Applied Sciences XAMK in Kouvola and Kymenlaakson liitto, investigated reusing construction materials in Kymenlaakso during 2018-2020. The project faced hurdles due to the lack of standard methods. It proved reuse is viable with motivation and proper planning, supporting waste prevention and circular economy principles. Key strategies included early material

identification, digital platforms for material trade and local collaboration, highlighting the importance of addressing reuse challenges and leveraging incentives for sustainable construction. (Maunula, Ahola & Räty 2020; XAMK n.d.)

4.2.6 Waste Sector

The waste management in Kymenlaakso is operated by several companies, such as Kymenlaakso Jäte Oy (2024a), its subsidiary Ekokaari Oy (2024), Remeo (n.d.) and Lassila & Tikanoja (2019), all implementing company-specific procedures in accordance with national waste legislation (Finlex 2011). In industrial symbiosis, waste management plays a crucial role in the transport and handling of processed material and resource flows. Regional projects, such as the agroecological symbiosis project "Kymenlaakson agroekologinen symbioosi" in 2019-2020 by XAMK, are conducted in collaboration with regional stakeholders, such as waste management companies. The agroecological symbiosis project aimed to develop new business models for primary and food production, enhance material flow utilization and reduce agricultural emissions by combining side stream utilization with renewable energy. The local waste management companies have a long history in collaborating with local energy and forest, pulp and paper companies (Kotkan Energia n.d.; Hämäläinen 2005) and the chemical industry (Kymenlaakson Jäte 2024b), thus aiming to enable waste utilization or potential final disposal of all types of waste fractions – metal scrap, sludge, pulp, toxic waste etc. – in an optimal way.

4.3 Resource Flows, Processes and Technologies Involved

Industrial symbiosis represents a complex and dynamic network where resources, materials and energy are exchanged among various enterprises and organizations within a specific geographical region. Identifying and utilizing material exchange opportunities, energy and by-products is crucial for its development. An exemplary study by Ismail (2020) presents a Life Cycle Assessment (LCA) for the Hyundai industrial complex, demonstrating LCA's utility in measuring environmental impacts and identifying potential synergies. An analysis like this will help pinpoint potential opportunities for industrial symbiosis and understand the challenges and key factors for successful implementation. Figure 7 (p. 35) illustrates Ismail's LCA flow chart for the manufacturing of automobile clutch covers. It specifically

highlights waste material (Scrap) and emissions (CO2) that are suitable for industrial symbiosis, marked in red.

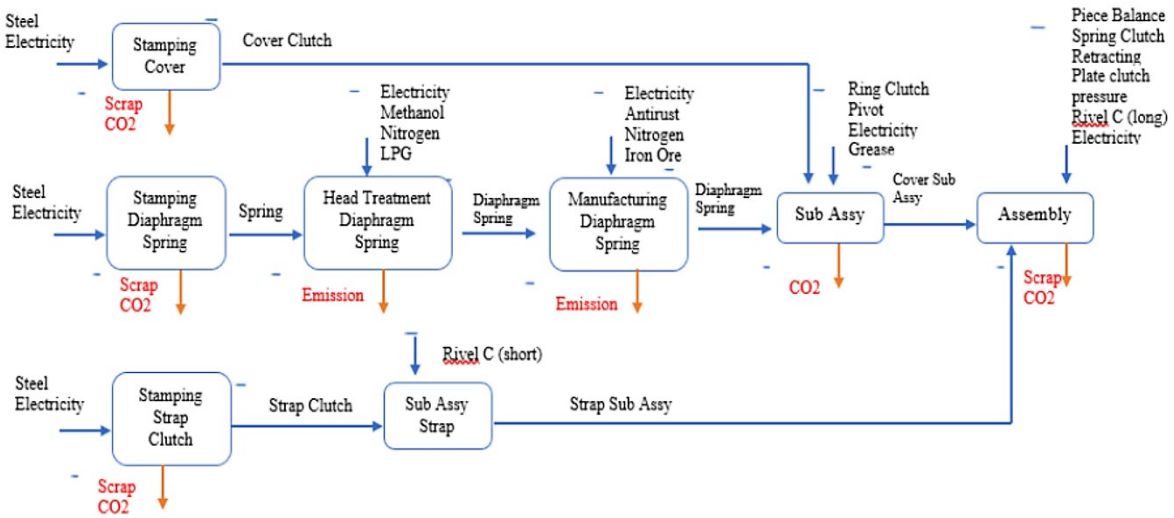

Figure 7. Input and Output of Clutch Cover Model 380A-8.5 Production. (Ismail 2020)

For any major industrial process in the Kymenlaakso industrial cluster, a similar thorough examination would be essential. The resource flows, processes and technologies in the Kymenlaakso industrial cluster are tightly interwoven, mirroring the compact industrial setting of the region. The close proximity of businesses in this area suggests a reduced necessity for specialized industrial parks or hubs focused on industrial symbiosis. This proximity could lead to cost savings during both the implementation phase and ongoing operations involving resource exchange or material transportation.

Previous studies by Sousa & Ometto (2011) and Graedel (1998) indicate that while emission or resource-based calculations are adequate for assessing physical fluxes like materials, energy, water and by-products, life cycle assessment (LCA) is crucial for evaluating non-physical flows. LCA's importance is particularly evident in service industries where dematerialization impacts the environment indirectly. LCA enables the analysis of intangible flows within industrial symbiosis, aligning with the trend of creating value through services rather than solely through physical products. This approach is vital in understanding the full scope of industrial symbiosis, especially in regions like Kymenlaakso where service industries play a significant role.

4.4 Enabling Factors and Barriers

Industrial symbiosis is centered on reciprocal exchanges of resources, materials and energy among diverse sectors within a specific geographical area. Understanding the facilitative factors and potential obstacles in Kymenlaakso's industrial landscape is crucial for identifying the possible benefits and challenges of industrial symbiosis. The findings and results related to this subject area are compiled in this section.

The proximity of enterprises, as highlighted by Mallawaarachchi et al. (2020), is a key driver for cooperation and resource sharing. In Kymenlaakso, businesses are advantageously positioned near each other and close to the capital region, with potential future trade opportunities with Russia. This proximity facilitates material exchanges, reduces logistical costs and encourages shared infrastructure use. Kymenlaakso's diverse industrial sectors, ranging from pulp and paper to forestry, energy, chemical production and logistics (Kymenlaakson liitto 2023a; Finder 2023a-b), align with Henriques et al´s (2021) emphasis on sectorial diversity for industrial symbiosis (IS). This variety increases the likelihood of mutualistic relationships and resource sharing.

Luhas et al. (2022) explored the circular bioeconomy, linking economic, ecological and fiscal aspects. Their findings support the use of diverse models for strategic decision-making. Kymenlaakso's vibrant knowledge-sharing culture, supported by academic institutions, industrial entities and national platforms like FISS (2023), is crucial for industrial symbiosis. This intellectual environment, as also noted by Haq, Välisuo & Niemi (2021), fosters effective communication and innovative thinking. Supportive policies focused on sustainability and the circular economy (Kestävä Kehitys 2023; Suomen YK-Liitto 2023; Valtioneuvosto 2022; FISS 2023; Kymenlaakso 2023) further encourage industrial symbiosis initiatives. These policies reflect Kymenlaakso's commitment to green practices and align with the European Commission's (2020) goal of promoting waste-free and circular economies across various sectors.

Competitive market dynamics and organizational barriers can impede industrial symbiosis in Kymenlaakso. The presence of multinational firms, such as Dongwha Finland (2023), noted by Yle (2023b), may limit knowledge sharing due to trade secret protection and

differing operational cultures. Henriques et al. (2021) identify economic challenges, such as insufficient financial incentives and limited investment resources, as significant obstacles to adopting industrial symbiosis. Regulatory constraints, particularly in the chemical and food sectors (Finlex 2015; Finlex 2021), can restrict the movement of certain materials and sharing of infrastructure, a concern echoed by the European Commission (2020).

Differences in organizational culture and a lack of trust between industries, as discussed in Kouvolan Sanomat (2020) and in the results of the online survey, are major barriers to effective industrial collaboration. These issues can hinder cooperation and limit resource exchange (Henriques et al. 2021). Additionally, companies may struggle to adopt new business strategies that facilitate industrial symbiosis, which involves increased collaboration and addresses social and ecological challenges (Talouselämä 2016). Currently, operator-specific, technically driven approaches that prevail (Levänen, Hossain & Wierenga 2022) may be more common also in the Kymenlaakso region.

Statistics Finland (2023a) reports that approximately 21-22% of jobs in Kotka and Kouvola – the two largest cities in Kymenlaakso – are linked to the auxiliary industry. Notably, 84% of the region's workforce is employed within their local municipalities, with a significant portion (74–77%) working in the service sector. Unemployment rates in these areas range between 12 and 15%. Since the local labor force is focused on service industries, the availability of technically qualified employees may to some extent hinder the adoption of certain industrial symbiosis -related practices. Table 1 (p. 38) provides a summary of the key factors that either promote or hinder the implementation of industrial symbiosis in the Kymenlaakso industrial cluster, compiling the results of this analysis.

Table 1. Industrial Symbiosis in Kymenlaakso: Enabling Factors and Barriers

Enabling Factors	**References**
Geographic Proximity: The Kymenlaakso Province benefits from its compact size and its proximity to the capital. This closeness potentially simplifies resource sharing among businesses. Additionally, there's optimism regarding the revival of business partnerships with Russia, contingent upon peace restoration after the Russia-Ukraine conflict**.**	Mallawaarachchi et al. (2020), Kymenlaakson liitto (2023a), Finder (2023a-b)
Diverse Industrial Landscape: Kymenlaakso boasts a mix of sectors, from forestry and pulp production to chemicals, energy and logistics. Such diversity elevates the chances of cross-sectoral collaborations, creating avenues for resource optimization.	Kymenlaakson liitto (2023a), Henriques et al. (2021)
Culture of Collaboration and Innovation: The region thrives on a culture that prioritizes knowledge exchange. This is nurtured by academic entities, industry associations and a nation-wide platform dedicated to industrial symbiosis. Such a milieu not only fosters innovation but also guides informed choices.	Luhas & al. (2022), Sokka, Lehtoranta & Melanen (2011), Xamk (2023), City of Kouvola (2022), FISS (2023), Haq, Välisuo and Niemi (2021)
Supportive Governance and Initiatives: The policy landscape of Kymenlaakso resonates well with national directives advocating for sustainable practices and circular economic principles, underpinning the significance of industrial symbiosis. Several state- and/or business-led support activities (national and regional) promote industrial symbiosis.	Kestävä Kehitys (2023), Suomen YK-Liitto (2023), Valtioneuvosto (2022), FISS (2023), Kymenlaakso (2023), European Commission (2020), Tallinen & Laine (2022)
Barriers	
Market Dynamics and Distrust: Intense rivalry, the influx of overseas corporations and inherent trust challenges can form impediments. Such dynamics might delineate boundaries, hampering the flow of information and cooperative initiatives. Economic adversities, whether tied to insufficient funds or resource scarcity, can also impede collaborations. Potential shortage of skilled workers on the labor market.	Kauppalehti (2020), Kouvolan Sanomat (2020), Henriques et al. (2021), Dongwha Finland (2023), Yle (2023b), Statistics Finland (2023a)
Legislative Constraints: Rigorous regulations, especially concerning areas like chemicals and edibles, might pose challenges in streamlining material sharing, potentially affecting the operational framework.	Finlex (2015, 2021), European Commission (2020)
Strategic Hurdles: Embracing novel strategies, which seamlessly embed collaboration and eco-consciousness, might be an uphill task. Presently, a majority of strategies remain tethered to singular entities with a pronounced tilt towards technological aspects.	Talouselämä (2016), Levänen, Hossain & Wierenga (2022)

4.5 Resource Savings, Waste Reduction and Organizational Cooperation

Exploring the Kymenlaakso industrial cluster reveals that adopting industrial symbiosis (IS) could significantly enhance resource efficiency and environmental benefits. This section draws on international, national and regional insights to highlight the potential gains in resource conservation and environmental improvement achievable through IS in the cluster.

As stated in chapter key feature of IS is its ability to reduce resource consumption. For example, energy and water management becomes more efficient, with energy recovery processes reducing reliance on fossil fuels and lowering greenhouse gas emissions (Benedetti 2017). Material exchanges, such as the transfer of wood waste and recycled paper between the pulp-paper and forestry sectors, exemplify the efficient use of resources and waste reduction (Business Kotka-Hamina 2023). IS also promotes material regeneration and cyclic usage, leading to decreased waste volumes. Wastewater exchange between industries, for instance, can enhance fertilizer production while reducing the need for artificial fertilizers, lessening the environmental impact of agricultural activities (Dansk Symbiosecenter 2021). The exchange of by-products like sawdust between forestry and energy sectors is recognized for reducing waste and maximizing resource use (Metsäkeskus 2023). The study "Kymenlaakson bio- ja kiertotalouden tiekartta 2025 – uudet tuulet" by Tallinen & Laine (2022) updates the original roadmap for Kymenlaakso's bioeconomy for 2025. This document – part of the regional "Biotalouden uudet tuulet" project, focusing on reforms in bioeconomics, reflects the region's dedication to low-carbon and carbon-neutral development through bio- and circular economy practices. It compiles inputs from various stakeholders, including businesses, municipalities, educational institutions and the Regional Council of Kymenlaakso and is supported by the European Union. The roadmap underscores the importance of cross-sector collaboration for sustainable growth in Kymenlaakso. According to Tallinen & Laine (2022), several organizations in Kymenlaakso have been actively promoting circular economy practices. These include:

- Cursor Oy: A development company for the Kotka-Hamina region, involved in business advisory services and development projects.
- ELY-Centre (Centre for Economic Development, Transport and the Environment): Provides funding, grants and support for various initiatives, including those related to the circular economy.
- City of Hamina: Implemented e.g., the "Ecological Hamina" program in 2019-2022, focusing on sustainable development.
- Hiilineutraali Kymenlaakso (Carbon Neutral Kymenlaakso): An initiative by the Regional Council of Kymenlaakso aimed at achieving carbon neutrality in the region.

- RIS3 – Bio and Circular Economy Expert Group: A group of experts from business, education, research and development organizations, focusing on regional collaboration in bio and circular economy matters.
- FISS – Industrial Symbioses in Finland: A network promoting industrial symbiosis, which is a key aspect of the circular economy.
- Hyötyvirta Business Area and Hyötyvirta Association: Focused on solutions related to renewable materials, material reuse and energy efficiency.
- Kinno (Kouvola Innovation Oy) Circular Economy Services Team: Works on developing the Hyötyvirta collaboration platform and ecosystem, coordinating with businesses, educational institutions and other stakeholders.
- CircPro Project: An international project aimed at integrating circular economy procurements into regional strategic goals, including a guide for planning and implementing circular economy procurements.

The list above forms a compilation of practical networking and cooperative organizations for local companies. Tallinen & Laine (2022) mention, that FISS's activities in Kymenlaakso are coordinated and executed by the regional operator Kinno (Kouvola Innovation Oy).

4.6 Comparison with Other Industrial Symbiosis Cases

This section examines various global and Finnish examples of industrial symbiosis that more or less resemble Kymenlaakso's situation. The Kymenlaakso industrial cluster can gain valuable insights from the successes of other industrial symbiosis cases, as discussed in sections 2.2.2 and 3.5.8 and mentioned formerly in this chapter. Comparing Kymenlaakso with rather similar industrial setups and varied geographical locations offers valuable perspectives and clarifies the distinctive operational readiness or implementation atmosphere of the case study area.

In Finland, Raahe and Nivalan Teollisuuskylä demonstrate effective industrial symbiosis through exchanges like waste heat and materials between businesses. These examples, detailed in reports by Nivalan Teollisuuskylä (2021) and Raahen Seutu (2019), show reduced resource usage, milder environmental impacts and improved industrial competitiveness.

Kymenlaakso's heavy industries and energy producers share similarities with these Finnish cases.

Denmark's Kalundborg is a well-known example of industrial symbiosis, focusing on resource exchanges among various industries and the community, leading to significant ecological and economic benefits (Kalundborg Symbiosis 2023). Despite differences, Kymenlaakso and Kalundborg share potential for inter-industry collaboration.

Kawasaki, Japan, presents another model of industrial symbiosis, emphasizing exchanges among industries like steel and petrochemicals (City of Kawasaki 2023). This approach results in resource conservation and environmental benefits. Kymenlaakso's industrial landscape, with its focus on heavy industries and energy, is similar to Kawasaki's.

Australia's Kwinana Industrial Area and the Baltic Industrial Symbiosis (BIS) Project have successfully integrated industrial symbiosis, leading to ecological and economic improvements (Kwinana 2023; Interreg 2020; Kwinana Industries Council 2023). While Kwinana focuses on heavy industry, Kymenlaakso has a more diverse industrial base. The BIS Project's broader scope also highlights Kymenlaakso's unique position.

Kymenlaakso has its own potential for resource circulation and symbiotic interactions, distinct from other clusters. However, it faces unique challenges and opportunities, including geopolitical changes like the Russia-Ukraine conflict and Finland's NATO membership (CFR 2023; Yle 2022).

Comparing Kymenlaakso with other industrial symbiosis examples underscores the importance of collaboration, learning and innovation. Learning from these cases can help Kymenlaakso identify its symbiotic potential and specific challenges.

5 Results

In previous chapters, the case study area, the Kymenlaakso industrial cluster, has been studied in terms of e.g., location, population and industrial sectors, compared to national and international case areas and assessed in relation to general perceptions and findings regarding industrial symbiosis. In this chapter, detailed interpretations of the research outcomes will be given. The results are based on previous insights and the survey results, forming a holistic overview.

5.1 Analysis of Industrial Symbiosis Opportunities & Challenges

Table 2 highlights the diverse benefits of industrial symbiosis. Industrial symbiosis demonstrates its capacity to conserve resources and enhance the environment across various regions, with the potential to stimulate economic growth.

Table 2. Summary of Industrial Symbiosis -Enabled Resource Savings, Environmental Advantages and Economical Benefits

Findings	**References**
Conservation of Resources	
Streamlining materials, along with the vital elements of energy and water.	Benedetti (2017)
Waste heat interchange reduces reliance on fossil fuels.	Dansk Symbiosecenter (2021)
Engaging in material exchanges decreases excess waste production.	Savikko et al. (2019)
Mitigating Waste Production	
Advocacy and actualization of material reuse and recycling practices.	Dansk Symbiosecenter (2021)
Implementation of inter-industry wastewater alternation.	Kalundborg Symbiosis (2023)
Solid waste swaps work effectively to minimize waste generation.	Metsäkeskus (2023)
Environmental benefits	
Attenuation in the emission of greenhouse gases.	Ellen McArthur Foundation (n.d.)
Augmentation of both air and water quality.	
Fostering a rich biodiversity.	
Economic benefits	
Leading to cost reductions.	Haq, Välisuo & Niemi (2021)
Amplifying the efficiency of resource utilization.	
Enabling new business opportunities.	

According to the study, the Kymenlaakso area offers significant potential for industrial symbiosis with its varied and interconnected industries. However, the ongoing conflict between Russia and Ukraine, along with economic and mobility restrictions, poses challenges to these symbiotic ambitions.

5.2 Implications of Circular Economy in Industrial Symbiosis

The findings of this study highlight the thematic uniformity and importance of circular economy approaches in industrial symbiosis, particularly in the Kymenlaakso region. When exploring the concept of industrial symbiosis, it becomes clear that building connections across different industries and stakeholders is essential (Haq, Välisuo & Niemi 2021). It's also crucial for circular economy -related incentives, programs and operations to create an environment that fosters mutual learning and collaboration among diverse participants. Interestingly, a significant challenge identified here is the lack of awareness (Mallawaarachchi et al. 2020; online survey). Efforts should not only focus on spreading the word but also on promoting a deeper understanding through tailored educational initiatives that emphasize the multifaceted benefits of industrial symbiosis. Another aspect that shouldn't be overlooked is the importance of innovative thinking. Breakthroughs in industrial symbiosis often coincide with innovative ideas (Ventura et al. 2023). By promoting research and the development of cutting-edge technologies and entrepreneurial frameworks that support industrial symbiosis, the future looks brighter. Additionally, attention has to be paid to policy landscapes (European Commission 2020). Advocating for supportive regulations, such as fiscal incentives, tax benefits and assistance, can potentially promote both circular economy and industrial symbiosis – one of its important implementations. Success stories in this field should not only be celebrated but also serve as models for broader adoption (Benedetti 2017). Businesses also have a role to play. Integrating local knowledge into core operations can help mitigate societal tensions and operational challenges. Interestingly, sustainable gains appear to be more closely linked to business strategies than mere technological upgrades. To achieve meaningful sustainability benefits, circular economy plans must incorporate societal considerations alongside operational details within business strategies (Levänen, Hossain & Wierenga 2022). Table 3 presents a summary.

Table 3. Summary of Implications of Circular Economy in Industrial Symbiosis

Implications of Circular Economy	Descriptions	References
Building Industry Alliances	The success of industrial symbiosis hinges on the cooperation of varied sectors. This calls for genuine collaboration and mutual insights.	Haq, Välisuo & Niemi (2021)
Enhancing General Understanding	Informational gaps can be detrimental. Addressing these through targeted educational endeavors can clarify the way forward.	Mallawaarachchi et al. (2020); Savikko et al. (2019)
Cultivating Fresh Ideas	Adapting to innovative concepts, particularly in technology and evolving business methods, is of utmost importance in the arena of industrial symbiosis.	Ventura et al. (2023)
Adapting Supportive Measures	An environment enriched by advantageous rules and financial boosts can greatly aid the forward momentum of industrial symbiosis.	European Commission (2020)
Highlighting Exemplary Endeavors	Showcasing projects that lean heavily on sustainability provides a reference point for others, encouraging a ripple effect of positive change.	Benedetti (2017); Mirata & Emtairah (2005); Levänen, Hossain & Wierenga (2022)

5.3 Economic and Social Implications

The Kymenlaakso region is at a pivotal point, with the potential for significant economic and social benefits through industrial symbiosis. This shift suggests improved resource efficiency, reduced environmental impact and enhanced industrial capability. Economically, Kymenlaakso could experience substantial gains. Focusing on resource-sharing and collective sustainability efforts may lead to cost savings, enhanced resource management and new business opportunities. The small geographical scale and selection of various industries in the province offers potential for effortless collaboration among businesses, diminishing the need to invest in specific industrial parks focused on industrial symbiosis. This perspective aligns with insights from Haq, Välisuo & Niemi (2021) and Henriques et al. (2021), who highlight the secondary benefits of decreased infrastructure costs and increased economic dynamism. For instance, local businesses could save significantly by avoiding new infrastructure investments. Finnsementti's initiative in Raahe (Raahen Seutu 2019) exemplifies this, using SSAB's blast furnace slag waste, thereby adopting industrial symbiosis principles. This move reduces CO2 emissions and supports environmental goals. Companies like MM Kotkamills and Sulzer Pumps Finland Oy have shown economic resilience through such innovative approaches.

Socially, industrial symbiosis could transform Kymenlaakso's community landscape. It promises to enhance sustainability awareness, community development and stronger social connections. This approach aligns with broader sustainability goals (Mirata and Emtairah 2005; Mallawaarachchi et al. 2020). It aims to create more robust, environmentally aware communities. Collaborative ecological efforts by industries can lead to cleaner environments, including air and water quality improvements – following the principles of a circular economy which emphasizes responsible use of resources and minimal environmental harm (Ellen McArthur Foundation n.d.). Socially, the collaboration fostered by industrial symbiosis can strengthen community bonds. The Baltic Industrial Symbiosis project illustrates this collaborative spirit (Dansk Symbiosecenter 2021). According to ILO (2022), IS creates jobs and has a positive impact on job retention, but duties may be subject to change.

5.4 Survey Analysis

This part addresses the results of the survey, targeted at local businesses. A link to the anonymous online survey was sent to 30 recipients from six fields of industry, yielding 18 completed questionnaires (25 questions) – 450 answers in total with an average answering time of 8 minutes (mean value of 16 respondents with two outliers excluded). The timestamps (Appendix 5) reveal that most answers were given within the six first days after opening, indicating that in similar conditions (anonymous local multi-question online survey with numerical multiple-choice answers), one week might suffice for duration.

The 18 completed questionnaires are analyzed predominantly at an indicative, qualitative level and in relation to other information and findings discussed in the thesis and in terms of the general consensus; national or regional perceptions regarding specific question topics. Thus, benchmarking and comparative analysis are used as qualitative data analysis methods. Due to the numerical quality (0, 1-5) of the answers, the percentages are discussed to obtain an indicative quantitative ratio for selected answers, e.g., answers with strong uniformity or notable difference. The questions are shown in Figure 8 (p. 46) and a bar chart with response percentages in Figure 9. The summary of a more detailed analysis, addressing answers one by one, is presented in Appendix 2. The complete analysis is conducted in Appendix 3.

1. How well do you think the concept of industrial symbiosis is known in your company?
2. How often does your company organize orientation or training programs for employees related to industrial symbiosis?
3. Do you know if pooling or exchange of resource flows happens between your company and other companies in Kymenlaakso or its vicinity – and if so, to what extent?
4. To what extent do you think the current waste management practices in Kymenlaakso serve the promotion of industrial symbiosis?
5. How do you think the operations of your company serve industrial symbiosis as a whole?
6. Do you think the operation of companies in Kymenlaakso is generally open and transparent regarding material procurement and resource flows?
7. How do you feel that general domestic regulation, legislation and local politics serve and promote industrial symbiosis in the Kymenlaakso region?
8. How much do you feel specifically industrial symbiosis -related national or local actors and organizations, knowledge banks, programs and initiatives support the implementation or promotion of industrial symbiosis in Kymenlaakso?
9. Do you feel that national or municipal investment subsidies or tax benefits are important in promoting industrial symbiosis?
10. Do you believe that industrial symbiosis enhances the profitability of companies in Kymenlaakso?
11. Do you believe that industrial symbiosis increases job creation in Kymenlaakso?
12. Do you believe that industrial symbiosis has a positive effect on environmental values and helps in mitigating climate change?
13. Do you feel that your company prepares for the challenges posed by climate change through means of industrial symbiosis?
14. How much do you think transportation costs affect resource distribution and material circulation in Kymenlaakso?
15. How much would you estimate technological innovations contribute to the promotion of industrial symbiosis in Kymenlaakso?
16. How would you rate the readiness of your company to utilize technology that supports industrial symbiosis and make investments in such technology?
17. Do you think that operating methods required by industrial symbiosis will increase energy consumption in your company?
18. How much do you think customer or product demand affects the introduction or implementation of industrial symbiosis?
19. How much do functional industrial symbiosis models, case examples and public opinions affect the realization of industrial symbiosis in companies in Kymenlaakso?
20. What is the atmosphere between companies in Kymenlaakso; e.g., the level of mutual trust and the ability to co-operate?
21. Do you believe that operating methods representing industrial symbiosis (between your company and other companies) will increase in the future?
22. Has the war in Ukraine had an impact on your company's resource flows and material procurement?
23. Has the war in Ukraine had an impact on your company's profitability figures?
24. Do you feel there are differences in industrial symbiosis implementation or readiness for collaboration between local, national, multinational and foreign companies in Kymenlaakso?
25. Do you feel there are differences in industrial symbiosis implementation or readiness for collaboration between small, medium-sized and large companies in Kymenlaakso?

Figure 8. Survey Questions. (2024)

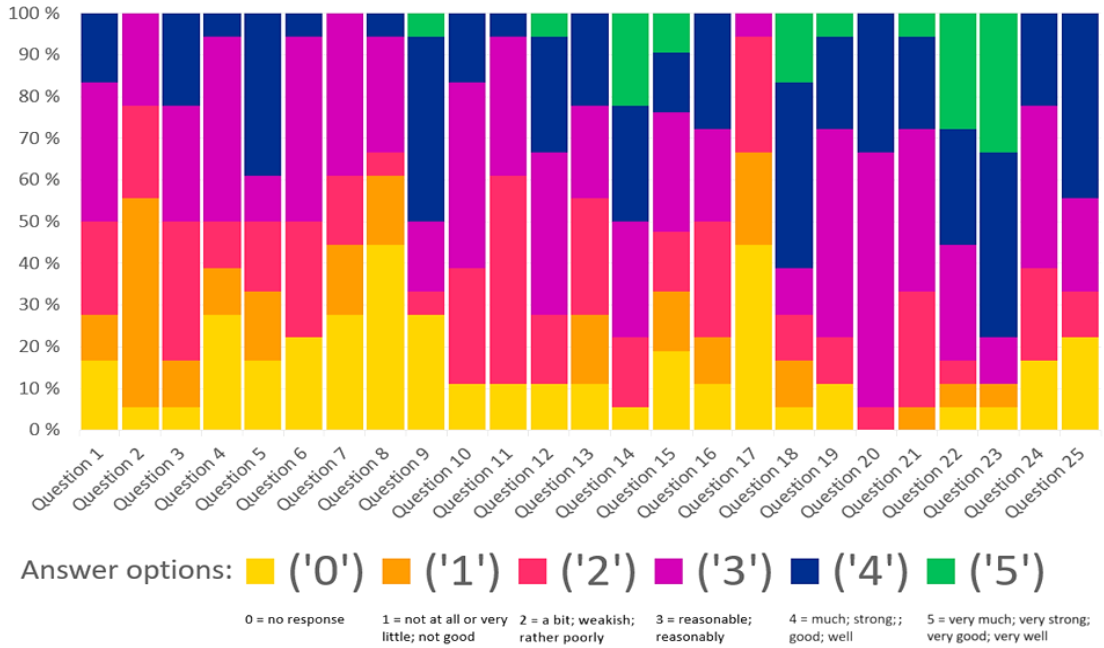

Figure 9. Question-Specific Responses. (2024). Percentage shares from Appendix 4.

When comparing the bar chart sections (Figure 9) to the survey questions (Figure 8), the following observations can be made: there is only limited or no industrial symbiosis -related training in most companies in Kymenlaakso (Q 2), Questions 8 and 17 were apparently difficult to answer (most “no response” -choices), public views and functional sample cases (Q 19), investment subsidies and tax benefits (Q 9), technological innovations (Q 15), market demand (Q 18), freight/transport costs (Q 14), geopolitical issues (Q 22 & Q 23) and the size and nationality or ownership base of companies (Q 24 & Q 25) are seen to have a significant impact on industrial symbiosis (IS). Additionally, the respondents think that the current waste management practices serve IS moderately well in Kymenlaakso (Question 4). The athmosphere among local companies is seen as moderate (Q 20). The respondents assess that IS -related operations will increase in the future (Q 21) and that IS strengthens the profitability of companies (Q 10). Written comments were mainly given by one anonymous respondent, for some questions two. The comments are discussed further in Appendices 2 and 3.

For auxiliary benchmarking, studies by the National Audit Office of Finland (2019) and the European Topic Centre on Waste and Materials in a Green Economy (Eionet 2019) were chosen as benchmarks. The studies address the 2017-2018 reform of Finland's National Material Efficiency Program, originally established in 2013 and the development of the Finnish Industrial Symbiosis System (FISS) operating model, aiming to evaluate the effectiveness of government actions in promoting and supporting business activities, particularly in industrial symbiosis. The studies suggest that the program has not been fully implemented as initially planned and underscore the need for more precise pre-assessment of the program's effectiveness and potential economic benefits. Current waste legislation and environmental permit practices are perceived as factors which may hinder the development of industrial symbioses. Additionally, improvements in e.g., the FISS (2023) database are considered important for better practical support of these symbioses. A study-related questionnaire survey conducted by the National Audit Office of Finland (2019) revealed differing views on the implementation of the renewed material efficiency program. Both studies recommend enhancing the state's role in promoting industrial symbiosis through legal and financial mechanisms.

The results of this study's survey are generally in line with the findings of the aforementioned studies. A significant dispersion in answers was seen in several responses (scattered, rather evenly distributed responses in e.g., questions 13, 14, 17 and 22). Additionally, '0' = no response, was a common choice among respondents in certain questions, which, however, may also reflect unsuccessful phrasing of the questions. Still, in line with the previous studies, the wide scattering of answers most likely reveals the complex nature of industrial symbiosis and genuine variation in general perceptions – thus expressing a need for more efficient information exchange and guidance among stakeholders.

In line with the preceding notion, answers to Q 2 indicate that more could be done in making industrial symbiosis known in the companies and among industries (50% answered that no training is given regarding industrial symbiosis) and that subsidies – legal and financial mechanisms – are essential in promoting industrial symbiosis, as in question 9, two thirds (66.67%) of the respondents answered that national or municipal subsidies and tax benefits are important to some degree (44.44% '4' = important, 16.67% '3' = rather important and 5.56% '5' = very important), while 22.22% chose '0' = no response. In Q 8, the recent historical weight value of municipal or state-driven institutions or organizations supporting industrial symbiosis especially in the Kymenlaakso region was difficult to assess for a third (33.3% '0' = no response) of the respondents, which indicates a notable degree of uncertainty regarding recent or ongoing IS-related fiscal support mechanisms, subsidies, programs and incentives.

The great importance of trust among stakeholders in industrial symbiosis was discussed in e.g., paragraphs 3.4 and 4.4. In the survey, 72.2% answered that the openness of business operations regarding material procurement and resource flows in Kymenlaakso is either variable or shady, indicating that investing in transparency and increasing mutual trust through municipal or regional guiding measures, incentives or business projects – e.g., in the spirit of the broader BIS Project (see 3.5.7) – could prove fruitful. A small conflict between public views and quantitative data arose from Q 17. The question addressed whether industrial symbiosis -related operations increase energy consumption in the companies. 44.45% answered '0' = no response. The rest of the answers were rather evenly distributed between '2' = increase a little (27.78%) or '1' = do not increase (22.2%). There may be big differences between industrial sectors and types of businesses (materials, procurement

channels, processing methods, resource flows, recyclability, distribution, transport needs, competition, availability, cooperation factors,…) in terms of energy use and the effect of industrial symbiosis -related operations, but in general, industrial symbiosis is considered to reduce energy consumption rather impressively, as seen in the working symbiosis between SSAB's steel mill and a local cement factory in Raahe (paragraph 3.5.1) and lower energy use at Kalundborg Symbiosis in Denmark (paragraph 3.5.3). A study by Li, Cui & Han (2015) states that in industrial parks the reduction in energy usage relative to the overall value of industrial production is 43.42%. Statements by Nordregio (Teräs & Mikkola 2016) and SCALER (2023) back the vision that low energy use and more efficient energy recycling are benefits of industrial symbiosis. At any rate, the 17th question seemed difficult to answer, which indicates, once again, that more data – both industry-related quantitative data on IS-related energy issues and other matters and more information on practical implementation and forms of support – should be spread and shared among businesses.

The survey analysis provides a comprehensive picture of industrial symbiosis in Kymenlaakso. The results reveal a relatively positive attitude towards industrial symbiosis in the region, driven by factors like environmental regulations, economic incentives and customer demand. While there's a clear motivation to adopt sustainable practices, companies face barriers, including financial constraints. Financial incentives and support mechanisms are seen as crucial in overcoming these barriers. Economic factors play a pivotal role and there's a need for subsidies and financial recovery before investing in symbiosis technologies. The impact of industrial symbiosis on energy consumption is complex and varies depending on specific practices and technologies. Customer demand greatly influences symbiosis implementation. Trust and cooperation among companies are vital for success. External pressures, successful models and public perception motivate companies to adopt sustainable practices. Companies' readiness to invest in technology supporting symbiosis varies. The ongoing war in Ukraine has significant repercussions, impacting resource flows, profitability and necessitating adaptive strategies and external support. Differences in symbiosis implementation based on ownership and nationality highlight policy and regulatory challenges. Size matters, as larger organizations have stricter obligations and more significant resources, while local SMEs play a crucial role in tightly-knit communities. In conclusion, Kymenlaakso shows a strong inclination towards industrial

symbiosis, but challenges and external events require careful consideration and support to ensure sustainable growth and adaptation.

5.5 Addressing the Research Questions

This thesis aimed to explore the complex network of industrial symbiosis in the Kymenlaakso region. Understanding Kymenlaakso's industrial dynamics is like navigating a complicated maze, where each step uncovers new insights, potential changes and the interconnected effects on the environment and the economy. It's essential to mention that the ideas shared in this chapter are not separate; they are the result of thorough research throughout the thesis. The initial research questions are as follows:

A. How does the Kymenlaakso industrial sector manage its resource flows, collaborations and symbiotic interactions?

To address this question, one must dive into the current state of Kymenlaakso's industries. Here, various industries like forestry, pulp production, chemical manufacturing, logistics and renewable energy engage in multifaceted interactions. The province showcases a complex network of resource exchanges and partnerships. Geographical proximity, as emphasized by Haq, Välisuo & Niemi (2021), provides a fertile ground for such collaborations. Additionally, the global drive regarding circular economy principles, which promote the circulation of materials to reduce waste, adds relevance to Kymenlaakso's approach to resource flows. Looking at initiatives like the Landskrona industrial symbiosis in Sweden can provide insights into how symbiotic relationships develop and thrive. Regionally, the perceptions, resource flows, collaborations and symbiotic interactions within Kymenlaakso have been examined in individual or collaborative studies conducted by researchers such as Sokka, Lehtoranta & Melanen (2011), Tallinen & Laine (2022) and Savikko et al. (2019).

B. What attracts and what discourages Kymenlaakso when considering industrial symbiosis?

The balance between the benefits and drawbacks of industrial symbiosis is deeply rooted in Kymenlaakso's distinctive character. When examining industrial ecology, it can be noticed that the core of industrial symbiosis aims to improve waste efficiency, reducing

environmental impacts. Technological advancements like Industry 4.0 hold the potential to enhance symbiotic relationships. Industry 4.0 means the fusion of smart digital advancements within the sectors of manufacturing and broader industrial activities, covering a variety of technologies such as networks of industrial internet-connected devices, artificial intelligence, extensive data analytics, robotics and the automation of processes (Ventura & al. 2023; SAP n.d.). However, alongside this optimism, there are challenges, including technical complexities, management obstacles and legal intricacies, as revealed in the online survey. Additionally, factors like geopolitical considerations due to historical connections with Russia and events like the Russia-Ukraine conflict could lead to potential disruptions.

C. Beyond the immediate, what are the causes and effects – both environmental and economic – of industrial symbiosis in the Kymenlaakso region?

Stepping back and looking at the big picture, the benefits of industrial symbiosis become clear. The region's commitment to circular economy principles reflects its environmental awareness. The awareness is rather evident despite a moderate level of knowledge regarding the concept or term of industrial symbiosis – a reality which came up in the online survey. Kymenlaakso's investment in renewable energy sources like hydropower demonstrates its dedication to sustainability. From an economic perspective, examining the financial contributions and successes of major industry players can provide insights into the profitability of symbiosis.

D. In operational industrial symbiosis, what are the driving forces and obstacles in Kymenlaakso?

Numerous factors contribute to the successful coordination of industrial symbiosis. Some boost its progress, while others slow it down. Supportive policies, government involvement and the advantage of geographical proximity are favorable factors. Conversely, technical challenges, trust issues and logistical hurdles pose obstacles. A deep exploration of Kymenlaakso's industrial landscape can provide insights into these dynamics. The key discoveries and references in addressing the research questions is presented in Table 4.

The online survey further enriched the answers to all research questions by gathering personal perspectives from representatives of regional companies. Their views are mostly in

line with popular perceptions, but in some cases differ from them. These issues are examined in chapter 5.4 and in Appendices 2 and 3.

Table 4. Addressing the Research Questions, Summary

Research Questions	**Key Discoveries and References**
A. How does the Kymenlaakso industrial sector manage its resource flows, collaborations and symbiotic interactions?	Complex industrial interplay, geographic advantage (Haq, Välisuo & Niemi 2021), circular economy strides (Ellen McArthur Foundation n.d.), learnings from Landskrona (Benedetti 2017), information gained from regional studies like Sokka, Lehtoranta & Melanen (2011), Kinno, Tallinen & Laine (2022) and Savikko et al. (2019)
B. What attracts and what discourages Kymenlaakso when considering industrial symbiosis?	Environmental sustainability through waste efficiency (Mallawaarachchi et al. 2020), potentials of Industry 4.0 (Ventura et al. 2023), geopolitical overlays (CFR 2023), technical development; lack of knowledge and training; lack of sufficient subsidies and tax benefits (online survey)
C. Beyond the immediate, what are the causes and effects – both environmental and economic – of industrial symbiosis in the Kymenlaakso region?	Emphasis on circular economy (European Commission 2020), renewable energy commitment (Pohjolan Voima 2023), economic metrics and success stories (Yle 2022), ecological benefits; a tighter network of local businesses; vulnerability to negative geopolitical changes (online survey)
D. In operational industrial symbiosis, what are the driving forces and obstacles in Kymenlaakso?	Policy and government dynamics (Henriques et al. 2021), strong incentives and support mechanisms promote; technological and trust challenges and logistical intricacies interfere (Henriques et al. 2021; online survey)

5.6 Summary of Results

The examination of the Kymenlaakso industrial cluster, in conjunction with comparisons to instances of successful industrial symbiosis, has provided crucial insights into the potential opportunities and challenges within the region. The diverse industrial landscape in Kymenlaakso underscores the region's substantial potential for exchanging residual heat, materials, water and energy (Kymenlaakson liitto 2023a; Savikko et al. 2019; Benedetti 2017; Dansk Symbiosecenter 2021). However, concerning industrial symbiosis, there exists room for improvement in terms of educating and supporting companies at both national and regional levels (FISS 2023; Kouvola Innovation Oy 2022; online survey).

The composition of the Kymenlaakso cluster bears a resemblance to successful instances of industrial symbiosis in Finland and around the world, featuring a blend of heavy industries

and energy production (Kymenlaakson liitto 2023d; Benedetti 2017; Kalundborg Symbiosis 2023; City of Kawasaki 2023). Kymenlaakso boasts favorable conditions for industrial symbiosis, including a tightly knit and robust industrial network, efficient transport infrastructure, a tradition of collaboration and an eagerness for supportive policies (Kymenlaakson liitto 2023c; Haq, Välisuo & Niemi 2021; City of Kwinana 2023; European Commission 2020; online survey). Factors impeding the adoption of industrial symbiosis practices include limited awareness, institutional inertia, possible shortage of skilled personnel and – despite the region's compactness –, a partially fragmented industrial landscape (Statistics Finland 2023a; Henriques et al. 2021; Kymenlaakson liitto 2023d; online survey). Limited awareness is further evidenced in the survey, with one-third (33.3%) of respondents indicating that the concept of industrial symbiosis is either poorly (22.2%) or very poorly (11.11%) known within their company.

The implementation of industrial symbiosis holds potential for significant environmental benefits, including reduced greenhouse gas emissions, minimized waste generation and enhanced resource efficiency (Mallawaarachchi et al. 2020; Pohjolan Voima 2023; Interreg 2020). Beyond its environmental advantages, industrial symbiosis can drive economic growth, job creation and the emergence of new business opportunities, thus enhancing regional competitiveness (Ellen McArthur Foundation n.d.; Finder 2023a; Kymenlaakson liitto 2023d).

6 Discussion and Recommendations

This section explores the possibility of industrial symbiosis in the Kymenlaakso industrial cluster. It also examines the study's findings, focusing on the potential for resource conservation and environmental improvement.

6.1 Critical Examination and Suggestions

The study pointed out that there is a large volume of resources, including waste heat, materials and energy sources – some of them already in effective circulation –, within the Kymenlaakso industrial cluster (Suomen Pakkausyhdistys 2022; Metsäkeskus 2023). To establish a firm foundation for industrial symbiosis, businesses must navigate through a polarized situation, balancing societal expectations with operational necessities. Sustainability's essence lies more in business frameworks than just technological innovation, as highlighted by Levänen, Hossain & Wierenga (2022). Achieving industrial symbiosis in Kymenlaakso has its challenges, from coordinating multiple industries to navigating legal complexities and addressing intellectual property concerns. These challenges align with insights from scholars like Mallawaarachchi et al. (2020). However, the potential rewards are enticing: reduced environmental impact, enhanced resource efficiency, economic gain and job creation. The region's vision, as articulated by Kymenlaakson liitto (n.d.), aligns with these ambitions. In summary, Kymenlaakso's journey underscores the importance of holistic growth, collaborative industrial ventures and a supportive legislative framework. Achieving this vision requires building trust, fostering innovation and facing and overcoming challenges head-on.

Key factors for successful adoption of symbiosis in Kymenlaakso include a close-knit industrial network, a history of collaboration and a supportive political environment (FISS 2023; European Commission 2020; Henriques et al. 2021). However, challenges such as transparency issues (online survey), geopolitical turmoil, fragmented industrial landscapes and institutional inertia must be addressed to strengthen resilience and develop viable symbiosis plans. The impacts of industrial symbiosis in Kymenlaakso extend across environmental, economic and social dimensions. The goal is to align with sustainability and

circular economy goals (European Commission 2020; Ventura et al. 2023). The economic benefits are also promising, with increased competitiveness, job creation and new business opportunities on the horizon (Kymen Sanomat 2015; Yle 2022). To unlock this potential and overcome challenges, several strategies can be suggested. These include promoting partnerships, sharing knowledge, fostering innovation, shaping symbiosis-friendly policies and highlighting success stories (Ventura et al. 2023; Mallawaarachchi et al. 2020; online survey).

An analysis of the industrial landscape in the Kymenlaakso region reveals a diverse mix of sectors, including logistics and chemicals, paper and pulp – despite a decrease in paper demand (Yle 2023c; Kymenlaakson liitto 2023a). This diversity poses challenges, particularly in terms of waste management and efficient resource utilization. Global events like the Russia-Ukraine conflict underline the importance of adaptable supply chains and innovative local resource management approaches. Given the region's strong ties to global markets (Yle 2023e; Port of HaminaKotka 2024), the need for sustainable practices becomes even more pressing. Levänen et al. (2022) emphasize the role of intermediary practices in aligning institutional logics, suggesting that effective industrial symbiosis requires similar guidance and collaborative expertise at all organizational levels.

In general, the key to successful industrial symbiosis appears to be balancing structured planning with the inherent self-organizing nature of businesses. Many projects fail when plans disregard the actual interests and economic motivations of companies, as presented in studies by Costa and Ferrão (2010) and Gibbs & Deutz (2007). Government involvement sometimes focuses on objectives like job creation, leading to impractical exchange relationships (Gibbs & Deutz 2007). The economic aspect is crucial, as many planned exchanges may not be profitable, especially when broad goals lead to increased costs and discourage investment (Chertow 2007). The need for businesses to relocate to specific industrial areas or seek distant symbiosis partners can be a hindrance, although proximity is not always essential for success (Lombardi & Laybourn 2012). Trust issues, shadiness or the protection of trade secrets may also hinder the adoption of industrial symbiosis -related operation methods (Kouvolan Sanomat 2020; Boom-Cárcamo & Peñabaena-Niebles 2022; online survey). According to Lankinen (2016), the key lies in balancing the coordination of industrial symbiosis projects with businesses' natural inclination to form their own

partnerships. A user-friendly information system that adapts to market changes and assists companies in independently establishing exchange relationships is an important element.

The findings from the online survey helped shed light on the practical aspects and challenges faced by businesses in the Kymenlaakso region, enriching the insights presented in this research. While the survey provided valuable insights into the perceptions and experiences of businesses in Kymenlaakso, it is important to acknowledge that self-reported data can sometimes be influenced by respondent bias and may not always fully reflect the complexities of real-world industrial symbiosis implementations. Additionally, certain survey responses indicated a level of skepticism regarding the feasibility and economic viability of industrial symbiosis, suggesting that further research and practical considerations are needed to address these concerns and foster successful implementations in the region.

6.2 Insights to Contemplate

The emerging insights from this study, in line with findings from McKinsey & Co (2022), suggest the integration of Industry 4.0 and digitization as a potential avenue for refining resource management in the Kymenlaakso industrial cluster. Incorporating IoT (Internet of Things) and intelligent data analytics could ease the conduction of necessary LCA analyses and serve as a catalyst to enhance the efficiency of resource flows, leading to optimized exchanges and reduced waste. These technological advancements align with the principles of circular economy, which prioritize resource efficiency. To leverage this synergy, Kymenlaakso should integrate industrial symbiosis into its broader sustainability vision, weaving it into the fabric of the circular economy. A key consideration should be the cultivation of local resilience and diversifying procurement channels, preparing the region to withstand unforeseen global or national events such as the ones at hand (the war in Ukraine, the influx of asylum seekers over the Russian border and other hybrid threats, the conflict in Gaza and the instabilities in the Middle East and Africa, changing global trade relations, the upcoming presidential election in the U.S., the tension between China and Taiwan, the unpredictability of the Russia-China axis, the future development of the Americas etc.). This entails nurturing local collaborations, diversifying resources and formulating strategies to mitigate the impacts of external disruptions.

6.3 Practical Guidelines and Policy Recommendations

For businesses in Kymenlaakso looking to incorporate the principles of industrial symbiosis into their operations, this study provides concrete guidance, such as the list of IS-collaborative local organizations in chapter 4.5. Accordingly, one starting point is active engagement in networks and platforms that support symbiosis, such as FISS (2023), Kiertokymi (n.d.) and Kinno (Kouvola Innovation Oy). These forums facilitate resource exchange, information sharing and the creation of commercial synergies. A close examination of existing resource and waste streams can shed light on potential symbiotic partnerships, highlighting currently underutilized assets. Additionally, advocating for policy frameworks that strengthen industrial symbiosis can further drive progress. In the face of looming global challenges, Kymenlaakso possesses a valuable tool in industrial symbiosis to promote sustainable resource management. By leveraging technology (combined physical and digital), embracing circular economy principles and forging strategic collaborations, local businesses can chart a course toward sustainable growth.

Establishing a supportive policy framework stands as a significant policy recommendation. Authorities should focus on developing policies and regulations that nurture and encourage industrial symbiosis. These can include incentives, subsidies and regulations that promote collaboration and resource sharing, as highlighted by the European Commission (2020). Addressing the identified knowledge gap is of paramount importance. Policymakers should prioritize awareness campaigns and educational initiatives that showcase the advantages of industrial symbiosis. These efforts should target both industry participants and the general public, as suggested by Mallawaarachchi et al. (2020). Innovation plays a pivotal role in effective industrial symbiosis. Policymakers should allocate resources to encourage research and development projects aimed at creating technology and business models that support industrial symbiosis, as noted by Ventura et al. (2023).

Recognizing the significance of collaboration in industrial symbiosis, governments should provide platforms and mechanisms to facilitate cooperation among diverse industries and stakeholders. Initiatives such as knowledge-sharing programs and matchmaking platforms can enhance collaboration, as discussed by Haq, Välisuo & Niemi (2021). Successful industrial symbiosis cases, whether within Kymenlaakso or elsewhere, should be

acknowledged, backed and replicated. Policymakers should emphasize the identification and promotion of such success stories to encourage broader adoption of industrial symbiosis practices, aligning with the insights shared by Benedetti (2017). In table 5, the previous three sections are summarized, displaying an overview of the presented insights and guidelines.

Table 5. Sections 6.1 – 6.3, Summary

Section	Main Points
Critical Examination and Suggestions	The Kymenlaakso industrial cluster has diverse industries but faces challenges in waste management and resource utilization.
	Global events emphasize the need for local resource management and supply chain resilience.
	Adopting sustainable practices like industrial symbiosis is urgent for this region to strengthen resilience, diversify procurement channels and enhance material circulation.
Insights to Contemplate	Integration of Industry 4.0 and digitalization for resource optimization and waste reduction.
	Alignment of industrial symbiosis with circular economy principles for holistic sustainability.
	Building local resilience through collaboration, resource diversification and contingency planning.
Practical Guidelines & Policy Recommendations	Active engagement in collaboration platforms and networks promoting industrial symbiosis.
	Comprehensive resource mapping to identify underutilized resources and waste products.
	Advocacy for supportive policies at regional and national levels to incentivize symbiosis initiatives.
	Developing a supportive policy environment.
	Creating awareness and providing education/training.
	Supporting research and development.
	Facilitating collaboration.
	Scaling up successful cases.

6.4 Limitations

The thesis aims to assess the potential of industrial symbiosis by mapping a wide variety of background factors and resources within the Kymenlaakso industrial cluster. Various sources are examined, together with an online survey, providing insights into the complexities of industrial symbiosis and its broader implications.

Although the study is based on an orderly research design, as discussed in chapters 1 and 2, it's important to acknowledge certain limitations. These constraints may affect the scope of the conclusions and the generalizability of the findings. The study primarily utilizes secondary data and insights sourced from various documents and an online survey. Apart from the online survey, the heavy dependence on existing texts and records may restrict the depth and breadth of the investigation, potentially missing recent developments or varied viewpoints from different stakeholders in the Kymenlaakso industrial ecosystem. Focusing predominantly on the Kymenlaakso industrial cluster in Finland, with only occasional references to other cases, also sets a boundary. While this approach allows for an in-depth analysis of a specific area, it may limit the ability to apply the findings to different geographical or industrial settings.

The survey's sample size comprises of 18 respondents out of 30 recipients, each providing 25 answers, which creates a reasonably comprehensive picture of local perceptions in this compact area. Still, the age or gender of the final recipients of the anonymous survey is not known. It is possible that some respondents have delegated the task of answering to colleagues, as this option is mentioned in the introduction of the survey. Given the anonymous nature of the survey, with no specific data stored about respondents apart from their answers and digital timestamps, it is challenging to ascertain if certain job positions or industrial sectors were overrepresented in the responses. However, the initial selection of only five representatives per industrial sector and the broad range of responses suggest a diverse respondent pool, rather than a homogeneous group from similar company types or demographics. Hence, the structure of the questionnaire results in a total of 450 (18 x 25) individual survey responses and provides a rather broad spectrum of opinions from Kymenlaakso's business representatives. Despite certain limitations, this volume of data offers a valuable compilation of local opinions on the subject matter.

Acknowledging these limitations reflects not a shortfall but a dedication to openness. It outlines the scope of the research journey and points to areas ready for further investigation. Regardless of potential shortcomings, this study adds to the discussion of industrial symbiosis in Kymenlaakso and provides valuable information for those leading circular economy efforts both in Finland and abroad.

6.5 Recommendations for Further Research

Future research could further explore the complex dynamics of resources and conduct comprehensive life cycle analyses within the Kymenlaakso industrial cluster. This study has focused on a holistic review and the potential of resource exchanges in a general and qualitative manner. Collecting more present-day industrial symbiosis -related quantitative data and statistics would open up the current state of the cluster for businesses, academics, local administratives and regional IS -related program or project operators. As suggested by Somoza-Tornos, Graells & Espua (2017), in-depth investigations of resource exchange are essential for quantifying the potential of industrial symbiosis. Examining successful instances of industrial symbiosis across different locations and sectors by means of quantitative data analysis could provide valuable insights into the factors contributing to their success, as highlighted by Benedetti (2017). These insights could serve as guidance for industry-specific strategic development in Kymenlaakso. Quantitative data about Kymenlaakso can be obtained from e.g., the ECOREG system, which has been in operation for decades (Kymenlaakson liitto 2023f). The system tracks Kymenlaakso's eco-efficiency through a blend of environmental, economic and socio-cultural indicators, detailed in ECOREG publications and annual reports. Monitoring helps to detect trends, achieve climate and energy goals and prepare for climate change impacts. (Kymenlaakson liitto 2023g.)

Future studies should assess the environmental, economic and social impacts within the Kymenlaakso region to gain a clear understanding of the advantages of industrial symbiosis. In-depth analyses of this nature are crucial for well-informed policy-making, as emphasized by Nobre & Tavares (2021). Examining policies and regulations that either support or hinder industrial symbiosis is of utmost importance. Further research in this area can shed light on necessary adjustments and the significant role of policy in promoting symbiotic practices,

aligning with the insights shared by the European Commission (2020). Involving a diverse range of stakeholders in discussions within Kymenlaakso encourages a collaborative approach to the evolution of industrial symbiosis. Inclusive and effective symbiotic initiatives can result from dialogues that encompass multiple perspectives, as discussed by Haq, Välisuo & Niemi (2021). Additionally, investigating variations in perceptions and expertise among different types of company employees, as discussed in chapter 2.1.2, can help transition from assumptions to scientifically validated information.

Incorporating multiple case studies in future research could enrich the understanding of industrial symbiosis across different contexts. While this study's qualitative approach offers depth, it may not fully capture the impacts and benefits of symbiotic activities in Kymenlaakso. Future studies could use quantitative research methods like life cycle assessments or economic analyses for a more rounded view of industrial symbiosis's ecological and fiscal outcomes. Data accessibility remains a potential challenge, as some entities might be reluctant to disclose detailed information about their resource management and symbiotic practices, which could limit the ability to fully characterize the state of industrial symbiosis in the cluster and identify its future prospects and challenges.

Figure 10 shows one of the eldest and most notable industrial parks in the world, The Kalundborg Eco-Industrial Park in Denmark (Kalundborg Symbiosis).

Figure 10. Kalundborg Eco-Industrial Park (Ensia 2014/Symbiosis Center)

7 Conclusion

In the beginning of the study, the research background and questions were introduced and the methodology, which included document analysis and a review of secondary data, was discussed. The findings related to the circular economy and industrial symbiosis, including case studies, were reviewed. A case study of the Kymenlaakso industrial cluster was presented, examining resource dynamics and the environmental and economic impacts in this region. Kymenlaakso is rich in industrial players, particularly in the paper and pulp industry and logistics, with a strong history of eastern trade, which is currently facing challenges due to the geopolitical situation. Additionally, an online survey was conducted and the survey results were presented, comparing them with the other findings of the study. These findings primarily align with general views and perceptions. It was notable that the awareness of the energy-saving potential of industrial symbiosis was not widespread among survey respondents, suggesting variations in individual knowledge, business sectors, basic information and concerns about the potential impact of industrial symbiosis on energy consumption. Finally, the key discoveries and their broader implications were synthesized, emphasizing the role of industrial symbiosis in promoting sustainability at regional, national and global levels. Insights and policy implications were provided regarding the Kymenlaakso industrial cluster, along with guidelines for future research.

Based on the research, the promising prospects for industrial symbiosis in the Kymenlaakso region have become evident. The examination has confirmed the environmental, economic and social benefits of industrial symbiosis, highlighting significant potential for resource exchange and identifying both catalysts and barriers to its implementation. Additionally, the crucial role of this approach in enhancing sustainability and circularity has been underscored by the findings. Looking ahead, there is a pressing need for further research to delve into the complicated details of resource flows, to conduct impact assessments, evaluate policies and increase stakeholder involvement. Exploring effective case studies is also important. These diverse research paths aim to enhance our comprehension of industrial symbiosis and how to apply it effectively, with the objective of sharing this knowledge with stakeholders.

When examined closely, industrial symbiosis transcends being just a theoretical concept, instead presenting itself as a practical route towards a future where sustainability and collaboration become central. It urges policymakers, industries and communities in Kymenlaakso to work together to unlock the unused potential within their industrial area. The research aims to inspire change, motivating stakeholders to embrace industrial symbiosis as a key driver of progress and sustainability in the Kymenlaakso region. The experiences and revelations in Kymenlaakso carry implications that extend beyond its borders, particularly in a society navigating toward the principles of a circular economy amidst climate variations, economic and cultural shifts and geopolitical dynamics. Industrial symbiosis emerges as a guiding tool, steering regions and industries toward a future characterized by enhanced sustainability and collaboration. In this imagined future, the concept of waste transforms into resource conversion, leading to positive outcomes across environmental, economic and societal dimensions.

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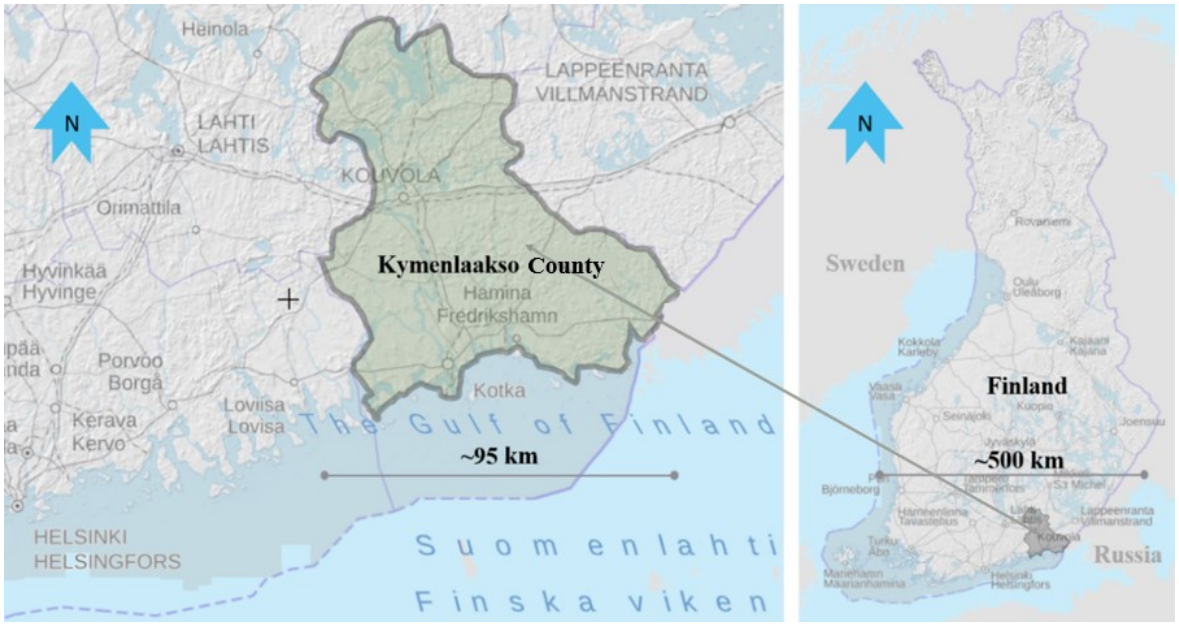
Appendix 1. Map of the Kymenlaakso Province



Map of the Kymenlaakso Province. (National Land Survey of Finland - Kansalaisen karttapaikka, modified base map 2023)

Note: The former Kymenlaakso municipality Iitti, which appears on many older maps as part of Kymenlaakso, was merged into the neighboring Päijät-Häme Province on January 1, 2021.

Appendix 2. Summary of the Survey Analysis

Question	Key Findings of the Survey	Notions and Respondent Comments	Comparative Analysis Sources
Question 1	Mixed levels of industrial symbiosis awareness.	33.33% have a reasonable understanding. 22.22% and 11.11% view it as quite or very poorly known. A respondent suggests regional actors implement symbiosis principles. Growing, yet uneven, recognition and application of symbiosis in Kymenlaakso.	National Audit Office of Finland (2018); Eionet (2019); Henriques et al. (2021); Haq, Välisuo & Niemi (2021)
Question 2	Lack of industrial symbiosis training in businesses.	50% do not offer any training. Need for enhanced training initiatives.	Eionet (2019); Haq, Välisuo & Niemi (2021)
Question 3	Wide variety of resource exchange practices.	50% perceive resource exchange happening to a reasonable to significant degree. Examples of practical resource sharing in the region. Room for enhancing collaboration and awareness.	Business Kotka-Hamina (2023) Savikko et al. (2019) Mallawaarachchi et al. (2020); Haq, Välisuo & Niemi (2021)
Question 4	Mixed perception of waste management supporting symbiosis.	44.44% view waste management practices as reasonably effective. Challenges in waste management, particularly legislative bureaucracy.	Savikko et al. (2019)
Question 5	Mixed perception of how well companies serve symbiosis.	38.89% believe their operations align well with symbiosis principles. Legislative challenges impact investment decisions in symbiosis operations.	National Audit Office of Finland (2018); Henriques et al. (2021); Mallawaarachchi et al. (2020); European Commission (2020)
Question 6	Variability and opacity in company operations.	44.44% perceive operations as variable. 27.78% view operations as secretive. 5.56% consider operations to be open and transparent. Comment: Procurement not very transparent. New EU Sustainability Reporting Directive (CSRD) to increase transparency.	The National Audit Office of Finland (2018); Eionet (2019); Henriques et al. (2021); Mallawaarachchi et al. (2020); Ecobio (2023)
Question 7	Mixed perception of support by regulation and politics.	38.89% feel these factors serve symbiosis reasonably. 27.78% did not respond to this question. More robust regulatory and political support is needed.	The National Audit Office of Finland (2018); Eionet (2019); Henriques et al. (2021); Mallawaarachchi et al. (2020)
Question 8	Lack of information; mixed perception of support by actors and organizations.	44.44% respondents answered '0' (no response). Comment: Nascent stage of symbiosis networks. Comment: Importance of considering local and national dynamics. Targeted support from organizational entities is needed.	Savikko et al. (2019); Sokka, Lehtoranta and Melanen (2011); Xamk (2023)
Question 9	Importance of national/municipal incentives.	44.44% view these incentives as important. Comment: Complex relationship between legislation and symbiosis. Need for subsidies to offset costs.	European Commission (2020)
Question 10	Moderate belief in profitability enhancement.	44.44% feel it reasonably enhances profitability. Comment: Waste-to-resource concept. Economic benefits vary among companies.	Haq, Välisuo & Niemi (2021); Henriques et al. (2021); National Audit Office of Finland (2019); Eionet (2019)
Question 11	Cautious optimism regarding job creation.	50% believe it might contribute to job creation to a small degree. 33.33% see reasonable potential for job creation. Comment: Impact on job creation may vary based on material flows. Potential for job creation discussed in thesis.	Kouvola Innovation n.d. National Audit Office of Finland (2019); Eionet (2019)
Question 12	Positive impact on environmental values and climate change mitigation.	38.89% believe it has a reasonable effect on the environment. Comment: Importance of efficient resource utilization and waste minimization. Comment: Need for support and resource efficiency.	The National Audit Office of Finland (2019); Eionet (2019); European Commission (2020); Ventura et al. (2023); Haq, Välisuo & Niemi (2021)
Question 13	Mixed approach towards integrating industrial symbiosis for climate change preparedness.	Uneven adoption of symbiosis practices. Comment: External support needed for climate resilience. Emphasis on resource efficiency and sustainable practices.	Savikko et al. (2019); Sitra (n.d.)

(…Summary of the Survey Analysis)

Question	Key Findings of the Survey	Notions and Respondent Comments	Comparative Analysis Sources
Question 14	Transportation costs significantly influence resource distribution and material circulation.	50% acknowledge a major impact of transportation costs. Comment: Underestimation of transportation's impact. Transportation's pivotal role in resource flow dynamics.	Kymenlaakson liitto (2023d); Savikko et al. (2019)
Question 15	Belief in the role of technological innovations.	33.33% view technology as contributing reasonably. 27.78% believe technology contributes a lot or very much. Comment: Optimism about technological contributions. Technological innovation as a key driver in symbiosis.	Savikko et al. (2019); National Audit Office of Finland (2019); Eionet (2019)
Question 16	Varied readiness to invest in symbiotic technology.	27.78% rate readiness as good. 27.78% consider readiness weak. 22.22% see readiness as reasonable. Comment: Interest in symbiotic technologies but financial constraints. Importance of financial viability and support for implementation.	Ventura et al. (2023); National Audit Office of Finland (2019); Eionet (2019); Henriques et al. (2021)
Question 17	Mixed perception on the impact of symbiosis on energy consumption.	44.44% did not respond. 27.78% think it might increase it a little. 22.22% believe it won't increase energy consumption. Comment: Impact depends on practices. The relationship between symbiosis and energy consumption is complex. According to scientific data, industrial symbiosis decreases energy consumption.	National Audit Office of Finland 2019; Eionet 2019; Henriques et al. 2021; Kotkan Energia 2023; Li, Cui & Han 2015; Teräs & Mikkola 2016; SCALER 2023
Question 18	Customer demand greatly impacts symbiosis implementation.	61.11% believe customer demand greatly impacts. Comment: Challenges in specialized manufacturing processes. Success dependent on adaptability to market demands.	Kauppalehti 2020; Kouvolan Sanomat 2020; Henriques et al. 2021; Mallawaarachchi et al. 2021; Yang et al. 2022
Question 19	Functional models, case examples, and public opinion impact symbiosis realization.	77.78% acknowledge their impact. Comment: Public pressure influencing business practices. External pressures and successful models motivate sustainability.	Mirata & Emtairah 2005; European Commission 2020 National Audit Office of Finland 2019; Eionet 2019 Kouvolan Sanomat 2020
Question 20	Moderate to good atmosphere of mutual trust and cooperation.	Predominantly positive atmosphere of trust and cooperation.	Eionet 2019; Mallawaarachchi et al. 2020; European Commission 2020; Kouvolan Sanomat 2020
Question 21	General belief in the increase of industrial symbiosis practices in the future.	Majority foresee a reasonable to significant increase in symbiotic operations.	Haq, Välisuo & Niemi (2021); European Commission (2020); National Audit Office of Finland 2019; Eionet 2019; FISS 2023; Dansk Symbiosecenter 2021
Question 22	Ukraine war significantly impacts resource flows and material procurement.	Majority (83.4%) acknowledge a moderate to very significant impact on resource flows. Comment: Reduced support for Russia and shift in resource procurement.	Kinno (Kouvola Innovation Oy 2022)
Question 23	Ukraine war significantly impacts the profitability of companies.	Majority (44.44% 'much' and 33.33% 'very much') indicate a substantial effect on profitability. Comment: Highlighting the need for adaptive strategies and external support.	Kinno (Kouvola Innovation Oy 2022)
Question 24	Differences in industrial symbiosis implementation and readiness based on ownership or nationality.	38.89% feel differences are moderate, 22.22% believe they are significant. Comment: Highlighting differences in policy and regulatory frameworks.	Haq, Välisuo & Niemi (2021); Henriques et al. (2021); Kinno (Kouvola Innovation Oy (2022); Ecobio 2023; Benedetti (2017); Mirata & Emtairah 2005; Ruiz–Puente, Romero–Arozamena & Evans (2015)
Question 25	Impact of size on industrial symbiosis.	Larger organizations have stricter obligations and bigger material resources. Comment: Emphasizing the importance of local SMEs in industrial symbiosis.	Ecobio (2023); Benedetti (2017); Mirata & Emtairah (2005); Ruiz–Puente, Romero–Arozamena & Evans (2015)

The complete one by one survey analysis is presented in Appendix 3.

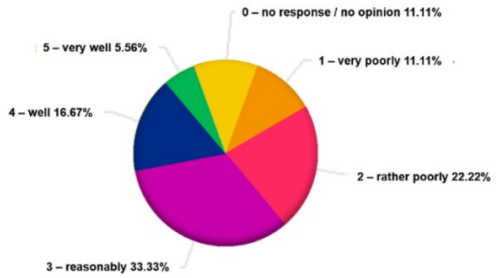
Appendix 3. Question-Specific Survey Analysis

In this appendix, the survey questions are presented one by one in English and Finnish (the original language). The questions are supplemented with pie charts indicating the percentage shares of given answers and thematic headlines showing the indicative subject area of the questions under the title. The answers for each question will be analyzed in relation to other findings of the study.

Understanding and awareness of industrial symbiosis:

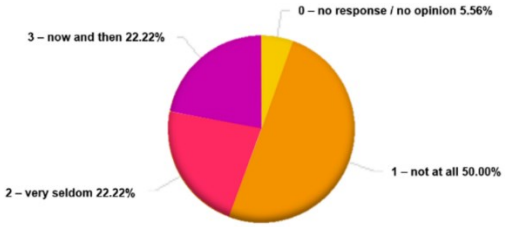
1. How well do you think the concept of industrial symbiosis is known in your company?
"Miten hyvin teollisen symbioosin konsepti tunnetaan mielestänne yrityksessänne?"

Question 1: How well do you think the concept of industrial symbiosis is known in your company?



The survey results for the first question about industrial symbiosis awareness show mixed levels of familiarity. A notable 33.33% of respondents have a reasonable understanding, while 22.22% and 11.11% view it as quite or very poorly known. This reflects a range from moderate to low awareness and aligns with the thesis discussions, which indicate that while the practices of industrial symbiosis may be known as an inherent part of circular economy, the depth of understanding varies (National Audit Office of Finland 2018; Eionet 2019; Henriques et al. 2021). A written comment by one respondent (translated): "The concept of industrial symbiosis is not probably very familiar as a term, but regional actors, especially subsidiaries in the region as well as subcontractors, implement the concept as well as possible" suggests that the term may not be widely known, but its principles are being implemented to some degree. This echoes the thesis's point about the implicit adoption of symbiotic practices in the region (Haq, Välisuo & Niemi 2021). The survey and other findings of the thesis together highlight a growing, yet uneven, recognition and application of industrial symbiosis in Kymenlaakso, suggesting a need for better awareness and education in the area.

2. How often does your company organize orientation or training programs for employees related to industrial symbiosis?
"Kuinka usein yrityksenne järjestää teolliseen symbioosiin liittyviä työntekijöiden perehdytys- tai koulutusohjelmia?"

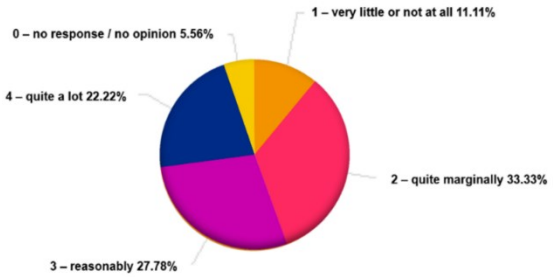


The answers to the second question indicate that half (50%) of the businesses in Kymenlaakso do not offer any training on industrial symbiosis, with only a minority occasionally conducting such programs. This lack of training aligns with the thesis findings, suggesting a disparity in understanding and implementing industrial symbiosis in Finland and underscoring the need for enhanced training initiatives (Eionet 2019; Haq, Välisuo & Niemi 2021). Addressing this could improve the adoption of symbiotic practices in Kymenlaakso

Resource flows and material exchange:

3. Do you know if pooling or exchange of resource flows happens between your company and other companies in Kymenlaakso or its vicinity – and if so, to what extent?

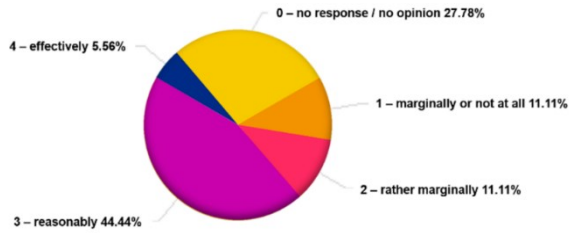
"Tiedättekö, tapahtuuko yrityksenne ja muiden Kymenlaakson tai lähialueen yritysten välillä resurssivirtojen yhdistämistä tai vaihtoa – ja jos, niin missä määrin?"



The survey responses to question three reveal a wide variety of practices. While 11.11% of respondents report very little or no resource exchange, 33.33% observe it to a small extent and a combined 50% perceive it happening to a reasonable to significant degree. One respondent gave a written comment (translated): *"Kotkamills, which operates in the area, e.g., recycles the recycled cardboard produced in the area at its fiber plant on a large scale. A regional operator collects the fibers and delivers them to the factory's fiber plant. Kotkan Energia and IFF also operate in an integrated manner (own understanding). There are good examples of combining resource flows in the area. More of this could happen in the port area (metal recycling, cardboard waste)".* The mention of Kotkamills recycling cardboard and the integrated operations of Kotkan Energia and IFF exemplifies practical resource sharing in the region. These insights align with the thesis findings, which highlight the presence and potential for industrial symbiosis in Kymenlaakso. The thesis notes active resource exchange in some companies and suggests broader implementation potential across the region (Business Kotka-Hamina 2023). The survey results reflect this, showing varied levels of resource sharing from minimal to substantial. The survey and thesis together indicate a diverse landscape of resource pooling and exchange in Kymenlaakso. This aligns with the thesis's observations on the region's industrial symbiosis potential (Business Kotka-Hamina 2023; Savikko et al. 2019), with room for enhancing collaboration and awareness to expand these practices (Mallawaarachchi et al. 2020; Haq, Välisuo & Niemi 2021).

4. To what extent do you think the current waste management practices in Kymenlaakso serve the promotion of industrial symbiosis?

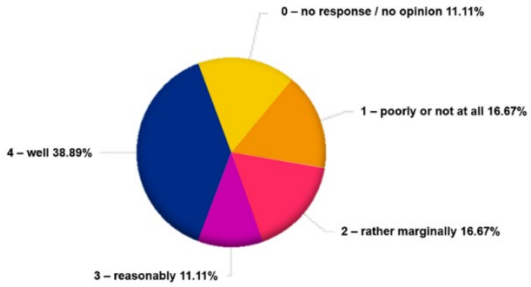
"Missä määrin Kymenlaakson nykyiset jätehuoltokäytännöt palvelevat mielestänne teollisen symbioosin edistämistä?"



The responses to question four reveal a moderate perception of Kymenlaakso's waste management practices in supporting industrial symbiosis. Most respondents (44.44%) view these practices as reasonably effective, while a notable proportion sees them as less effective. A notable share of respondents (27.78%) answered 0 (= no response) to the question – perhaps because of lack of comparative data: an issue the companies could perhaps focus on in the future. The following comments were given by two respondents (translations): 1. *"The challenge is mainly legislative bureaucracy; things could work more flexibly".* 2. *"Enlightenment and the interest of consumers and waste separation at the source are still taking shape. There*

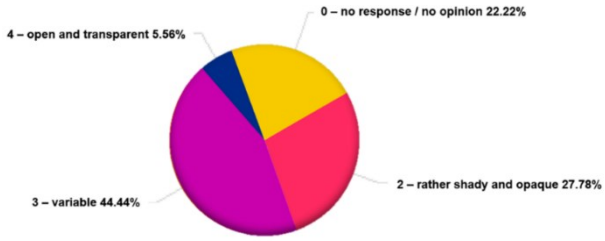
are sorting points next to large shops". "These perspectives align with the thesis findings, which highlight challenges in waste management, particularly legislative bureaucracy, hindering optimal industrial symbiosis (Savikko et al. 2019). The respondent's comment on the need for more flexible systems and consumer involvement in waste separation echoes the thesis's emphasis on improving waste management frameworks to better facilitate industrial symbiosis in Kymenlaakso.

5. How do you think the operations of your company serve industrial symbiosis as a whole?
"Palveleeko yrityksenne toiminta mielestänne kokonaisuutena teollista symbioosia?"



The responses to question five indicate a mixed perception of how well companies in Kymenlaakso serve industrial symbiosis. A significant 38.89% believe their operations align well with industrial symbiosis principles, while a comparable proportion view their contribution as poor or very poor. This mixed response mirrors the thesis findings, which – on a general level – suggest variable levels of engagement and effectiveness in industrial symbiosis (National Audit Office of Finland 2018; Henriques et al. 2021; Mallawaarachchi et al. 2020). The respondent's comment about legislative challenges impacting investment decisions in symbiosis operations aligns with the thesis's discussion on regulatory barriers hindering optimal industrial symbiosis in Europe (European Commission 2020). This highlights the need for more supportive policies and frameworks to enhance the role of companies in industrial symbiosis.

6. Do you think the operation of companies in Kymenlaakso is generally open and transparent regarding material procurement and resource flows?
"Onko Kymenlaakson alueen yritystoiminta mielestänne yleisesti avointa ja läpinäkyvää materiaalihankintojen ja resurssivirtojen suhteen?"



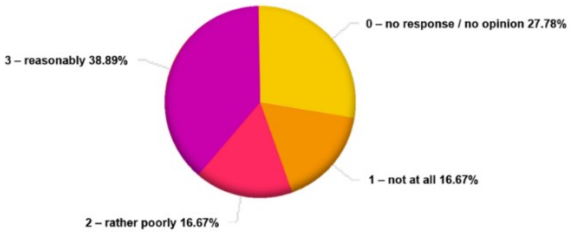
The responses to the sixth question reveal a general perception of variability and some opacity in the operations of companies in Kymenlaakso regarding material procurement and resource flows. A notable 44.44% of respondents perceive these operations as variable, while 27.78% view them as rather secretive and opaque. Only a small fraction, 5.56%, consider these operations to be open and transparent. One comment was given (translated): "*Companies do not have to tender publicly, so procurement is not very transparent".* The thesis discusses the importance of collaboration and open communication for effective industrial symbiosis, as highlighted by The National Audit Office of Finland (2018), Eionet (2019), Henriques et al. (2021) and Mallawaarachchi et al. (2020). The survey responses align with these findings, suggesting that while there is some level of openness, there is also a significant degree of variability and lack of transparency in the region's industrial operations. This variability could impact the efficiency and effectiveness of industrial

symbiosis initiatives, as open communication and transparency are crucial for the successful exchange and optimization of resources. The previous comment about procurement not being very transparent further underscores the need for more openness in operations to foster industrial symbiosis. The new EU Sustainability Reporting Directive (CSRD), which entered into force in January 2023 and was implemented on January 1, 2024, requires companies with more than 500 employees to gather data and submit annual sustainability reports starting from 2025 (Ecobio 2023), will hopefully increase transparency regarding material procurement and resource flows. Yet, as the commenter points out, not all companies want to publicly disclose their procurement channels due to corporate secrecy or competitive advantage.

Regulatory and policy environment:

7. How do you feel that general domestic regulation, legislation and local politics serve and promote industrial symbiosis in the Kymenlaakso region?

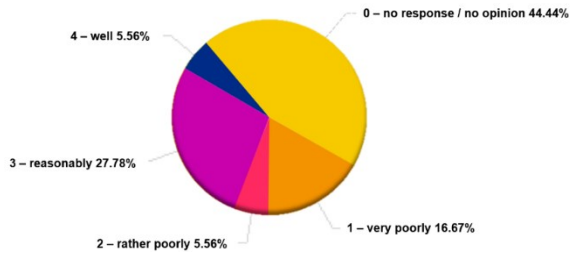
"Miten koette yleisen kotimaisen sääntelyn, lainsäädännön ja paikallispolitiikan palvelevan ja edistävän Kymenlaakson seudun teollista symbioosia?"



The responses to the seventh question indicate a mixed perception regarding the support and promotion of industrial symbiosis by domestic regulation, legislation and local politics in the Kymenlaakso region. 38.89% of respondents feel that these factors serve industrial symbiosis reasonably, while a third view them as not supportive (16.67%) or rather poorly supportive (16.67%). Notably, 27.78% of respondents did not respond to this question. The thesis findings – for example the perceptions of Savikko et al. (2019), The National Audit Office of Finland (2018), Eionet (2019), Henriques et al. (2021) and Mallawaarachchi et al. (2020) – emphasize the crucial role of supportive policies and regulatory frameworks in facilitating industrial symbiosis. The survey responses reflect a recognition of some level of support, but also suggest a need for more robust and effective regulatory and political backing to fully realize the potential of industrial symbiosis in Kymenlaakso. The lack of strong positive responses and the significant non-response rate may indicate uncertainty or a lack of awareness about the extent of support provided by local regulations and politics for industrial symbiosis. This aligns with the thesis's emphasis on the need for more conducive policies and a supportive political environment to enhance industrial symbiosis practices.

8. How much do you feel specifically industrial symbiosis -related national or local actors and organizations, knowledge banks, programs and initiatives support the implementation or promotion of industrial symbiosis in Kymenlaakso?

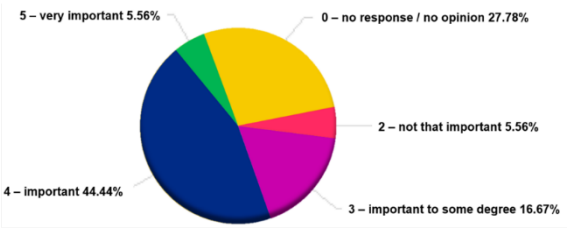
"Kuinka paljon erityisesti teollisen symbioosin edistämiseen keskittyneet valtakunnalliset tai paikalliset toimijat ja organisaatiot, tietopankit, ohjelmat ja aloitteet tukevat teollisen symbioosin toteuttamista tai edistämistä Kymenlaaksossa?



Question 8 reveals a significant lack of information, as up to 44.44% of the respondents answered '0' = no response. Otherwise, the responses reveal a varied perception of the support provided by national or local actors and organizations for industrial symbiosis in Kymenlaakso. 27.78% of respondents feel that these entities offer reasonable support, while 22.22% perceive the support as poor or very poor. Only 5.56% believe the support is good. The following comments were given (translations): 1. *"Many different projects are planned for the area (battery materials, hydrogen economy), but they still have a long way to go"*. 2. *"A bit of a tricky question, because the symbiosis creator can come from a different part of Finland and take over the material flows without the entity in question using Kymenlaakso's services/producing benefits for Kymenlaakso"*. The first comment indicates a nascent stage of symbiosis networks and technologies in certain fields of industry and underlines the need for long-term development and integration, as discussed in the thesis. The second comment underscores the importance of considering both local and national dynamics in fostering effective symbiotic relationships a theme also recurrent in the thesis. Drawing on references such as Savikko et al. (2019), Sokka, Lehtoranta and Melanen(2011) and Xamk (2023) and regional cooperative bodies listed in chapter 4.3, the thesis acknowledges the presence of national and local actors and initiatives promoting industrial symbiosis in Finland and in the Kymenlaakso region. However, the survey responses suggest that data flow is not working and the impact and effectiveness of these efforts in Kymenlaakso are perceived as moderate to low. This aligns with the thesis's discussion on the need for more robust and targeted support from local and national entities to enhance the implementation and promotion of industrial symbiosis in the region. The mixed responses and the presence of non-responses may indicate a gap between the existing support mechanisms and the perceived needs or awareness levels among industrial actors in Kymenlaakso.

9. Do you feel that national or municipal investment subsidies or tax benefits are important in promoting industrial symbiosis?

"Koetteko, että kansalliset tai kunnalliset investointituet tai veroedut ovat tärkeitä teollisen symbioosin edistämisessä?

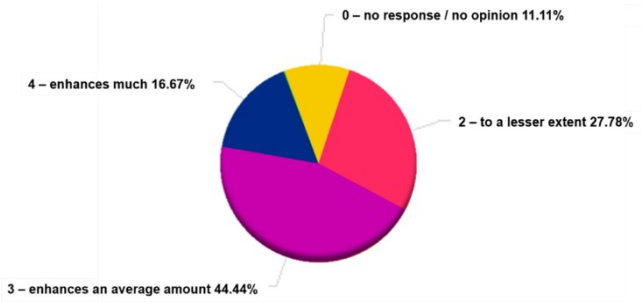


Responses to question 9 reveal that a large share of respondents (44.44%) view national or municipal investment subsidies or tax benefits as important in promoting industrial symbiosis, with an additional 5.56% rating them as very important. However, 27.78% did not respond and a small percentage view these incentives as less significant. This perspective aligns with the thesis findings, which underscore the importance of policy support in facilitating industrial symbiosis. The thesis references, such as the European Commission (2020), highlight the role of policy instruments, including financial incentives, in creating environments conducive to industrial symbiosis. These incentives are crucial for offsetting initial costs and encouraging companies to adopt symbiotic practices. Two respondents commented (translations): *"I wouldn't see that you would get support for these projects, but my own experience with the subject has been that legislation first creates a problem and then a solution. One example is the waste law updated by the Marin government, where packaging waste was diverted from the private market to the responsibility of the municipality, as a result of which the private business field is no longer allowed to form material symbioses. There is simply not enough material for everyone and the beneficiaries are named in the law. In this situation, investment subsidies are of no help"*. The respondent's comment reflects a specific national context, illustrating the complex relationship between legislation and industrial symbiosis. This is echoed in the thesis, in e.g., chapter 3.1, (where stakeholder cooperation in formulating supportive legislation is mentioned) and in paragraph 5.2.2, in which studies by National Audit Office of Finland (2018) and Eionet (2019), addressing the impact of

policies and legislation on industrial symbiosis, are addressed. Also the studies by Henriques et al. (2021) and Mallawaarachchi et al. (2020) discuss how policy decisions can either facilitate or hinder the development of industrial symbiosis networks. Both the survey responses and thesis findings highlight the significance of financial incentives and supportive policies in advancing industrial symbiosis. While the survey indicates a general recognition of the importance of subsidies and tax benefits, the thesis provides a broader context, showing how these incentives fit into the larger policy landscape influencing industrial symbiosis initiatives.

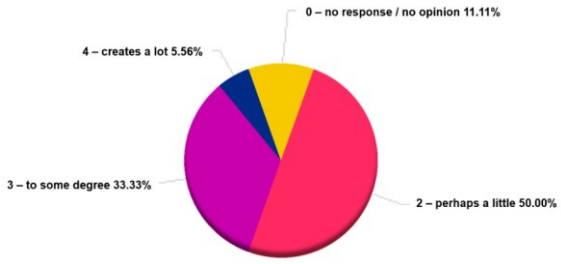
Economic and environmental impact:

10. Do you believe that industrial symbiosis enhances the profitability of companies in Kymenlaakso?
"Uskotteko, että teollinen symbioosi lisää yritysten kannattavuutta Kymenlaaksossa?"



The answers to the tenth question indicate a moderate belief in the profitability enhancement of industrial symbiosis in Kymenlaakso. 44.44% of respondents feel it reasonably enhances profitability, while 16.67% believe it significantly does so. However, 27.78% see only a small degree of profitability enhancement. This perspective aligns with the thesis findings, which suggest that industrial symbiosis can lead to economic benefits, including cost savings and new business opportunities (Haq, Välisuo & Niemi 2021). One comment was given (translated): *"It would increase for sure, because one person's waste is another person's opportunity. Its utilization possibilities are only limited to non-existent or certain parties according to the law".* The respondent's comment reflects a common understanding in the field: waste from one process can become a resource for another, potentially unlocking new economic value (Henriques et al. 2021). This concept is central to industrial symbiosis and is echoed in Finnish and international contexts, where the efficient use of resources is seen as a key to profitability and sustainability (National Audit Office of Finland 2019; Eionet 2019). The survey responses and thesis insights together suggest that while there is recognition of the economic benefits of industrial symbiosis in Kymenlaakso, the extent of these benefits varies among companies, with a general trend towards moderate to significant profitability enhancement.

11. Do you believe that industrial symbiosis increases job creation in Kymenlaakso?
"Uskotteko, että teollinen symbioosi lisää työpaikkoja Kymenlaaksossa?"

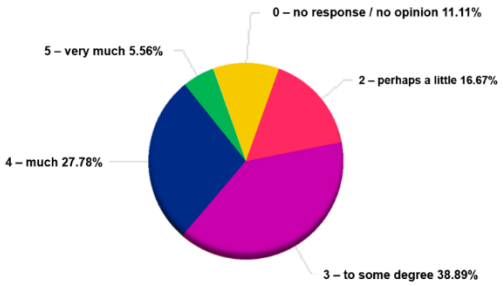


The responses to question 11 reveal a cautious optimism. While 50% believe it might contribute to job creation to a small degree and 33.33% see reasonable potential, the overall sentiment is tempered, as only 5.56% believe the positive impact

on job creation is significant. On comment was given (translated): *"Another tricky question. Would definitely add otherwise, but if the processing of material flows can be performed elsewhere, then the only task is to transport the material away From Kymenlaakso. This is rarely much of a problem and I don't think it creates much employment".* This cautious stance aligns with the thesis findings, which suggest that while industrial symbiosis has the potential to foster economic and social benefits, including job creation, its impact in Kymenlaakso is still evolving (Kouvola Innovation n.d.). The thesis acknowledges the potential of industrial symbiosis to stimulate new employment opportunities, particularly in innovative and sustainable industries (National Audit Office of Finland 2019; Eionet 2019). However, as the respondent's comment highlights, the actual job creation impact may vary depending on how material flows and processing are managed within or outside the region. Collectively, the survey responses and thesis findings suggest that while industrial symbiosis holds promise for job creation in Kymenlaakso, its real impact may be modest and dependent on the specific dynamics of material and resource flows in the region.

12. Do you believe that industrial symbiosis has a positive effect on environmental values and helps in mitigating climate change?

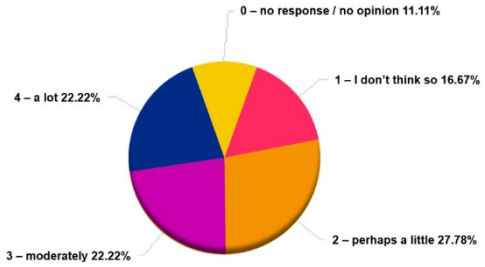
"Uskotteko teollisen symbioosin vaikuttavan myönteisesti ympäristöarvoihin ja auttavan hillitsemään ilmastonmuutosta?"



Regarding question 12, the majority of respondents recognize the positive impact of industrial symbiosis on environmental values and climate change mitigation, with 38.89% believing it has a reasonable effect and a combined 33.34% viewing it as having a significant or very significant impact. This aligns with the thesis findings, which emphasize the role of industrial symbiosis in promoting environmental sustainability. References like the National Audit Office of Finland (2019), Eionet (2019) and European Commission (2020) highlight the importance of efficient resource utilization and waste minimization as key aspects of industrial symbiosis, being consistent with studies by e.g., Ventura et al. (2023) and Haq, Välisuo & Niemi (2021), which discuss the broader environmental benefits of industrial symbiosis, such as reduced greenhouse gas emissions and enhanced biodiversity. In the survey, one respondent commented (translation): *"Yes, because unnecessary logistics should be removed from all operations. The same material should always have a new cycle of life in the area without excessive consumption of natural resources. Finland's sustainable development business field is not only not fed enough, but its operating conditions are currently weak".* The respondent's comment echoes the thesis's discussion on sustainable practices and resource efficiency as essential components of circular economy and industrial symbiosis (Benedetti 2017; Ellen McArthur Foundation n.d.), but also reflects the complex nature of industrial symbiosis and companies' need for guidance and support (Eionet 2019). Still, in general, the survey data and thesis findings concur that industrial symbiosis has a positive impact on environmental values and climate change mitigation in Kymenlaakso.

13. Do you feel that your company prepares for the challenges posed by climate change through means of industrial symbiosis?

"Koetteko yrityksenne valmistautuvan ilmastonmuutoksen asettamiin haasteisiin teollisen symbioosin keinoin?

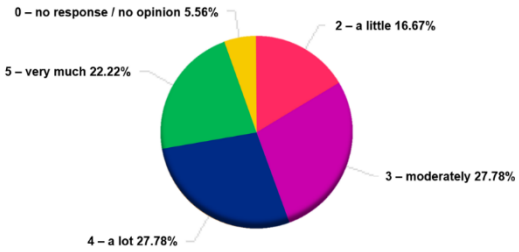


The responses to question 13 reveal a mixed approach by companies in Kymenlaakso towards integrating industrial symbiosis for climate change preparedness. This mirrors the thesis's findings, which indicate an uneven adoption of industrial symbiosis practices in the region. The thesis highlights that while some companies are proactive in embracing industrial symbiosis as a tool for climate resilience, others lag behind. This is in line with insights from sources like Savikko et al. (2019), which emphasize the need for more comprehensive adoption of sustainable practices in industrial operations. One respondent gave a comment (translation): *"It would take a little help from the operating environment to pull bigger changes, but the previously mentioned avoidance of unnecessary logistics and resource efficiency are our main themes. Zero emissions is a vision".* The respondent's comment about the necessity of external support and focus on resource efficiency reflects the thesis's discussion on the importance of an enabling environment for industrial symbiosis. This perspective finds support in Finnish national policies and initiatives, as discussed in sources like Sitra (n.d.), which advocate for enhanced collaboration and support mechanisms to foster sustainable industrial practices. Both the survey results and the thesis underscore the potential of industrial symbiosis in contributing to climate change mitigation, while also highlighting the need for a more uniform and supported approach across the Kymenlaakso industrial sector.

Operational and technical aspects:

14. How much do you think transportation costs affect resource distribution and material circulation in Kymenlaakso?

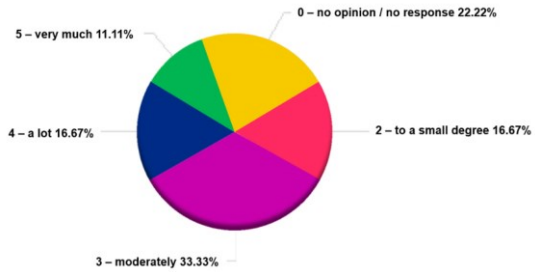
"Kuinka paljon arvelette kuljetuskustannusten vaikuttavan resurssien jakeluun ja materiaalikiertoon Kymenlaaksossa?



The responses to question 14 indicate that transportation costs significantly influence resource distribution and material circulation in Kymenlaakso, with a combined 50% of respondents acknowledging a major impact (27.78% '4' = a lot & 22.22% '5' = very much). This aligns with the thesis findings that emphasize the role of logistics in industrial symbiosis. A comment by one respondent (translated): *"Rather slightly, because road transport has been a little too cheap for years".* suggests an underestimation of transportation's environmental and economic impact, resonating with the thesis's discussion on the need for efficient logistics management (Kymenlaakson liitto 2023d; Savikko et al. 2019). In essence, the survey and thesis converge on the criticality of transportation in shaping resource flow dynamics, underscoring its pivotal role in the effective implementation of industrial symbiosis in Kymenlaakso.

15. How much would you estimate technological innovations contribute to the promotion of industrial symbiosis in Kymenlaakso?

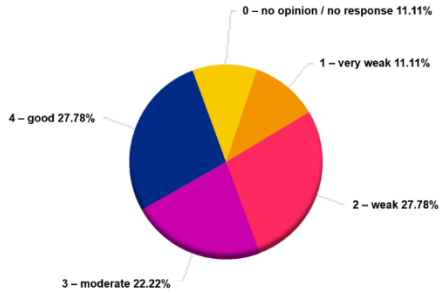
"Kuinka paljon arvioisitte teknologisten innovaatioiden edistävän teollista symbioosia Kymenlaakson alueella?



Responses to question 15 indicate a moderate to high belief in the role of technological innovations in advancing industrial symbiosis in Kymenlaakso. A third (33.33%) views technology as contributing reasonably, while 27.78% believe it contributes a lot or very much. This perspective aligns with the thesis findings, which emphasize the importance of technological advancements in facilitating industrial symbiosis. The thesis discusses how innovations, particularly in waste management and resource efficiency, are crucial for industrial symbiosis (Savikko et al. 2019). These technologies enable more efficient use of resources and help in identifying new opportunities for material exchange. A comment by one respondent (translated): *"New projects and letters of intent would bring new technology to Kymenlaakso. Let's hope they will be realized in a great way!"* echoes this sentiment, suggesting optimism about future technological contributions to industrial symbiosis. Furthermore, the thesis refers to studies like National Audit Office of Finland (2019) and Eionet (2019), which highlight the role of technology in enhancing material efficiency and circular economy practices. These studies support the survey findings, indicating that technological innovation is a key driver in the successful implementation of industrial symbiosis, potentially leading to more sustainable industrial practices in Kymenlaakso.

16. How would you rate the readiness of your company to utilize technology that supports industrial symbiosis and make investments in such technology?

"Millaiseksi arvioisitte yrityksenne valmiuden hyödyntää teollista symbioosia tukevaa teknologiaa ja investoida siihen?"

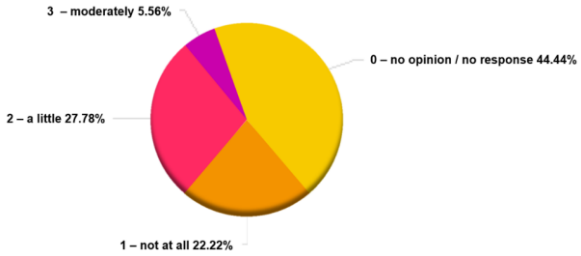


Answers to question 16 indicate a varied readiness among Kymenlaakso companies to invest in technology supporting industrial symbiosis. While 27.78% rate their readiness as good, an equal number (27.78%) considers it weak and 22.22% see it as reasonable. A written comment (translation): *"There is a lot of interest in these, but with the current performance, the investment readiness is non-existent. Possible through subsidies, but direct investment in these requires recovery in finances and cash flows"*, reflects a common challenge: interest in symbiotic technologies exists, but financial constraints and the need for subsidies hinder direct investment. This aligns with the thesis findings, which emphasize the importance of financial viability and support for successful industrial symbiosis implementation (Ventura et al. 2023; National Audit Office of Finland 2019; Eionet 2019). These studies highlight the need for financial incentives and support mechanisms to facilitate the adoption of symbiotic practices and technologies. The thesis also references the work of Henriques et al. (2021), underscoring the importance of economic factors in the success of industrial symbiosis initiatives. Both the responses and the thesis findings converge on the importance of financial readiness and support for the adoption of

industrial symbiosis technologies. The need for subsidies and financial recovery before investing in these technologies is a key factor that resonates with the broader discussions in the thesis about the economic aspects of industrial symbiosis.

17. Do you think that operating methods required by industrial symbiosis will increase energy consumption in your company?

"Uskotteko, että teollisen symbioosin edellyttämät toimintatavat lisäävät yrityksenne energiankulutusta?

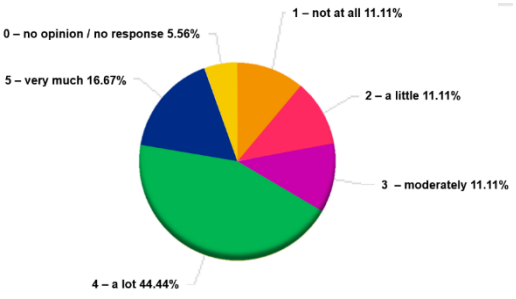


Answers to question 17 reveal a mixed perception regarding the impact of industrial symbiosis on energy consumption. A significant 44.44% did not respond, indicating a possible lack of clarity or opinion on the matter. Among those who did respond, 22.22% believe it will not increase energy consumption at all, while 27.78% think it might increase it a little. A written comment (translation*): "It depends a little on what it means in practice. Digitization is sought for solutions to excessive bureaucracy, but regardless, it may increase workload and consumption. There are also examples that the requirements of the law can be fulfilled painlessly"*, suggests that the impact depends on the specific practices and the balance between digitization and increased workload. This reflects the thesis findings, which discuss the complex relationship between industrial symbiosis and energy consumption. The thesis, drawing on references like National Audit Office of Finland (2019) and Eionet (2019), suggests that while industrial symbiosis aims to optimize resource use, including energy, the actual impact on energy consumption can vary depending on the specific practices and technologies implemented. The thesis also refers to Henriques et al. (2021), highlighting the importance of considering the overall environmental and energy impact of industrial symbiosis practices. Nonetheless, in general, industrial symbiosis is considered as a means to decrease energy consumption and enhance effective energy circulation (Kotkan Energia 2023; Li, Cui & Han 2015; Teräs & Mikkola 2016; SCALER 2023). The survey and other findings both indicate that the effect of industrial symbiosis on energy consumption is not straightforward and depends on various factors, including the specific methods and technologies used.

Market and public opinion:

18. How much do you think customer or product demand affects the introduction or implementation of industrial symbiosis?

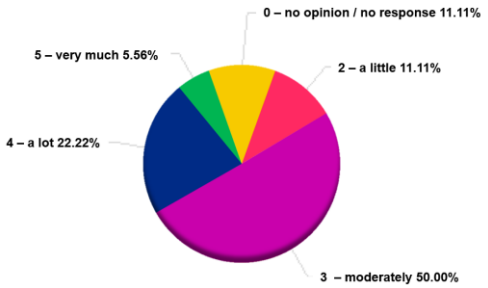
"Kuinka paljon uskotte asiakas- tai tuotekysynnän vaikuttavan teollisen symbioosin käyttöönottoon tai toteutukseen?"



Regarding question 18, the majority of respondents (61.11%) believe that customer demand greatly impacts the implementation of industrial symbiosis. This aligns with the thesis's exploration of market dynamics and mirrors its findings, which indicate that market forces such as demand are key drivers in shaping industrial symbiosis practices (Kauppalehti 2020; Kouvolan Sanomat 2020; Henriques et al. 2021; Mallawaarachchi et al. 2021). One respondent's comment (translated): *"Some products manufactured in the area have extremely precise acceptance criteria and therefore e.g., material recycling has its challenges. For example, reusable or recycled material is not suitable for all uses".* The comment echoes the thesis's insights into the complexities of implementing industrial symbiosis in certain specialized manufacturing processes or industries (Yang et al. 2022). This applies e.g., to the chemical industry, in which handling of hazardous substances or toxic waste may hinder the implementation of industrial symbiosis regardless of favorable market demand or the willingness of potential business partners to cooperate in material circulation. According to the survey answers and other findings, the success of industrial symbiosis is dependent on the adaptability of industries to evolving market demands and on the compatibility of recycled or repurposed materials within existing production frameworks.

19. How much do functional industrial symbiosis models, case examples and public opinions affect the realization of industrial symbiosis in companies in Kymenlaakso?

"Kuinka paljon hyvin toimivat teollisen symbioosin mallit, tapausesimerkit ja julkiset mielipiteet vaikuttavat teollisen symbioosin toteutumiseen Kymenlaakson yrityksissä?"

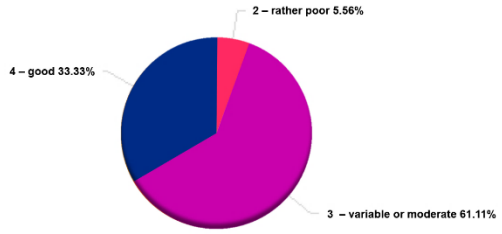


In the answers to question 19, a large majority (77.78%) acknowledges at least a reasonable impact of functional industrial symbiosis models, case examples and public opinion on the realization of industrial symbiosis in Kymenlaakso. This is in line with the findings of the thesis. As seen in references like Mirata & Emtairah (2005) and the European Commission (2020), practical models and public perception play a crucial role in shaping industrial symbiosis initiatives. One comment was given (translation): *"Hamina's battery factory project is a good example of how public pressure changes the flow of raw materials in building design. The construction company tries to downplay its environmental impact under public pressure. We'll see how it goes"*. This opinion reflects the thesis's exploration of how external pressures and successful models can motivate companies to adopt more sustainable practices, resonating with insights from sources like the National Audit Office of Finland (2019) and Eionet (2019). The survey data and the thesis text collectively highlight the significant role of existing symbiosis models, public perception and case studies in influencing the adoption and implementation of industrial symbiosis in Kymenlaakso.

Inter-company relations:

20. What is the atmosphere between companies in Kymenlaakso; e.g., the level of mutual trust and the ability to co-operate?

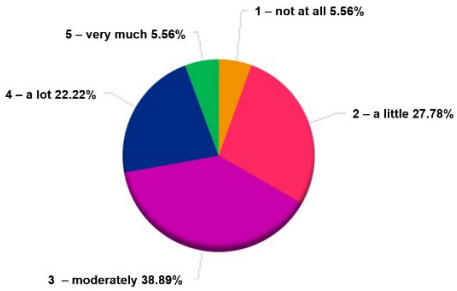
"Millainen on mielestänne yritysten välinen ilmapiiri Kymenlaaksossa; esimerkiksi keskinäinen luottamus ja yhteistyökyky?"



Responses to question 20 – indicating a predominantly moderate to good atmosphere of mutual trust and cooperation among companies in Kymenlaakso – align with the thesis's findings. The thesis discusses the importance of trust and collaboration for successful industrial symbiosis (Eionet 2019; Mallawaarachchi et al. 2020; European Commission 2020) and the negative impact of distrust in business operations, as highlighted by Kouvolan Sanomat (2020). The thesis emphasizes that inter-company trust and cooperation are crucial for industrial symbiosis, resonating with the survey's indication of a generally positive atmosphere in Kymenlaakso.

21. Do you believe that operating methods representing industrial symbiosis (between your company and other companies) will increase in the future?

"Uskotteko, että teollista symbioosia edustavat toimintatavat (yrityksesi ja muiden yritysten välillä) lisääntyvät tulevaisuudessa?"

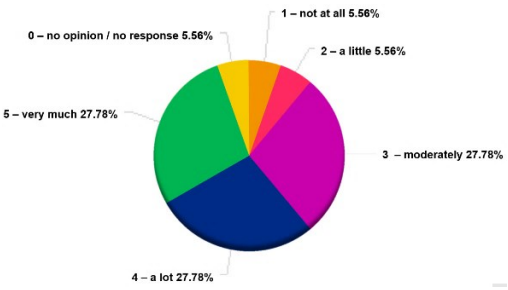


Answers to question 21 show a general belief in the increase of industrial symbiosis practices in the future and thus align with the thesis's projection of growing adoption. The thesis, refering to studies like Haq, Välisuo & Niemi (2021) and the European Commission (2020), suggests an upward trend in industrial symbiosis, driven by environmental, economic and technological advancements and national or supranational initiatives and cooperation programs like FISS and the BIS Project (National Audit Office of Finland 2019; Eionet 2019; FISS 2023; Dansk Symbiosecenter 2021). This perspective is mirrored in the survey responses, where a majority foresee a reasonable to significant increase in symbiotic operations. Both the survey results and the thesis findings suggest optimism about the future of industrial symbiosis in Kymenlaakso, driven by a combination of environmental imperatives and evolving industrial practices.

The war in Ukraine, a major external factor affecting the region:

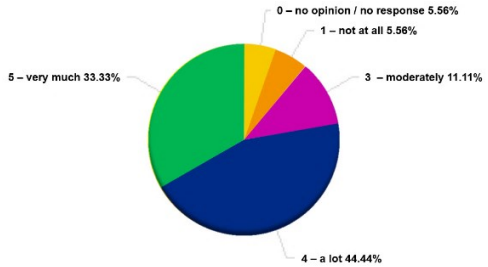
22. Has the war in Ukraine had an impact on your company's resource flows and material procurement?

"Onko Ukrainan sota vaikuttanut yrityksenne resurssivirtoihin ja materiaalihankintoihin?"



The survey responses to question 22, which indicate a significant impact of the Ukraine war on resource flows and material procurement in Kymenlaakso companies, are in line with the thesis findings. E.g., in the referred study by Kinno (Kouvola Innovation Oy 2022), the geopolitical shifts and their substantial effects on regional industries are discussed, particularly in terms of resource procurement and supply chain disruptions. The conflict involving Russia and Ukraine has led to a re-evaluation of resource dependencies and procurement strategies in the Kymenlaakso region. This shows in the survey responses, where a majority of respondents (83.4%; options '3' = moderately, '4' = much - and '5' = very much, 27.8% each) acknowledge a moderate to very significant impact of the war on their company's resource flows. A written comment in line with these perceptions was also given (translation): *"Supporting Russia in all trade has been reduced and the shutdowns of the factories in the region have partly forced the companies to look for turnover elsewhere".* In summary, both the survey results and the thesis underscore the profound influence of geopolitical changes on industrial operations in Kymenlaakso, aligning with the broader narrative of the thesis about the region's economic and industrial adaptation in response to external events.

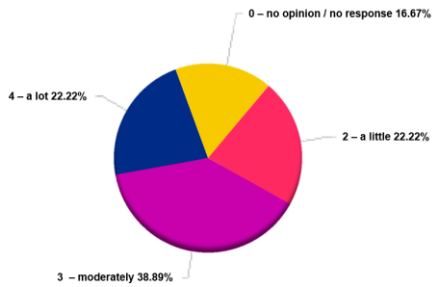
23. Has the war in Ukraine had an impact on your company's profitability figures?
"Onko Ukrainan sota vaikuttanut yrityksenne kannattavuuslukuihin?"



Strongly linked to the previous question, the survey responses to question 23 reveal a significant impact of the war in Ukraine on the profitability of companies in Kymenlaakso. The majority of respondents indicate a substantial effect, with 44.44% stating 'much' and 33.33% 'very much'. This aligns with the thesis findings, particularly the study by Kinno (Kouvola Innovation Oy 2022), which discusses the economic repercussions of geopolitical shifts on regional industries. The thesis emphasizes how the conflict and subsequent economic constraints, including trade disruptions and increased operational costs, have adversely affected the financial performance of companies in Kymenlaakso. This is mirrored in the survey results, where a significant portion of respondents acknowledge a notable decline in profitability due to the war. This situation highlights the importance of adaptive strategies and resilience in the face of external pressures and emphasizes the industries' need for external support: relevant data, subsidies, tax reductions and practical guidance – a theme which has come up in other parts of the survey.

Company size and origin:

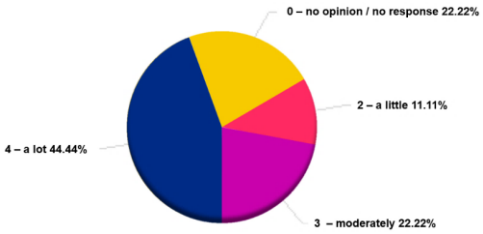
24. Do you feel there are differences in industrial symbiosis implementation or readiness for collaboration between local, national, multinational and foreign companies in Kymenlaakso?
"Koetteko, että paikallisten, kansallisten, monikansallisten ja ulkomaisten yritysten välillä olisi eroja teollisen symbioosin toteutuksessa tai yhteistyövalmiudessa Kymenlaaksossa?"



Question 24 explores the perceived differences in industrial symbiosis implementation and readiness for collaboration among companies with differing ownership or central management (nationality). The survey results indicate a general consensus that there are indeed differences, with 38.89% of respondents feeling these differences are moderate and 22.22% believing they are significant. This view aligns with the thesis findings, which highlight the complexity of industrial symbiosis and the varying capabilities and motivations of different types of companies. For instance, local companies might have a stronger connection to the community and a more immediate interest in regional sustainability efforts, as suggested by studies like Haq, Välisuo & Niemi (2021), which emphasize the role of local engagement in industrial symbiosis. On the other hand, multinational and foreign companies may bring different perspectives, resources and technologies, as discussed in Henriques et al. (2021), but might face challenges in adapting to local contexts. One written comment was given in the survey (translation): *"There are many differences. I really can't understand that a foreign mining company or entity is allowed to use Finnish soil freely with incomplete permit processing, but a local entrepreneur is not allowed to build even a sauna cabin on his own plot of land without the permission of the municipal government, according to building permit decisions (I'm not talking about my own experience)".* The comment is in line with the findings of Kinno (Kouvola Innovation Oy 2022), which focus on the influence of policy and regulatory frameworks on industrial activities, especially the effects of the ongoing war in Ukraine and its effects on the local business life. Naturally, the sanctions aimed at Russia, a traditional trade partner of many companies in Kymenlaakso, greatly affect the operational and cooperation readiness of both national and foreign companies in the context of industrial symbiosis.

25. Do you feel there are differences in industrial symbiosis implementation or readiness for collaboration between small, medium-sized and large companies in Kymenlaakso?

"Onko pienten, keskisuurten ja suurten yritysten välillä mielestänne eroja teollisen symbioosin toteutuksessa tai yhteistyövalmiudessa Kymenlaakson alueella?"



For question 25, there was a comment in the survey (translation): *"Yes, because bigger organizations have stricter obligations and bigger material resources. The requirements for all parties also increase as larger cooperation patterns are concerned."* Indeed, the material flows and capacity of large companies are of more importance in terms of general environmental issues and natural resources. Requirements in e.g., sustainability reporting (Ecobio 2023) may be stricter for larger companies, but as mentioned in the thesis (regarding Landskrona: 3.5.5.), local companies are of great importance in the context of industrial symbiosis. The overall weight value and investments of small and medium-sized local enterprises (SMEs) in industrial symbiosis -related processes and collaboration may be greater in relation to the size of the companies and financial figures (Benedetti 2017; Mirata & Emtairah 2005). Industrial symbiosis may function best in closely knit areas; in tightly woven environments such as industrial symbiosis parks or small communities (Ruiz–Puente, Romero–Arozamena & Evans 2015). Due to this – as if as a moral obligation and as an investment in the well-being of the vicinity, local residents and the local business economy –, the financial support and industrial symbiosis -related guidance of locally based small and medium-sized companies could be enhanced also in Kymenlaakso.

Appendix 4. Survey Answers as Percentage Shares

Answer option	('0')	('1')	('2')	('3')	('4')	('5')	
18 responses /question	% of 18	% of 18	% of 18	% of 18	% of 18	% of 18	Total %
Question 1	11,11	11,11	22,22	33,33	16,67	5,56	100
Question 2	5,56	50	22,22	22,22	0	0	100
Question 3	5,56	11,11	33,33	27,78	22,22	0	100
Question 4	27,78	11,11	11,11	44,44	5,56	0	100
Question 5	16,67	16,67	16,67	11,11	38,89	0	100
Question 6	22,22	0	27,78	44,44	5,56	0	100
Question 7	27,78	16,67	16,67	38,89	0	0	100
Question 8	44,43	16,67	5,56	27,78	5,56	0	100
Question 9	27,78	0	5,56	16,67	44,44	5,56	100
Question 10	11,11	0	27,78	44,44	16,67	0	100
Question 11	11,11	0	50	33,33	5,56	0	100
Question 12	11,11	0	16,67	38,89	27,78	5,56	100
Question 13	11,11	16,67	27,78	22,22	22,22	0	100
Question 14	5,56	0	16,67	27,78	27,78	22,21	100
Question 15	22,22	16,67	16,67	33,33	16,67	11,11	100
Question 16	11,11	11,11	27,78	22,22	27,78	0	100
Question 17	44,44	22,22	27,78	5,56	0	0	100
Question 18	5,56	11,11	11,11	11,11	44,44	16,67	100
Question 19	11,11	0	11,11	50	22,22	5,56	100
Question 20	0	0	5,56	61,11	33,33	0	100
Question 21	0	5,56	27,78	38,89	22,22	5,56	100
Question 22	5,56	5,56	5,56	27,78	27,78	27,78	100
Question 23	5,56	5,56	0	11,11	44,44	33,33	100
Question 24	16,67	0	22,22	38,89	22,22	0	100
Question 25	22,22	0	11,11	22,22	44,44	0	100

Table based on survey responses (Kyselynetti 2024)

Note: Since the percentages are rounded to two decimal places (e.g., 16.6666…= 16.67), the computational total % may be 100 +/- 0.0 - 0.2 based on the figures presented in the table.

Appendix 5. Digital Timestamps of the Survey Responses

Respondent #1	3.12.2023 20:10	3.12.2023 20:13
Respondent #2	3.12.2023 20:16	3.12.2023 20:19
Respondent #3	4.12.2023 7:35	4.12.2023 7:43
Respondent #4	4.12.2023 8:44	5.12.2023 8:01
Respondent #5	4.12.2023 8:59	4.12.2023 9:09
Respondent #6	4.12.2023 9:51	4.12.2023 10:00
Respondent #7	4.12.2023 10:15	18.12.2023 8:21
Respondent #8	4.12.2023 10:40	4.12.2023 10:50
Respondent #9	4.12.2023 10:57	4.12.2023 11:03
Respondent #10	4.12.2023 12:50	4.12.2023 12:54
Respondent #11	4.12.2023 13:25	4.12.2023 13:33
Respondent #12	4.12.2023 15:00	4.12.2023 15:17
Respondent #13	4.12.2023 15:07	4.12.2023 15:12
Respondent #14	5.12.2023 8:25	5.12.2023 8:28
Respondent #15	8.12.2023 10:54	8.12.2023 10:59
Respondent #16	8.12.2023 13:06	8.12.2023 13:38
Respondent #17	8.12.2023 13:31	8.12.2023 13:36
Respondent #18	21.12.2023 8:50	21.12.2023 9:07

Timestamps from Kyselynetti (2024)