IIIEE Theses 2021:23

Constraints and Enablers for Industrial Symbiosis between SMEs in the Swedish Agri-Food Sector

An Exploration of the Role of Trust, Knowledge, Awareness, and Willingness

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Thesis for the fulfilment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, May 2021

Published in 2021 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
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ISSN 1401-9191

Acknowledgements

This thesis is the final step in what has been an amazing chapter in my life. It is a difficult decision to leave a job you enjoy, your family, and friends and move an ocean away to pursue a Masters in a new country. Lund has been such a wonderful place to live and study, with the many beautiful parks and centuries old buildings to inspire a curious mind. Thank you to my partner, 'sambo', and now fiancée Raneal for joining me on this journey, supporting me and taking on these challenges together. It was an adventure down all sorts of winding and sometimes uphill roads, but the journey continues, and the views are unbeatable. Oh, and to our newest family member Elton, thanks for being so cute, taking me away from the screen to go on lots of walks, and keeping my toes warm as I typed.

I would not be here without my family, and that can be taken as literally as you so please, but your support and confidence in me has empowered me to continue growing. It was amazing living in Europe and getting to know my extended family better in Romania and Hungary, after having lived a continent away for most of my life.

To the insti family, thank you for your positivity, energy, and camaraderie. The IIIEE has some truly impressive minds roaming the halls, and I will take any chance I can to keep in touch with this dedicated group of environmental superheroes. This program has taught me so much.

This thesis would not have been possible without the support of my supervisor Philip. Thank you for giving me the independence and freedom to tackle this challenge, while guiding me with your notable experience and mastery of these topics.

To the leaders at the companies that made it into this thesis, your time, willingness, openness, and insights form the backbone of this work, and for that I am very grateful. To the many others who helped guide my work, from researchers, professionals in the field, and my peer-reviewers, this would be a mess of a thesis were it not for your support. To each and every person who has been a part of this thesis, thank you.

Finally, to my classmates in Batch 26, a massive congratulations is in order. We learned so much together, took on the task of fixing this world, navigated a worldwide pandemic, had some amazing insti and park parties, and zoom call after zoom call, we finally made it. I am very excited to see the bright futures ahead of you all.

László

20 May 2021

Abstract

Research conducted on industrial symbiosis often brings up the importance of trust and collaboration related constraints and enablers if inter-organizational efforts are to be pursued. This is also found in literature related specifically to Sweden and its agri-food sector. There are limited examples of collecting empirical evidence on trust in relation to IS and even less so with a focus on SMEs. This study works from a supposition that applying collected empirical data to an analytical framework on the interchanges between trust, knowledge, awareness, and willingness (TKAW) will increase understanding whether synergies can exist between them and thus it will also test the usability of this analytical framework. This study conducted content analysis through a literature review and collected qualitative data on TKAW and on constraints and enablers through semi-structured interviews and surveys with five agri-food case-company SMEs and two facilitators in Skåne, Sweden and input findings into the TKAW analytical framework. The results showed that a theoretical network of synergy would exist between them as per the frameworks logic. Constraints and enablers relevant to the companies that were both additional to and in line with the literature examined were discovered such as the importance of information access, cooperation between actors and the importance of trust. These findings provide useful insight for other practitioners to understand key enablers and constraints to plan for industrial symbiosis opportunities, and to help facilitators focus and target their support for the companies they are working with. The work concludes that the TKAW framework can be used together with empirical data collected through case studies, and thus provides opportunities for future input to more complex modelling applications such as agent-based modelling.

Keywords: Industrial Symbiosis, SMEs, Agri-Food Industry, Trust

Executive Summary

A major area putting stresses on the environment is our means of food production (Food and Agriculture Organization of the United Nations, 2019). In fact, in Sweden, one third of every household's greenhouse gas (GHG) emissions are related in some way to food consumption (Livsmedelsverket, 2020). Industrial symbiosis (IS) is a term that refers to synergies, or collaborative partnerships between firms that results in the exchange of material or energy by-products (Pigosso et al., 2018). This leads to both economic benefits as resource-efficiency is often improved, and environmental benefits, because of less resource extraction and less waste (Mirata & Emtairah, 2005).

Research conducted on industrial symbiosis often brings up the importance of trust and collaboration related challenges if inter-organizational efforts are to be made (Hewes & Lyons, 2008). This is also found in literature related specifically to Sweden and its food sectors (Beckeman, 2011). There are limited examples of collecting empirical evidence on trust in relation to IS and even less so with a focus on SMEs (Rincón-Moreno et al., 2020). While there is ample research on tools for technical matches, there is less available on overcoming these social and organizational challenges (Hewes & Lyons, 2008). This also sets the groundwork for further research of these aspects through the use of modelling tools (Batten, 2009). Recently there have been more efforts made to model and analyze these trust related aspects; however, they do not collect empirical data from companies and instead rely of theoretical assumptions (Ghali et al., 2017). Overall, trust and social embeddedness which defines the nature, depth and degree of inter-relationships is seemingly less studied than the other more technical aspects of industrial symbiosis (Chertow & Ehrenfeld, 2012; Ghali et al., 2017; Schiller et al., 2014) and there is a specific lack of such studies done on SMEs (Pigosso et al., 2018).

This study works from a supposition that applying collected empirical data to an analytical framework on the interchanges between trust, knowledge, awareness, and willingness (TKAW) will increase understanding whether synergies can exist between them and thus it will also test the usability of the framework. This informs further research to be conducted using modelling tools such as agent-based modelling (Lütje et al., 2020). Therefore, the study seeks to use an existing framework by Ghali et al. (2017) which is based on trust, knowledge, awareness and willingness, adapt it as an analytical framework and collect empirical data to test the framework with. Exploring the complexities of trust between organizations, knowledge of the concept and innovations, awareness of opportunities, and a willingness to accept a symbiotic relationship may help foster more exchanges and lead to more circularity in the Swedish agri-food sector.

This thesis sought to contribute to understanding of constraints and enablers to IS for SMEs and how aspects of trust, knowledge, awareness, and willingness (TKAW) can be gathered from case studies and used to test a conceptual model developed for future simulation through agent-based modelling. The purpose of the study is to address the gaps in understanding of TKAW social aspects roles in IS network creation in relation to SMEs and recommend future research potential. The thesis operationalizes this aim and purpose by seeking to achieve the following objectives:

- Identify examples of key constraints and enablers to establishing by-product resource linkages between SME agri-food firms in Skåne, Sweden. These include food growers as well as food processors.
- Delineate how linkages between agri-food SMEs may be achieved by addressing their constraints, enablers, and TKAW aspects.
- Delineate how facilitators may help support efforts to find possible resource linkages.

- Test an analytical framework and lay the groundwork for further research by using modelling tools to generate simulated results.

These objectives have therefore led to the study's three research questions:

RQ 1) What are SME specific constraints and enablers to industrial symbiosis in Skåne, Sweden?

RQ 2) How can trust, knowledge, awareness, and willingness (TKAW) aspects from empirical study be applied to a proposed analytical model to support industrial-symbiosis creation?

RQ 3) How are SMEs efforts to enter IS networks and increase TKAW aspects supported by facilitators?

To answer these questions and operationalize the study, the **research methodology** included conducting a literature review for content analysis followed by qualitative empirical data collection from five case study companies through semi-structured interviews and a survey. There were also two exploratory interviews with facilitators and attendance at an online conference. These findings were then analyzed using coding to find common themes and core concepts, as well as applying the findings through a characterization process to convert responses as useable inputs to the previously mentioned analytical framework.

The **main findings** were presented in relation to each research question. For **RQ 1** they were as follows: The identified **constraints** for SMEs included operating strictly within a business-to-business setting, having limited institutional capacity and resource availability; supply and demand mismatches and reliance; limited governmental support; food shelf-life; organics certifications; allergen strictness and cross-contamination worries; and finally, the fact that in small companies' by-product and waste planning are not top priorities. The identified **enablers** were found to be participating in regional networks; having a higher absorptive capacity; having a meta-knowledge on their networks TKAW aspects; increased cooperation between actors; increased access to information; a higher potential value of by-products; and values-based and ethically driven company cultures.

To answer **RQ 2**, the interviews and surveys served as inputs to a **TKAW analytical framework**. Each TKAW aspect ended up having a company leader, while one company fell outside of the network as a follower needing support to enter the network. This enabled the framework logic process to be completed and satisfied as seen in the following Figure I below:

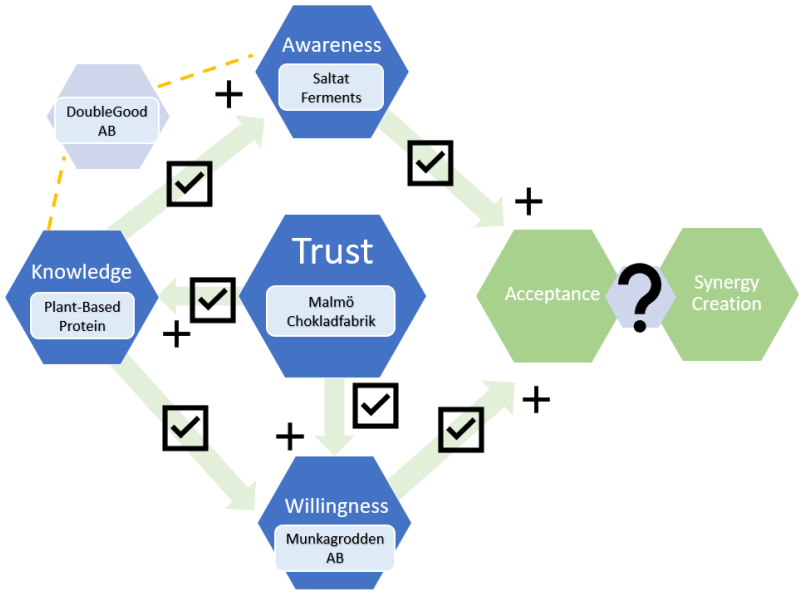

Figure I: Completed TKAW Framework

This was unexpected, and a good indicator that even with a random selection of actors, there is an opportunity to study potentials for co-operation and synergy creation. Trust was an important aspect to all companies, knowledge and awareness levels varied, while overall willingness was high from all case companies. This undertaking applied real-world empirical values to the TKAW aspects instead of fixed theoretical values and therefore tested the applicability of empirical data to the TKAW framework. This informs further study using more complex modelling applications such as agent-based modelling.

The findings for **RQ 3** were that facilitators can help with trust building, knowledge diffusion, but also need development and ways of incorporation into networks. Noted relevant facilitators were industry organizations as well as venture groups that share similar business goals, structure, and visions. The case companies felt local authorities and governments could be more of an active facilitator and this could have implications for Sweden's National Plan for Circular Economy which mentions IS as a key pillar. Finally, an EU-wide facilitator platform recently launched called CircLean which aims to support SMEs efforts in Europe to achieve industrial symbiosis through the development of an online platform for knowledge, a common methodology and a labelling scheme.

The contributions of the thesis are targeted at three main audiences. The first one being **practitioners**, as discussing ways of becoming more aware of industrial symbiosis opportunities, increasing their knowledge on the concept, and identifying common enablers and constraints can help practitioners across the food-sector in Skåne get ahead of regulation or legislation efforts from governments. It can also inform them to better develop their institutional and absorptive capacities well in advance to take advantage of potential resource-exchange opportunities.

Second, the study helps inform **facilitators**, be they industry associations, government authorities or private consultants, of constraints and enablers and how they may help companies diffuse knowledge in their networks. This can be done by better understanding the importance that trust, knowledge, awareness and willingness play in network creation and diffusion and then targeting focus to support these aspects where they need it most.

Third, the study shows potential for future research in **academia**. Developing a way to measure the ability and capacity for the companies to effect change in the networks would increase the robustness of the TKAW analytical framework. The importance of the TKAW aspects could also be input to a sensitivity analysis to better determine how the variables effect outcomes. There is another opportunity for a deeper examination of the constraints and enablers as per the resource-based view which refers to the knowledge, capacities, and resources of the company, and the resource-dependency view which offers the perspective of interdependence between companies for key resources. This would require gathering more detailed internal company information. Finally, the most applicable opportunity would be to apply empirical findings as inputs to a modelling application such as agent-based modelling, and better simulate the network diffusion and synergy creation. This study informs these efforts as the analytical framework and its logics ended up being useable with empirical data. As these modelling applications have capability to increase complexities on the framework, more case study companies can be included, increasing the empirical data collection. This could also be applied to an active network to validate the model.

Overall, the study offered a unique opportunity to work together with a diverse group of SME case companies in the Skåne agri-food sector to determine important factors to achieve more by-product resource exchanges, test an analytical framework for industrial symbiosis, and look for ways to increase collaboration in their networks to contribute in a small way to a more circular agri-food industry in Skåne.

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Abbreviations

ABM – Agent-Based Model

EU – European Union

GHG – Greenhouse Gases

IS – Industrial Symbiosis

NPK – Nitrogen Phosphorus Potassium

RQs – Research Questions

SMEs – Small Medium Enterprises

TKAW – Trust, Knowledge, Awareness, Willingness

1 Introduction

"If we fix the food, we also fix the planet" Johan Rockström, 2018

The compounding effects of increasing resource consumption, increasing populations and land-use changes are contributing to a changing climate. We have now entered a new epoch, one of the Anthropocene where human activities are responsible for many of Earth's altered physical, biological, and chemical processes (IPCC, 2019). A major area putting stresses on the environment is our means of food production (Food and Agriculture Organization of the United Nations, 2019). In fact, in Sweden, one third of every household's greenhouse gas (GHG) emissions are related in some way to food consumption (Livsmedelsverket, 2020). Food production also contributes to land-systems change, such as deforestation, soil degradation and biodiversity loss (Food and Agriculture Organization of the United Nations, 2019). Agriculture is also responsible for over 70% of global water usage (Meybeck et al., 2012).

All of this must also be understood within the context of a positive feedback loop, where a changing climate is also putting increasing pressure on crops and livestock (Bajzelj & Richards, 2014). Yields as a result of climate change may be 10 to 25% lower while productions levels need to increase by 60% by 2050 to feed a growing population (Food and Agriculture Organization of the United Nations, 2019). With the food productions systems left in their current state they will rely on an increase of virgin resources such as fertilizer and pesticides (Bajzelj & Richards, 2014). This presents an issue as the nitrogen, phosphorus, and potassium (NPK) fertilizers are reliant on finite resources, such as phosphate rock, which is estimated to be depleted in 50 to 100 years (Cordell et al., 2009). Additionally, due to an excess application of fertilizers, runoff of these substances to streams, rivers and lakes contribute to increasing eutrophication (Cordell et al., 2009). In the EU, about 20% of all food production is lost or wasted (European Commission, 2020). Therefore, a transformation of the agri-food industry is needed to overcome these challenges.

Industrial symbiosis (IS) is a term that refers to synergies, or collaborative partnerships between firms that result in the exchange of material or energy by-products (Pigosso et al., 2018). This leads to both economic benefits as resource-efficiency is often improved, and environmental benefits, because of less resource extraction and less waste. IS is a concept vital to achieving a circular economy, and thus is finding more political and corporate support (Fraccascia et al., 2019). In fact, the latest EU Circular Economy Action Plan mentions IS as one of the key enablers of a circular economy and outlines a certification and reporting scheme that is industry led (European Commission, 2020). Companies are major contributors to resource depletion, biodiversity loss, and to the pollution of air, land, and water (Chen et al., 2017). Solutions to these problems require systemic change, not just within a company's boundaries, but also outside of them (Chen et al., 2017). Therefore, finding linkages between other firms to help close the resource loops in well-managed industrial networks is an important goal (Pigosso et al., 2018).

The Nordic countries and in particular Sweden are leaders in the recycling and waste management sectors and are therefore an interesting case to study, with only around 1% of waste going to landfill (Hillman, 2015). This thesis will therefore be focussed on Sweden, in particular the southern region of Skåne due to its high contribution to the country's agri-food sector (Olsson, 2015). The Swedish National Plan for Circular Economy also acknowledges IS as one of the key pillars for a transition to a more sustainable economy and therefore the concept shows widespread political support (Government Offices of Sweden, 2020).

The study will focus on agri-food producing small-medium enterprises (SMEs) in Skåne and the unique implications they face when looking into implementing IS. It is estimated that in Europe SME's contribute to 64% of industrial waste with contributions in the food sector being made up of food waste, waste water and packaging materials (Publications Office of the European Union, 2014). It will seek to address a gap in knowledge when it comes to achieving IS specifically between SMEs (Ormazabal et al., 2016).

As an inter-organizational endeavor, IS is a complex goal, requiring coordination, innovation and adapting of existing processes (Aid, 2017). This is particularly challenging for SMEs due to their limited capacities, both in terms of human and financial capital (Davies et al., 2016). Research often describes the need for more studies to be done on how the agency or capabilities of firms can be supported through facilitation or inter-organizational efforts (Yeo et al., 2019). It is also often mentioned in the literature that social aspects such as trust, knowledge, awareness and willingness (TKAW) to engage in these linkages are important constraints or enablers (Hewes & Lyons, 2008). Constraints in this study are to be understood as factors that work against or hold companies back from IS linkages and enablers are factors that would motivate or assist in the creation of IS linkages. A potential way to analyze these linkages is through the use of agent-based modelling, which is a model used to simulate interactions between autonomous agents and make predictions about their behaviour (Ghali et al., 2017). Further opportunities exist to explore these TKAW aspects deeper through empirical study of case organizations by academics (Mirata & Emtairah, 2005). These findings could help practitioners in their companies overcome the constraints and take advantage of the enablers either on their own, or with external facilitator support such as government bodies, research organizations or private consultants, who through this understanding are then able to help with these aspects of trust, knowledge, awareness, and willingness.

1.1 Problem Definition

Research conducted on IS often bring up the importance of trust related and collaboration challenges if inter-organizational efforts are to be made (Hewes & Lyons, 2008). This is also found in literature related specifically to Sweden and its food sectors (Beckeman, 2011). Sterr & Ott (2004), postulate that functioning IS networks develop "through a solid foundation of comprehensive information transparency… in order to realize suitable output-input connections, mutual trust among the industrial actors and the willingness to cooperate are essential" (p. 963).

There are limited examples of collecting empirical evidence on trust in relation to IS and even less so with a focus on SMEs (Rincón-Moreno et al., 2020). While there is ample research on tools used for technical matches, there is less available on overcoming these social and organizational challenges (Hewes & Lyons, 2008). Bichraoui et al. (2013) argues that financial or operational problems of implementing IS can be solved using the variety of tools for technical matches, however; human social aspects and decision making is more difficult to assess and solve. This gap therefore sets the groundwork for further research of these aspects through the use of empirical data collection and modelling tools (Batten, 2009).

Recently there have been more efforts made to model and analyze these trust related aspects; however, they do not collect empirical data from companies and instead rely of theoretical assumptions (Ghali et al., 2017). Overall, trust and social embeddedness which defines the nature, depth and degree of inter-relationships is seemingly less studied than the other more technical aspects of IS (Chertow & Ehrenfeld, 2012; Ghali et al., 2017; Schiller et al., 2014) and as mentioned there is a specific lack of such studies done on SMEs (Pigosso et al., 2018).

The diffusion of the concept and innovations related to it are also impacted by the TKAW aspects and there is an opportunity to study how diffusion can be achieved in networks as an outcome of TKAW links (Ghali et al., 2017). Moreover, testing an analytical framework on the interchanges between these aspects can develop understanding whether synergies can be self-organized or aided by facilitation efforts and also may allow for further research to be conducted using modelling tools such as agent-based modelling (Lütje et al., 2020). Therefore, the study seeks to use an existing framework by Ghali et al. (2017) which is based on trust, knowledge, awareness and willingness, use it as an analytical framework or story/narrative-based model, and then collect empirical data to test the framework with.

Exploring the complexities of trust between organizations, knowledge of the concept and innovations, awareness of opportunities, and a willingness to accept a symbiotic relationship may help foster more exchanges and lead to more circularity in the Swedish agri-food sector.

1.2 Aim and Research Questions

This thesis sought to contribute to understanding of constraints and enablers to IS for SMEs and how aspects of trust, knowledge, awareness, and willingness (TKAW) can be gathered from case studies and used to test a conceptual model developed for future simulation through agent-based modelling. The purpose of the study is to address the gaps in understanding of TKAW social aspect roles in IS network creation in relation to SMEs and recommend future research potential. The thesis operationalizes this aim and purpose by seeking to achieve the following objectives:

- Identify the constraints and enablers to establishing by-product resource linkages between SME agri-food firms in Skåne, Sweden. These include food growers as well as food processors.
- Delineate how linkages between agri-food SMEs may be achieved by addressing their constraints, enablers, and TKAW aspects.
- Delineate how facilitators may help support efforts to find possible resource linkages.
- Test an analytical framework and lay the groundwork for further research done by using modelling tools to generate simulated results.

These objectives have therefore led to the study's three research questions:

RQ 1) What are SME specific constraints and enablers to industrial symbiosis in Skåne, Sweden?

RQ 2) How can trust, knowledge, awareness, and willingness (TKAW) aspects from empirical study be applied to a proposed analytical model to support industrial-symbiosis creation?

RQ 3) How are SMEs efforts to enter IS networks and increase TKAW aspects supported by facilitators?

1.3 Scope and Delimitations

The scope of the thesis will be geographically limited to Skåne, Sweden. The richness of soils and the moderate climate of this southern region of Sweden is particularly favourable for food production, and over 25% of food produced in Sweden is produced in Skåne (Olsson, 2015). While Skåne has a higher proportion of large companies than the rest of Sweden, there is a noticeable shift towards micro (<10 employees) and small companies (10-49 employees) in this region (Olsson, 2015). This trend and the drivers behind it are further developed in Chapter 2.

The study will therefore look at analyzing five case studies spread across Skåne, particularly in the agri-food industry with companies classified as SMEs as per the European Union (EU)

definition of <250 employees (Moore & Manring, 2009). It will present these specific case companies' constraints and enablers to industrial symbiosis, capture their social qualitative aspects on TKAW and finally input them into an analytical framework developed from an existing agent-based model. If the framework is determined as compatible and effective with empirical data, it can provide further research opportunities for future simulation in an agent-based model. These results will be further analyzed and discussed in relation to the findings from the literature review and further recommendations made for practitioners, facilitators, and researchers.

The study is limited to virtual by-product and waste synergy exchanges as per Mirata (2018) which will be further defined in Chapter 2, and because it will not examine specific clusters of companies in very close proximity to each other, other forms of synergies such as utility, service and supply synergies will not be discussed. The original intent of the study was to better understand how agent-based modelling could provide a solution for increasing IS uptake by SMEs; however, it was found that no available study had tested their models with actual empirical data. This led to a smaller scope to use case studies as tests for whether an existing agent-based modelling analytical framework would be useable with empirical data.

Empirical collection also presented its own challenges as the study did encounter a limitation on including case companies with higher complexities and more opportunities for material exchanges, and most of the case companies were small with limited resource flows. This limitation came about due to challenges during the Covid-19 pandemic, language barriers as well as limited time from participants. Some food producers contacted were actually owned or operated by larger conglomerate firms and therefore did not fit the study parameters for size. However, testing empirical collection of TKAW aspects and application of these to the analytical framework does not require companies have detailed technical experience on participating in IS exchanges and instead it is enough that they are knowledgeable about IS and interested in developing their capacity towards these opportunities and can speak to the TKAW social aspects of this ambition.

1.4 Ethical Considerations

To best design the study in a fair and ethical manner, there were a set of guiding principles and responsibilities clearly set by the institute under which this study was written. The study is not funded by any external organization and there has been no external influence on the analysis or the conclusions of the study. It strives to present findings in an objective and unbiased manner, incorporating multiple views and disciplines.

As this study involved the participation of practitioners, it is important to mention any participation was voluntary and prior informed consent was collected before collecting and recording data. Names have been redacted from the study, and care was taken to not include or ask for information which provides competitive and confidential advantage to the companies. Prior to the interview, the respondents were informed about the aim and scope of the study and provided with the three overarching research questions guiding the work. They were not asked leading questions, and while the interviews were semi-structured, care was taken to not present bias or limit responses to some intended outcome.

The results and conclusions of the study are not directly linked back to individuals at the companies, and therefore an appropriate level of anonymity is maintained when discussing more sensitive aspects such as relationships, reputations, and credibility. All collected data is stored on the author's personal computer and is not accessible to the public.

The research design has been reviewed against the criteria for research requiring an ethics board review at Lund University and has been found to not require a statement from the ethics committee.

1.5 Audience

The intended audience for this study can be broken down into three main groups. The first group are the practitioners who are looking to overcome their own challenges or act on opportunities towards a more circular value-chain through implementing industrial symbiosis in their own businesses. The second group is those who may act as facilitation actors in an industrial symbiosis network. These may be municipalities or other levels of government, industry-cluster organizations, food industry associations, or even waste management or utility providers. Third, this study could prove useful to those in academia, who may wish to understand more about the gap in implementing industrial symbiosis in agri-food SMEs and how analyzing trust, knowledge, awareness, and willingness aspects can be done using modelling applications.

1.6 Disposition

This study is laid out into five chapters. Following this Chapter 1 introduction to the nature of the problem and the intended outcome of the study, Chapter 2 begins by presenting the concepts and current state-of-knowledge in the field of industrial symbiosis through a literature review on industrial symbiosis both in general, and specific to SMEs. It identifies major constraints and enablers found in the literature. Section 2.5 will discuss the diffusion of the concept between companies, followed by Section 2.6 with a discussion on the unique implications trust has on by-product exchanges. In Section 2.7 and for the remainder of Chapter 2, the focus will be to describe the conceptual and analytical frameworks used to address the gaps found in the literature review, which form the basis upon which the research questions will be answered.

Chapter 3 goes on to describe and help the reader understand the research design used to answer the research questions, and the methods used to collect data, and what kind of materials were collected. It closes by describing how the collected data was analyzed.

Chapter 4 covers the findings of the empirical data collection through the examined case studies. Section 4.1 introduces the five case study companies and presents the data collected through interviews and surveys. It discusses their perceived constraints and enablers to industrial symbiosis and how they score their own levels of trust, knowledge, awareness, and willingness. Section 4.2 analyzes the five companies' scores in the TKAW analytical framework to examine the interplay between these aspects and how they may help to create company synergy linkages. This is followed by Section 4.3 which discusses the role facilitators are perceived to have in supporting these linkages.

Chapter 5 covers the discussion on the findings of the case studies in relation to the findings in the literature review. Section 5.2 serves to reflect on the methods used for the study, as well as the relevance of the analytical framework to the study.

Finally, Chapter 6 summarizes the main conclusions of the study, including some takeaway points for the practitioners, facilitators, and researchers interested in this study. It closes by offering some potential areas to build on this research in the future.

2 Literature Review

The aim of this chapter is to first introduce the agri-food sector in Skåne. It will then discuss the current state of knowledge on constraints and enablers to industrial symbiosis both in general and in particular to SMEs. Later, the importance of trust and how the concept of IS may diffuse among actors either through self-organization or through the help of facilitators is described. Finally, the chapter discusses and outlines the conceptual/analytical framework based on a discussion on diffusion and a potential for modelling TKAW.

2.1 Agri-Food Sector in Skåne

The agri-food sector in Skåne is well developed, with a trend moving towards larger and more specialized farms in Sweden (Swedish Board of Agriculture, 2018). About 2% of the population is employed by the food and agriculture sector, with over 70% being older than 50 years (Swedish Board of Agriculture, 2018). Sugar beets and fruits are almost exclusively produced in this region due to the richness of the soils and the temperate climate, and the dairy sector also plays a large role. Other significant crops are cereals, oilseeds, potatoes and legumes such as peas and beans (Olsson, 2015).

A growing trend in Skåne, has been the 'Smaka på Skåne -Närproducerat och noga utvalt' concept, which can be translated to 'Taste Skåne - produced nearby and chosen with care' (Olsson, 2015). This concept is aiming to help consumers and local producers choose locally produced food products that must be cultivated, caught, or raised in Skåne. These products are mostly delivered by SMEs highlighting their importance in this study and there is a growing institutionalization of this mindset in Sweden (Olsson, 2015). A compounding factor for this demand has been the Covid-19 pandemic, which saw 67% of food producers in a survey say they have increased demand for Swedish produced products (Livsmedelforetagen, 2021). This makes a case for strengthening the capacity and capabilities of SMEs to deliver high-quality locally produced food in an environmental manner.

The contemporary involvement of the food industry with IS has been the conversion of food wastes to ethanol for use in other processes, production of biogas for applications such as fueling public transport and also the recovery and sharing of residual and low-grade heat (Mirata, 2018). Additional avenues for IS in the food sector include using by-products for feed and recovering waste heat for the heating of stables and greenhouses. Other new experiments include using by-product proteins to create a new type of fish feed (Johnsen et al., 2015), while others have found high-value applications through the application to nutraceutical and pharmaceutical industries (Mirabella et al., 2013).

A study on the Händelö/Norrköping region and its IS activities showed that while there is ongoing innovations in the area with food producers, it also mentioned there is a need for more support for the network and 'systems solutions' involving the municipality and county governments as facilitators (Johnsen et al., 2015). The next section will provide a deeper description of IS that places it in the context of this study.

2.2 Contextualizing Industrial Symbiosis to the Study

To best understand the meaning when using the term industrial symbiosis, it is common to refer to one of the most cited definitions by Chertow, (2000) which defines it as:

"Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchanges of materials, energy, water, and/or by-products." (Chertow, 2000)

Chertow, (2000) then goes on to define five *types* of material exchanges which are presented in Table 2-1 below:

Table 2-1. Type of IS Exchanges

IS Type	*Type of Exchange*	*Examples of Links to Agri-food*
Type 1	Through waste exchanges	Food waste to pharmaceuticals (Mirabella et al., 2013)
Type 2	Within a facility, firm and/or organization	Onsite wastewater sludge capture and conversion to biogas (Chertow, 2000)
Type 3	Among firms that are co-located in a defined eco-industrial park	Sharing of residual and low-grade heat (Mirata, 2018)
Type 4	Among local firms that are not co-located	Converting by-product proteins to fish-feed (Johnsen et al., 2015)
Type 5	Among firms organized "virtually" across a broader region	Inclusion of farmers into a network through truck or other means of transport of materials (Chertow, 2000)

Source: Author, adapted from Chertow (2000)

This thesis will focus on Type 5 of material exchanges or "virtual exchanges", between firms that can be organized virtually in the broader region of Skåne. The reason this type of exchange is more applicable to this study is because the participants that were available were spread out over the broader region of Skåne and, furthermore; the analytical framework which will be better discussed in section 2.7 is a form of theoretical modelling of probabilistic and potential synergies, which is more inline with the virtual organization definition.

Therefore, it may be more fitting to refer to the definition of IS offered by Lombardi & Laybourn (2012), which allows for a broader application of the term to include organizational and knowledge-related learning through these synergies:

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

This definition further builds on the fact that there is value in having a deeper understanding of the diffusion of knowledge in the networks, and that value can come from changing business culture to plan for more capacity towards eco-innovation. The following sections will introduce IS applications both in general and in relation to SMEs and bring up the discussed relevant constraints and enablers in both settings.

2.3 Application of Industrial Symbiosis in General

This section presents the opportunities, outcomes, and pathways towards IS. It then goes on to discuss constraints and enablers and provide a summary of these to be used during empirical collection.

2.3.1 Opportunities for Industrial Symbiosis

The most cited aspects to determine when developing a traditional IS network between any agents are their geographical location, what sort of regulatory system they operate within, the homogeneity or heterogeneity of the agents, and also what levels of participation occur between these agents (Simboli et al., 2014). Additionally, motivations for entering an IS network must be understood. This can be examined through a resource-based view which states that companies seek sustainable competitive advantage, by expanding and maintaining internal company resources which are unique and vital to the company's success. These internal organizational resources and capabilities define the company's assets whether they are human or organizational and are important to develop to adapt to new innovations and market opportunities (Barney, 1991; Madhani, 2010). Companies may be motivated to enter an IS network to therefore gain additional capacity or control over a resource, usually for their own gain (Pfeffer & Salancik, 1978). Consideration from a resource-dependency perspective, may however highlight to agents that joining networks may introduce risks through dependency on external resources and them not having full control over this (Chen et al., 2017).

Other than the firm motivations, industrial symbiosis presents other additional opportunities. As presented in the introduction, there are many environmental challenges facing the food sector, and industrial symbiosis may provide a path towards a more sustainable model. Mirata & Emtairah (2005) presented a framework that included the following six operational goals:

1. *Better balanced and more stable local economy;*
2. *Increased employment, social cohesion and inclusiveness;*
3. *Reduced emissions of toxic and polluting substances;*
4. *Increased recycling;*
5. *Increased material, resource, and energy efficiency;*
6. *Substitution of renewable resources for exhaustible ones.*

These six goals outline how industrial symbiosis efforts help to achieve economic, social, and environmental improvements on a grander scale.

To take advantage of these goals and opportunities, there are three major avenues for entering into an IS network. IS networks may be self-organized, planned or facilitated through some external party (Chertow, 2007). Self-organized IS occurs when symbiotic exchanges are developed organically or through serendipity by the industrial actors themselves. Planned organization typically involves a municipality, industrial park, or regional planning commission that sets up the exchange but does not take part in it themselves (Chertow & Ehrenfeld, 2012). Finally, facilitated IS has some third-party organization become a part of the symbiotic exchange by sharing resources and also the economic benefits and knowledge (Boons et al., 2017).

Benefits of having facilitators help achieve industrial symbiosis as per Mirata et al. (2017) include:

- *generating awareness and encouraging engagement;*
- *acting as a connecting hub for improved communication, interaction, and build-up of trust;*
- *facilitating the formation of a shared vision and objectives;*
- *brokering information, relationships, or knowledge;*
- *offering specialized knowledge, administrative capabilities and physical assets;*
- *reducing transaction costs and implementation-gap times;*
- *securing access to external resources (e.g. finance, technology, policy);*
- *assisting the formulation of suitable business models and governance mechanisms;*
- *legitimising the emerging relationships/networks and acting as a bridge between private and public sector*

These facilitators or intermediaries can be municipalities, regional authorities, business associations, non-governmental organizations, research and knowledge institutions, utility and waste management companies, and specialised consultants (Mirata et al., 2017). Batten (2009), argues that some combination of self-organized with facilitated approaches were most effective at transitioning agents into clusters and then into networks. The next sections will discuss enablers and constraints that are important to understanding the emergence of IS between companies.

2.3.2 Enablers

Enablers in this study are to be understood as factors that promote or encourage further linkages between firms. The literature focusses on the cultural changes that need to occur for IS to be established between agents. A shift from a dominant and individualistic mode of business to one of collaboration is mentioned as the main enabler for further network development (Mulrow et al., 2017). From here on, self-organization may be achieved through efforts to manage resource pricing, resource restraints, environmental regulations or other external signals requiring innovation and partnership (Mulrow et al., 2017). It was also often discussed that new business models could help shift the transition from a linear production model to a circular model (Chen et al., 2017). An example presented is how firms felt waste management companies could facilitate the shift by focusing their business models on the *quality* of waste collected, instead of charging by the *quantity* collected (Rincón-Moreno et al., 2020). Facilitation efforts by academic researchers, regional authorities, consultants, or other reputable intermediaries contribute to finding opportunities and possible linkages (Mirata et al., 2017). Perhaps the most thorough and easily understood compilation of IS enablers and constraints found in the literature is provided by Golev et al. (2015). It includes seven key aspects: commitment to sustainability, information availability, cooperation between actors, technical feasibility, regulatory aspects, community involvement, and economic aspects. These seven aspects can work as either enablers or constraints depending on their condition for each relevant firm. The aspects are better defined and summarized in section 2.3.4.

2.3.3 Constraints

Constraints in this study are to be understood as factors that are working against or demotivating a company from entering an IS network. To better understand constraints through the resource-based view as defined earlier, Pigosso et al. (2018) list the following barriers to widespread uptake of IS: "(i) commitment to sustainable development; (ii) access to detailed qualitative/quantitative data on residue streams; (iii) cooperation and trust among companies; (iv) technical feasibility; (v) regulatory framework; (vi) limited community awareness; and (vii) lack of a clear business case". These are rather closely related to the seven aspects by Golev et

al. (2015) as mentioned earlier, so to simplify the study for better communication with case companies, these seven aspects provide the basis for the discussion on both enablers and constraints. When examining IS through the resource-dependency view, cited constraints included (i) reliance on agents, and (ii) lack of control over external factors (Chen et al., 2017). These largely fall under the category of co-operation between actors, and thus the seven aspects are useful for a discussion of enablers and constraints both for the resource-based view and the resource-dependency view. The next section presents these seven-aspects and details them further.

2.3.4 Summary Table for Enablers and Constraints

The seven aspects summarization of IS constraints and enablers by Golev et al. (2015) is presented in Table 2-2 below, upon which the survey for data collection will be based on to answer research question 1 due to its categorization, making it easier for practitioners to follow and understand. Furthermore, as discussed in the previous section, the seven aspects are a close fit to cited enablers and constraints found elsewhere in literature.

Table 2-2. Summary of Enablers and Constraints

Enablers and Constraints	***Description***
Commitment to Sustainability	Organizational strategy, goals, and performance measures have to motivate managers to develop and participate in the synergy projects, contributing to the company's and regional sustainability.
Information Availability	The detailed qualitative and quantitative data on waste streams and local industries' material/water/energy requirements provide the starting point for the development of regional resource synergies.
Cooperation Between Actors	The cooperation and trust between key players, sharing of information, and network development are crucially important factors for new synergy projects. A coordinating body can significantly contribute to this.
Technical Feasibility	Technical feasibility is an indispensable condition to proceed with a potential synergy. A lack of technical knowledge within the industries may be an additional barrier for a new project. This can be compensated by involving a consulting company or research organization.
Regulatory Aspects	The uncertainties in environmental legislation and difficulties to obtain approvals for waste reuse projects from the regulatory authorities may also be a constraint for potential synergies. At the same time, compulsory legal requirements to recycle specific materials, higher taxes for waste disposal, and so on, are enablers for synergy projects.
Community Involvement	Community awareness (of the environmental and economic impacts that industries generate) can be a strong driver to initiate or stop the development of different projects. Well-established communication systems between the industries and local

	community, as well as environmental education programs, help to ensure the legitimate status of new synergies.
Economic Aspects	Synergistic connections are expected to bring a positive economic outcome along with environmental benefits. Economic feasibility may result in increased revenue, lower input costs, lower operational costs, and diversifying and/or securing water, energy, and material supplies.

Source: Golev et al. (2015)

2.4 Application of Industrial Symbiosis Specific to SMEs

To better prepare for the empirical study with SMEs, literature was examined regarding IS application in SMEs and their more specific enablers and constraints. It is noted that when it comes to SMEs, there is a general limited implementation of IS between these firms (Pigosso et al., 2018). This is the case even when SMEs make up 99% of the organizations in Europe, when using the under 250 employees definition (Moore & Manring, 2009). In Sweden, SMEs employ over 65% of people and generate over 61% of value-add to the country (European Commission, 2017). In Skåne, the agri-food sector makes up just under 2% of the workforce; however, this is higher compared to the nationwide figures of 1.5% (OECD, 2012). The region hosts 21% of Swedish agri-food economy or roughly 100,000 employees in this sector (OECD, 2012). As many SMEs are suppliers to other firms in a business-to-business setting, they suffer the most from inefficiencies such as waste and production processes, where-as the larger firms and producers are more prepared due to investments in large scale eco-efficiency and already well prepared for the efficient management of materials (Simboli et al., 2014).

In general SMEs have been primarily reactive instead of proactive to environmental issues (Pigosso et al., 2018). This may be due to their limited capacity to get ahead of the issues. One study found SME companies focussed mostly on complying with laws and regulations and alone did not have capacity to do more. Of those interviewed in that study, 65% had not heard of industrial symbiosis (Ormazabal et al., 2016). This provides further justification for a knowledge gap and opportunities to increase the diffusion of the concept between SMEs. Regarding an actual figure for how much resource-exchange is occurring between SME firms, Virtanen et al. (2017) estimates about 25% of waste material of SMEs is sold on to other firms who use this as an input. So, while many surveyed may not fully be familiar with the terms industrial symbiosis, due to their own enablers and constraints they are participating in some forms of it. To focus on ways to increase the exchange between SMEs even further the next sections describe some SME specific enablers towards IS followed by the constraints.

2.4.1 Enablers for SMEs

The literature examined mostly covered facilitated IS, and there was not as much focus on enablers and constraints for self-organization found. Examples included moving SMEs into eco-industrial parks to better access information on technical capabilities for exchange (Chen et al., 2017) and becoming part of a regional innovation network (Pigosso et al., 2018). These alliances helped SMEs leverage their limited resources and create more effective strategic relationships with other external stakeholders such as clients, government bodies and suppliers, which they otherwise would not have been able to do alone (Chen et al., 2017). As many SMEs operate within limited floor spaces, it was shown that having some limitation on the diversity and quantity of flows due to the reduced area also led to identifying efficiencies amongst the different firms (Mulrow et al., 2017). This aligns closely then with the co-operation between actors aspect in Golev et al. (2015) summary presented previously in Table 2-2.

One important concept described was a company's *'absorptive capacity'*, which is essentially their readiness and ability to transform, assimilate and apply new external knowledge into their firms to create value (Pigosso et al., 2018). This increases their capabilities and assets as per the resource based-view described earlier (Pigosso et al., 2018). Collaborating in networks of IS specifically for SMEs increases their absorptive capacity (Pigosso et al., 2018) and may also help increase their propensity for innovation (Simboli et al., 2014). It was also discussed that having meta-knowledge of social factors, such as trust, knowledge, awareness, and willingness would help an actor enter a symbiotic relationship (Ghali et al., 2017). Therefore, how company's felt about their absorptive capacity was a useful indicator if they would benefit from IS or be able to adapt to opportunities brought about by it.

2.4.2 Constraints for SMEs

When looking at SME firms, one major constraint is their institutional capacity and resource availability to participate in IS (Boons & Spekkink, 2012; Schmiegelow & Andersen, 2016). This includes less staff to focus primarily on knowledge gathering, tracking regulations, and innovating (Schmiegelow & Andersen, 2016). The actual operational and managerial challenges involved in re-organizing the logistics of a firm were discussed (Yazan & Fraccascia, 2020) as well as the uncertainty in terms of supply-demand quantity mismatches, since firms become reliant on each others resource flows and trust between these firms becomes strained (Chen et al., 2017). When operating in isolation, SMEs tend to have limited awareness of incoming environmental regulations (Chen et al., 2017). When analyzing their business relationships, being in a business-to-business setting as many SMEs are, puts constraints on what they can do on their own, without some pressure or direction from downstream firms (Ormazabal et al., 2016). When analyzing their governmental relationships, it is mentioned that SMEs have limited economic support from local governments (Ormazabal et al., 2016). This is compounded by the fact that traditionally governments have a command-and-control relationship with SMEs, leading to diminished *trust* and thus limited collaboration (Pigosso et al., 2018). SMEs have also been shown to have limited abilities to repay loans on new investments and therefore may not have well developed access to capital (Chen et al., 2017). These constraints found in the literature match closely to the seven aspects categorized by Golev et al. (2015) further supporting its usefulness for this study.

The following sections build on the mentioned concepts of having a better understanding of the social aspects of knowledge and awareness about other firms and their capabilities to enter IS exchanges, and the trust and willingness required between the firms to do so.

2.5 Diffusion

A key concept when analyzing how IS networks develop is to understand the concept of diffusion. This diffusion of knowledge and of the concept happen both internally within networks, and also externally to other organizations who may then enter into a network (Tao et al., 2019). The theory of diffusion of innovations was first popularized by Everett Rogers in his 1962 book Diffusion of Innovations, and since then many others have written on the topic. He postulates that the process of diffusion is heavily reliant on human capital and a strong social system (Rogers, 1962).

This knowledge diffusion or sharing, is influenced by structural properties of the social networks and connections between companies, and the intrinsic properties of these social connections, such as closeness, trust, strength of relationship, and nature of communication (Ghali et al., 2017). It is for this reason these intrinsic properties of social connections are so crucial for the study of IS. Examples of these principles are also presented by Chertow & Ehrenfeld (2012) where they summarize five developmental pathways that IS networks follow: 1) The Build and

Recruit model; (2) The Planned Eco-Industrial Park model; (3) The Self-Organizing Symbiosis model; (4) The Retrofit Industrial Park model; and (5) The Circular Economy EIP model. All five of these developmental pathways include social diffusion of knowledge through networks created by exercising the intrinsic properties of the social connections. In fact, having a meta-knowledge of these social factors, affects the perception of value and positively influences the diffusion of expertise between the different members in the network (Borgatti & Cross, 2003).

The diffusion of knowledge in creating industrial symbiosis synergies is not extensively studied, and it is difficult at this point to know the most significant aspects; however, many studies have pointed to trust between members. As Ghali et al. (2017) presents it, though these aspects are not fully understood, "*they are a necessary part of the diffusion of the IS philosophy and the identification of industrial synergy opportunity*"(p. 4). The following section further describes the importance of trust.

2.6 Trust and Social Embeddedness

The literature often cites trust as an integral part of creating and succeeding in an IS exchange (Ashton & Bain, 2012; Bichraoui et al., 2013; Chertow & Ehrenfeld, 2012; Ghali et al., 2017; Mirata et al., 2017; Velenturf & Jensen, 2016). It is often described as a form of social embeddedness, which defines the nature, depth, and degree of inter-relationships (Chertow & Ehrenfeld, 2012). These members in the network are considered socially embedded if their behaviours are in some ways influenced by other members in the network or they share social norms within the network (Ashton & Bain, 2012). This ultimately leads to trust in one another and ultimately in an exchange of information and knowledge seen as mutually beneficial (Ghali et al., 2017). Ashton & Bain (2012), called this social embeddedness and trust amongst members a *short mental distance* which creates the proximity needed to work together. Therefore, if actors are not necessarily geographically located close to one another, this 'short mental distance' can help bridge those gaps. In the case of Sweden, there seems to be a high level of social embeddedness and trust between actors (Baas, 2010).

With the importance placed on trust and social embeddedness, it is seemingly less studied than the other more technical aspects of IS (Ghali et al., 2017; Schiller et al., 2014). Examples found included using social network analysis to study by-product exchanges in the Kalundborg Industrial Symbiosis system by Doménech & Davies (2011). Albino et al. (2016) and Romero & Ruiz (2014) both used agent-based modelling to simulate how trust affects IS networks. However, they both used fixed theoretical values on these parameters. Ghali et al.'s (2017) study developed a model based on changing theoretical values of trust, knowledge, awareness and willingness; however, no empirical data collection was performed to obtain these values from actual companies. To better understand the applicability of agent-based modelling to studying these aspects, a deeper look is provided in section 2.7.1 below.

This thesis seeks to collect values based on empirical data collected from SMEs and then apply them to the same framework used by Ghali et al. (2017). The following section will therefore describe the conceptual framework for achieving this and through what lenses the problem will later be analyzed.

2.7 Towards a Conceptual and Analytical Framework

This section will discuss the lenses IS are examined under in this study, provide the definitions contextualized to this study for TKAW used in empirical collection, introduce the opportunities provided by agent-based modelling, and finally outline and explain how the TKAW analytical framework is intended to work.

This thesis will be following the previously presented lens on industrial symbiosis (section 2.2) as per Lombardi & Laybourn (2012)'s definition:

"Industrial symbiosis engages diverse organizations in a network to foster eco-innovation and long-term cultural change. Creating and sharing knowledge through the network yields mutually profitable transactions for novel sourcing of required inputs, value-added destinations for non-product outputs and improved business and technical processes."

It will seek to analyze specifically the Type 5 synergy possibilities between firms organized "virtually" across the broader region of Skåne. This means that companies that may not even know each other could be examined. It will attempt to present whether the "short mental distance" can be achieved through an analysis on TKAW between studied companies. The framework assumes that should a company not fit within the TKAW framework, it may be brought into the network by those who operate within it. The companies will all be classified technically as SMEs as per the European Commission definition of employing under 250 people (Moore & Manring, 2009). This is particularly fitting as the Swedish agri-food industry is mainly comprised of SMEs (European Commission, 2017).

The study aimed to include all food production sectors in Sweden, as defined by Jordbruksverket, the Swedish Board of Agriculture. The study has excluded any alcoholic beverages as this is a large and specialized industry on its own and subject to a unique operating environment and conditions (Swedish Board of Agriculture, 2018).

To study the diffusion of industrial symbiosis between the case study companies, the framework of an existing study completed by Ghali et al. (2017) will be used. This study modelled aspects of TKAW in an agent-based model and ran a simulation to see how behaviours and decisions would impact the members of the network. This study will not run a simulation but will instead test the framework to see if collected empirical data from SMEs interested in IS can be applied to this model framework.

This study will work within the following contextualized definitions of trust, knowledge, awareness, and willingness:

Trust: *defined as trust in a resource partner's ability to deliver the wastes/by-products to specification, volume, price, and time; the trust in someone using the resources to do so in a responsible way; trust in governance that the synergy can persist for long enough to justify the investment.*

Knowledge: *the understanding of the principles of industrial symbiosis and by-product resource exchange, including the technical and logistical aspects of setting such synergies up.*

Awareness: *the ability to identify potential industrial synergies and actors in or outside their networks.*

Willingness: *the attitude and desire to enter potential industrial synergies and commitments with actors in or outside their networks.*

Source: Author, based on Ghali et al. (2017) and discussions during CircClean event (CircLean, 2021)

The framework was based upon the agent-based modelling approach as per Ghali et al. (2017). The next section will describe the advantages of using an agent-based modelling approach in this way, followed by a section that presents the analytical framework developed based on this study.

2.7.1 Opportunities for Using Agent-Based Modelling

To help overcome some of the constraints on institutional capacity to collect information and self-organize into networks, agent-based modelling is one proposed and researched theoretical tool to help facilitate industrial symbiosis. Put simply, agent-based modelling is a mathematical and computer model of individual agents, their qualities, and how this relates to their interactions with the systems they operate within (Ghali et al., 2017). The main outcome intended when applying these agent-based models is to have a representation or modelling of the behaviours between agents (Ghali et al., 2017), and further study helps to validate these models through collective stakeholder approval (Batten, 2009). Models by nature are representations of the real world and must be understood as such. A popular aphorism states "All model are wrong, but some are useful" (Box, 1976). Therefore, while agent-based modelling has its limitations it can help simulate conditions not possible to be studied through traditional observation.

There have been various applications of agent-based models to facilitating IS systems found in the literature. Examples include having software developed specifically on the principles to match residue and resource networks for collaboration or using existing software packages such as iNex to find opportunities for exchange (Rincón-Moreno et al., 2020). The use of indicators, which are developed through quantifying into a mathematical model the qualitative identifiers of each firm (Couto Mantese & Capaldo Amaral, 2017) was in one instance used to develop a machine learning model, whereby simulations can show the transformation pathways required to achieve symbiotic opportunities (Lütje et al., 2020).

Further studies showed that in order to make these models most applicable, they should be paired with empirical research done with the stakeholders themselves, employing semi-structured interviews to capture individual actors' complexities (Rincón-Moreno et al., 2020). A strength of applying agent-based modelling to analyzing TKAW in IS creation is that the model can be used to change conditions and 'what if' scenarios should another socio-economic environment be studied. In this way once the model is developed its transferability or external validity increases (Bichraoui et al., 2013). A cited challenge of this approach was how companies can process large quantities of inventory data to populate an industrial symbiosis database and who would be responsible for updating the changing indicators or qualities of the company into the agent-based model (Yeo et al., 2019). The next section better describes the Ghali et al. (2017) study and analytical framework used by this study to answer research question 2.

2.7.2 TKAW Analytical Framework

The study that the TKAW part of this thesis was based on was done by Ghali et al. (2017) and it captured the intrinsic social aspects of trust, knowledge, awareness, and willingness, then assigned a set of logics and rules to these values and ran an agent-based model to simulate creation of synergies. This study was most relevant as it focused upon trust as an intrinsic requirement and important aspect of synergy creation which fit the findings of section 2.6 on trust and social embeddedness well.

To provide some understanding of the Ghali et al. (2017) study, it is now summarized. The study was motivated by the enabling effect of increased trust and social embeddedness. It proposed the TKAW model as a way to simulate the impacts of social factors within an agent-

based model. This agent-based model is meant to simulate the complex adaptive system which states that TKAW factors drive behaviour, interactions, and decision making between agents and their environment. The study also felt knowledge was a key factor in IS dynamics due to its transfer and diffusion among close social connection. The study references Boons & Spekkink (2012), who state that institutional capacity to acquire and use technical knowledge can act as a potential constraint, and while it did not play a role in IS development in a survey of eco-parks in the Netherlands, the diffusion of knowledge was still an integral part of the social factors contributing to increased trust and IS development.

The intent of using the agent-based model was to simulate theoretical situations which may be difficult to study through observation due to a lack of data. Of the agent-based model studies on IS referenced in the study, none had any form of implementation or empirical collection with observed data and therefore provided an opportunity to test the proposed TKAW framework with such data. The TKAW model used in the study allows for a final acceptance decision based on technical and economic parameters, once the potential network is known by those willing to participate; however, this step was not considered critical to testing the applicability of empirical data to the TKAW model proposed, and as the network is a theoretical test, it is not relevant to make an acceptance decision either. The study tested the framework on hypothetical experiments, which concluded social aspects are most relevant for increased IS synergy, and that while initial knowledge level has some influence by delaying initial synergies, by extending the timescale of the simulation the knowledge levels level out and become less critical. It concludes that the TKAW model is a useful framework for modelling synergy development as influenced by social aspects and suggests it is tested using case studies, surveys, or other empirical collection. The next section will discuss the process logics, design of the model, and briefly touch on how it can then be a potential input for an agent-based model.

Framework Overview

The companies that will be studied will function as the agents in this framework, and all logics will operate based on those developed by Ghali et al. (2017). The factors of where they fit in will be their strengths in TKAW social attributes. The primary assumptions of the model are that agents only exchange knowledge with those agents which they have a social contact with, and do not have a meta-understanding of the network as a whole. The companies would aim to seek synergies with each other.

It is important to state clearly that this study by Ghali et al. (2017) and this thesis will not focus on the input or output technical compatibilities based on resource flows. There is also no consideration about proximity. These aspects would be kept as neutral controls in a future agent-based model, in order to focus on the ways the social aspects affect the interactions. Therefore, synergies are presumed to occur due to serendipity, or through help from a higher scored network member.

This approach is influenced by the work of Boons et al. (2011) who postulate that diffusion of industrial symbiosis happens at two levels, the societal level and the regional industrial system level (Figure 2-1). When focussed in on the societal level (highlighted in green), there are certain aspects of the social system that help with the synergy creation. These include knowledge (i.e. knowledge and awareness), relational resources (i.e. trust and willingness) and therefore that is what is being captured by the Ghali et al. (2017) study and therefore in this study.

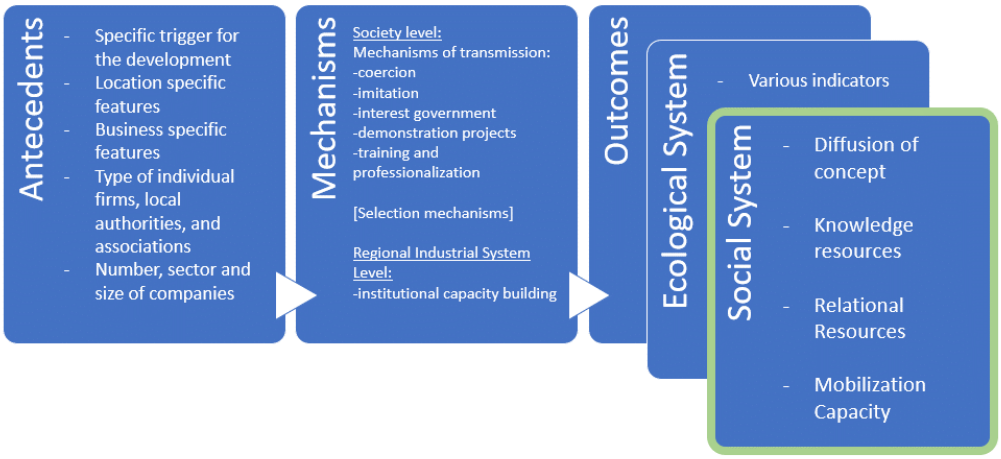

Figure 2-1. Conceptual framework for analyzing the dynamics of industrial symbiosis

Source: Adapted from Boons et al. (2011)

How The Framework is Used

The TKAW framework consists of four key nodes, or aspects which are trust, knowledge, awareness, and willingness (TKAW). Each aspect requires an agent to populate it, and this is the company which scores highest on each relevant aspect. The scores were determined through the survey that was sent out to the respondents, and each company's individual scores are presented in Chapter 4. The fact that there is a numerical weight to each aspect from a score, allows this numerical weight to potentially be assigned to the internal calculations of a future theoretical agent-based model. The higher the scores, the more possible potential linkages and thus, more opportunities to proceed to the final step of acceptance through an evaluation of technical and economic matches. The *logic rules* are as follows: Trust is the core aspect in the model, as those with higher levels of trust as per the Ghali et al. (2017) model, will be more likely to seek out synergies with others. These agents would then seek out those with a high knowledge score and high willingness score and help diffuse this trust to others. Figure 2-2 below visualizes this model and its logics to describe the assumptions of the framework:

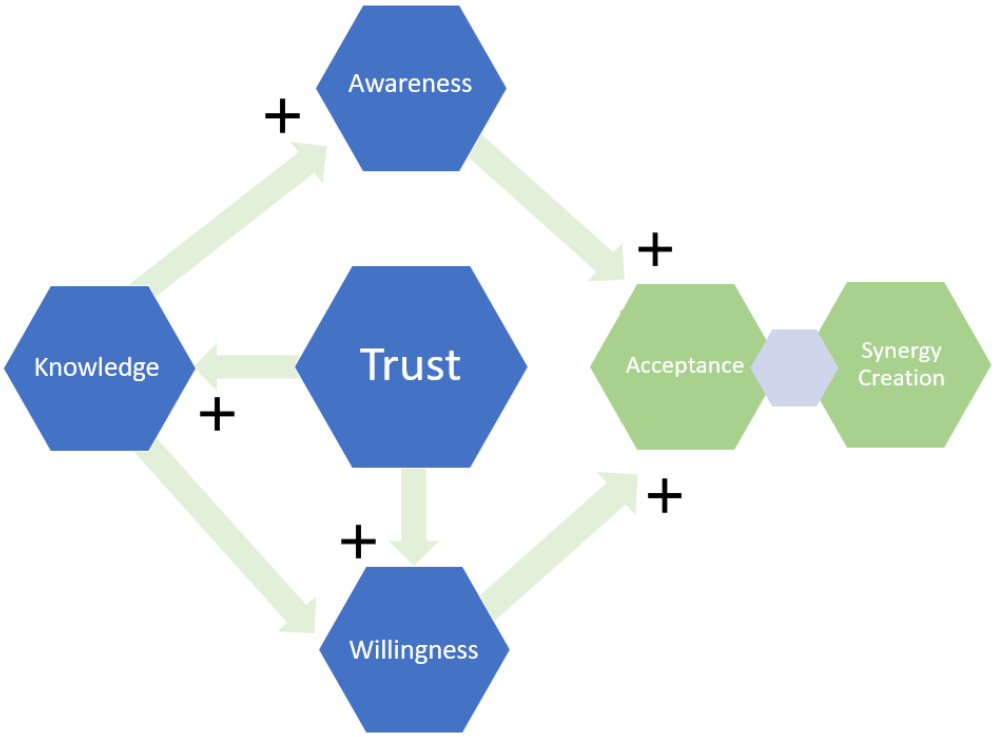

Figure 2-2. Analytical flowchart of the TKAW process logic

Source: Author, adapted from Ghali et al. (2017)

The highest self-scoring knowledge company is assumed by the model logics to diffuse this to others with high willingness internally, and also diffuse knowledge to the company that is most aware of synergies. It is beneficial to be a company with high awareness in this model, as it provides access to the higher knowledge companies, and thus allows entry into the network. So long as there is a company with a high willingness score and another company with a high awareness score, and no key social element remains empty, the logics allow for a decision of acceptance to occur in order for eventual synergy creation should technical and economic matches also exist.

The threshold for being able to occupy a TKAW aspect is that companies must score at least a +1 on an aspect. This score is derived from the five-point Kunin face scale used in the surveys. Based on the model logics, if all companies score all neutral or no company scores at least a +1 on either aspect, the framework links are not complete, and no theoretical linkage could occur. In an agent-based modelling situation, this would slow down potential synergy creation as alternates would need to be examined.

In the instance of a tie on the scores, the scores of all four aspects of each company are tallied, and those with the highest score are placed in the corresponding spot for their highest scoring aspect. This is to give recognition to the fact they are more actively contributing to TKAW as a whole in the network. The final two nodes of acceptance, and synergy creation process is left out of this study and only the blue aspects are analyzed. This is because these rely on an examination of technical and economic matches in the synergy, and as this study is merely testing the applicability of cases social aspects on this TKAW framework, it is not required.

This form of model testing and development is therefore a probabilistic model versus a discrete one (Uzzi, 1997). This means that companies' scores and their placement in the model are probabilistic distributions and not deterministic with only one possible solution (J. Ocampo, personal communication, April 7, 2021). In a probabilistic model inferences from data come with intrinsic uncertainty and therefore the author followed the logics and translated survey responses to the scores and placed them where they would most appropriately fit (Uzzi, 1997). These inferences of the data are called characterizations, which is a process to abstract collected empirical data and findings to populate logics and attributes in a model (Gao et al., n.d.). It is possible that following other logics or designing surveys in another way would yield different results.

The TKAW framework is a story/narrative-based model framework which is a required step before executing any computational model; however, if it is proven as useable with empirical data it can then be developed further into a simulation logic and inputs for an ABM. The results in Chapter 4 will therefore be analyzed based upon this framework and test its ability to apply and analyze empirical data. To close the literature review, the next section provides a summary of major findings of the content analysis.

2.8 Key Takeaways from Literature Review

To help relate the findings from the literature review to the research questions, the following Table 2-3 seeks to summarize the major findings in the literature review. The table was assembled by taking the main findings of each previous section and sorting them to the related RQs.

Table 2-3. Key Takeaways from Literature Review

Research Questions	*Key Findings*
RQ 1. What are the SME specific constraints and enablers to industrial symbiosis in Skåne, Sweden?	Overall, the seven aspects by Golev et al. (2015) are a useful summarization and categorization of IS constraints and enablers **Enablers:** Becoming part of a regional network (Pigosso et al., 2018) Higher absorptive capacity (Pigosso et al., 2018) Meta-knowledge on network's TKAW aspects (Ghali et al., 2017) **Constraints:** Being in a business-to-business setting (Ormazabal et al., 2016) Limited institutional capacity and resource availability (Boons & Spekkink, 2012) Supply and demand mismatch and reliance (Oberle et al., 2019) Limited governmental support (Pigosso et al., 2018)

RQ 2. How can trust, knowledge, awareness, and willingness (TKAW) aspects from empirical study be applied to a proposed analytical model to support industrial-symbiosis creation?	Allows to understand and model diffusion of knowledge and concept (Tao et al., 2019) Increases meta-knowledge of TKAW amongst members allowing for "shorter mental distance" (Ashton & Bain, 2012) Adds real-world empirical values to TKAW instead of existing fixed theoretical values (Ghali et al., 2017) Tests the applicability and compatibility of empirical data from SMEs interested in IS to the TKAW model framework by Ghali et al. (2017) Provides a foundation upon which further study through modelling techniques can be done (Batten, 2009; Rincón-Moreno et al., 2020)
RQ 3. How are SMEs efforts to enter IS networks and increase TKAW aspects supported by facilitators?	Sharing of institutional resources, knowledge and economic benefits (Boons et al., 2017; Golev et al., 2015) Increased co-operation between actors (Golev et al., 2015) Supporting development of absorptive capacity in firms (Pigosso et al., 2018) Increased awareness, communication and build-up of trust (Mirata et al., 2017)

Source: Author, based on main findings in literature review

3 Methodology

This section will describe the rationale behind the chosen research design and how the research was conducted and analyzed. It lays out the steps it took to reach the results, and ultimately how the research questions were answered.

3.1 Research Design

The chosen research design was a multiple case study approach. This was deemed as the most appropriate to answer the research questions pertaining to SMEs because it allows for an analysis of factors that are occurring in a real-life context in real-time (Crowe et al., 2011). The intent is to correlate the findings in the literature with those conducted through the case studies and compare them. Case studies also allow for a more in-depth analysis of influencing factors, reasons behind the how and the why and this fits well into the aims of this thesis (Yin, 2014). The reasons for multiple case studies were threefold: i)to capture multiple perspectives related to the research questions, ii)to draw cross-case linkages and therefore iii)lead to a result more representative of other companies who may benefit from the research (Crowe et al., 2011). Finally, multiple companies were needed in order to follow the previously described analytical framework. Figure 3-1 below shows the process of developing the study, selecting the cases and finally analyzing them as per Yin (2014).

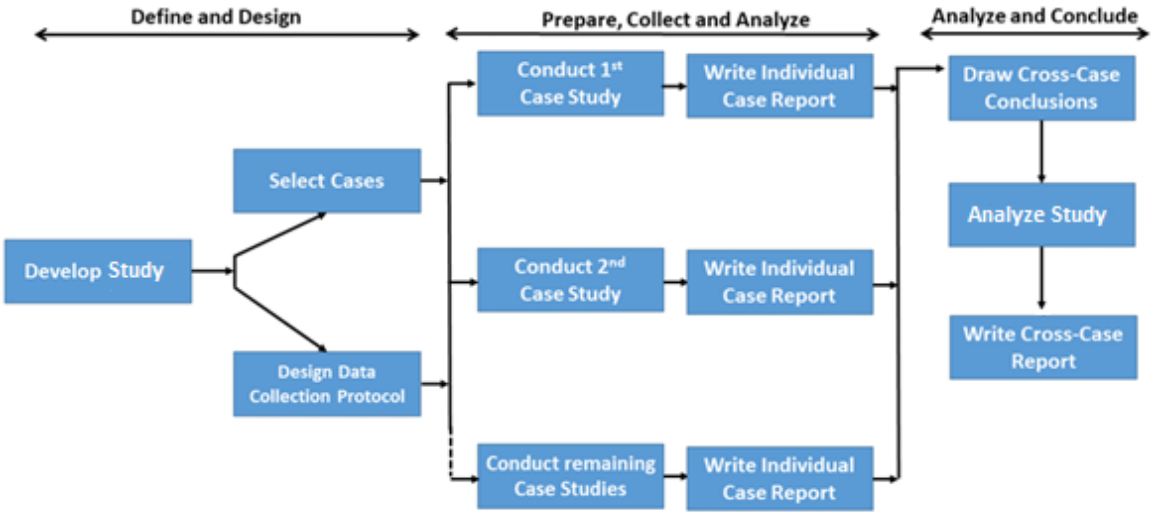

Figure 3-1. Case study research design flowchart

Source: Author, adapted from Yin (2014)

Through the selection of this research design a combination of an abductive and retroductive approach was taken to collect data. The abductive approach seeks to understand the social intricacies or aspects of TKAW and therefore create a descriptive account of the study groups (Blaikie & Priest, 2019). The retroductive approach then looks at any underlying mechanisms and tries to explain regularities (Blaikie & Priest, 2019).

These logics of inquiry were deemed the most relevant to understand the reasons why SMEs would be motivated to enter a symbiotic relationship and what influencing factors such as TKAW in this case, may have on those motives. The regularities of these motives can then be explained using a constructivist approach by employing a framework or model, which will be done later in the results section of this thesis based on the analytical framework presented in Figure 2-2 in the previous chapter.

3.2 Methods Used to Collect Data

Collection methods were a combination of content analysis on relevant peer-reviewed academic literature, a targeted survey as well as semi-structured interviews with case company contacts. Semi-structured interviews allowed for a certain openness that qualitative research demands; however, still offer some structure in order to ensure the conversations align within the scope, and research aims of the study (Creswell, 2014). The semi-structured interviews therefore followed the structure of the TKAW analytical framework presented earlier. The structure of these interviews is outlined in Appendix A. It is important to remember that the research is specifically targeting SMEs and therefore, due to limited capacities, a single manager may have to handle many roles and may only have limited understanding of details and specifics. This goes back to the limitations SMEs have in various capacities as discussed in the prior literature review. This was an anticipated aspect and therefore an expected challenge and limitation of the study.

The original study design aimed to include study visits to incorporate some more technical process related constraints and enablers; however, due to the challenges of Covid-19, all empirical data collection was collected online. The interviews were conducted over the phone and by online conferencing through zoom. They were not recorded, and notes were taken during the calls.

The survey was developed on a website called SoSci Survey, which offered many useful page functions that more standard surveys such as Survey Monkey and Google Forms did not allow for. It was also free for use under an educational license. The survey questions were developed based off the literature review, the analytical framework, and discussions with professionals in the field. The specific survey questions can be found in Appendix B. It started with questions addressing levels of understanding of IS, offered a scaled rating of the seven aspect constraints and enablers by Golev et al. (2015), had a Kunin face scale question on each TKAW aspect and finally ended with an opportunity for further comments. Further discussions for clarifications and additional resources were held over email and are not made public.

3.3 Materials Collected

The main takeaway materials were the semi-structured interview findings and the survey responses. The interviews operationalized the research questions and were influenced by the literature review, and key concepts found in this stage and therefore were not merely exploratory but already rather informed. The discussions also sometimes developed more organically.

There was a total of five SMEs all within the food sector in the Skåne region that took part, and they are listed below:

1. Munkagrodden AB: Vice Director
2. Plant-Based Protein: Operations Manager
3. DoubleGood AB: Chief Scientific Officer
4. Malmö Chokladfabrik: CEO
5. Saltat Ferments: Owner/Producer

The survey responses were downloaded as a .csv file and analyzed using Microsoft Excel and then coded in NVivo as described in the next section.

In parallel to these interviews, there were also some discussions with facilitators and participation in an online conference to collect more information and to inform the research. The findings from these discussions and proceedings will be presented at the end of Chapter 4.

3.4 Selection of Actors

The selection of the five companies was done by using initial contacts through the support of organizations including IUCSyd and Livsmedelsakademin. When many of the companies in these networks were unable to participate due to limited capacities and limited time, others were then cold contacted. These companies were found through their product offerings in local food stores in Malmö and Lund. They were all geographically operating within Skåne. As this study is qualitative, the cases were purposefully selected and therefore it is not attempting to make statistical inferences about the entire population of Skåne agri-food companies, and instead using their findings to test whether the TKAW framework can be populated by empirical data collection (Creswell, 2014). Therefore, sample representativeness is not required, and companies that were interested in IS and had some baseline knowledge of it participated. If, however, a more extensive study was done performing a simulation through the use of an agent-based model, it may be more important to have some statistical representativeness and a mixed-methods quantitative and qualitative research design.

It was advantageous to have a sample of businesses not interlinked with each other and operating within their own networks to better fit the aims of the study. This also ensured that the responses were not biased to one network or group's experiences. It also facilitated for a more open dialogue on each company's TKAW social aspects. It was intentional to aim to have a diverse set of actors, with food growers, producers, beverage producers and food processors. Following this study design, it is difficult to draw an exact sampling strategy for replicability; however, it should maintain external validity in case the study was to be replicated using other companies.

The most common approach when studying IS is to find a specific cluster of companies in close proximity to each other and determine their technical capacities and compatibilities for heat or residue exchange or other service-related exchanges closer to the Type 1 to 3 material exchanges as described in Table 2-1 in the previous chapter. In these studies there is also usually an anchor tenant (Mirata & Emtairah, 2005) with larger flows and higher levels of prestige. This study deviates from this typical approach and as mentioned is more in line with the Type 5 material exchange definition.

3.5 Data Analysis

The data analysis was done on qualitative data combining the use of descriptive analysis, and theory generation, categorizing and connecting, and content analysis based on coding manually and through the use of the software program NVivo (Blaikie & Priest, 2019).

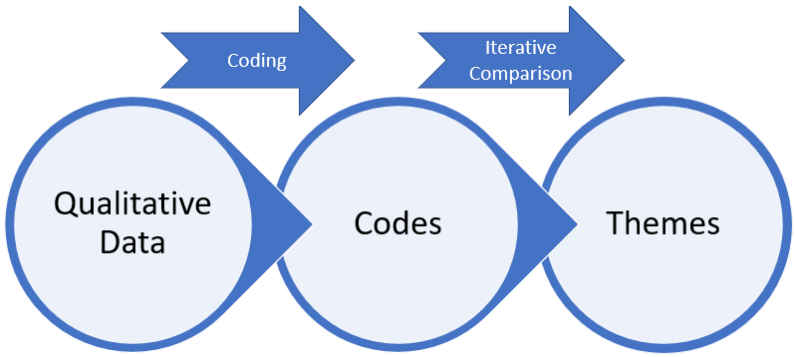

Figure 3-2. Content/Thematic Analysis

Source: Author

Content analysis is widely used by qualitative researchers, and allows for the development of a coding scheme through the use of a formal theory or conceptual framework (Potter & Levine-Donnerstein, 1999). In qualitative research, coding is "how you define what the data you are analyzing are about" (Gibbs, 2007). In this case the coding was done based on the conceptual framework as described earlier. The qualitative data was captured by typing up notes during and after the calls with the case companies. These notes were then entered into NVivo to come up with the main codes of the study. The first cycle coding looked for common themes and these were highlighted in NVivo. They were then categorized based on the frequencies they came up on the data collection as well as the relative importance they had.

After this synthesizing process, it was possible to come up with the analysis and discussion and theorize further. The results were triangulated with the findings of the literature review and discussed under this context to verify findings (Creswell, 2014). This process did seem redundant once it was finished, since the second-order codes output was the basic structure or categories of both the semi-structure interviews and the survey questionnaire that was sent out.

4 Results

In this section the case study companies' results are presented and analyzed. Their respective TKAW flowcharts are presented, and then placed into the full analytical framework flowchart. The chapter ends with takeaways from discussions with facilitators and how their viewpoints build onto the findings in the literature review.

4.1 Case Study SMEs

The study included five SME companies and a representative from each company was interviewed and asked to fill out a survey. The interviews were semi-structured, and therefore allowed for discussions to evolve; however, they followed the basic questions as listed in Appendix A. The surveys were sent after the interview once all concepts had been explained and defined. During the discussions on constraints and enablers with each company, the following seven aspects as categorized by Golev et al. (2015) earlier in Table 2-2 were used to guide the discussion:

- Commitment to Sustainability
- Information Availability
- Cooperation Between Actors
- Technical Feasibility
- Regulatory Aspects
- Community Involvement
- Economic Aspects

The survey also included these aspects and allowed respondents to choose how relevant each was as a constraint or an enabler on a numerical slider scale. It then used a Kunin face scale system to ask each respondent how they felt about each TKAW aspect. These were then converted to numerical scores as per the characterization process described in section 2.7.2. The questions for this TKAW section were as follows:

- What is your level of *trust* of the industrial actors in your current or potential networks?
- What is your *knowledge* level of IS compared to the industrial actors in your current or potential networks?
- What is your level of *awareness* of potential IS synergies with the industrial actors in your current or potential networks?
- What is your level of *willingness* to enter into potential IS synergies with industrial actors in your current or potential network?

The findings of the interviews and surveys will be presented in the section below. The five companies represent a range of food products including: beverages, desserts, a vegetable grower, a plant-based protein producer, as well as a fermenter. This range of products was chosen to show responses from a wider perspective and discuss the unique challenges in each type of product. All companies are located in the Skåne region of southern Sweden.

4.1.1 Munkagrodden AB

Munkagrodden AB is a medium sized food grower specialized in growing sprouts. It is a family-owned business and has been operating since 1992. It is the largest supplier of twelve varieties of sprouts in Sweden and sells its products to major retail chains, restaurants, and cafés. The company certifies its products under KRAV organic certification.

Interviewee Role:	Vice Director
Number of Employees:	45
Location:	Munka Ljungby, Sweden

The interviewee was a Vice Director of MunkaGrodden AB. Recently, about two to three months ago, MunkaGrodden AB had self-organized into its own industrial symbiosis exchange with another company in Stockholm that is buying any unsold product and fermenting it for seven days to produce plant nutrition for consumer use. Another project is likely to start soon after this study to do the same with pea shoots. If not engaged in these exchanges, the company would normally pay 20,000 SEK to throw away the unused product each month. Therefore, the opportunity to sell to others has been very attractive to them. In the survey, the respondent reported to have limited understanding of circular economy and some understanding of industrial symbiosis.

Constraints

The respondent echoed the constraint of shelf life of the product and mentioned it was a major constraint to consider when looking to set up exchanges. However, they also understood that the product would not need to be fresh in order to have value. They did not see cost as a major constraint either but mentioned they would consider it as relevant if it is not worth it. With their current exchanges the costs were included and were not extra for them.

All interviewees were also asked to fill out a survey, which had the seven categories listed adapted from Golev et al. (2015) and asked respondents to select how relevant of a constraint or an enabler each category or aspect is perceived as to their company (See Appendix B for survey questions and framing).

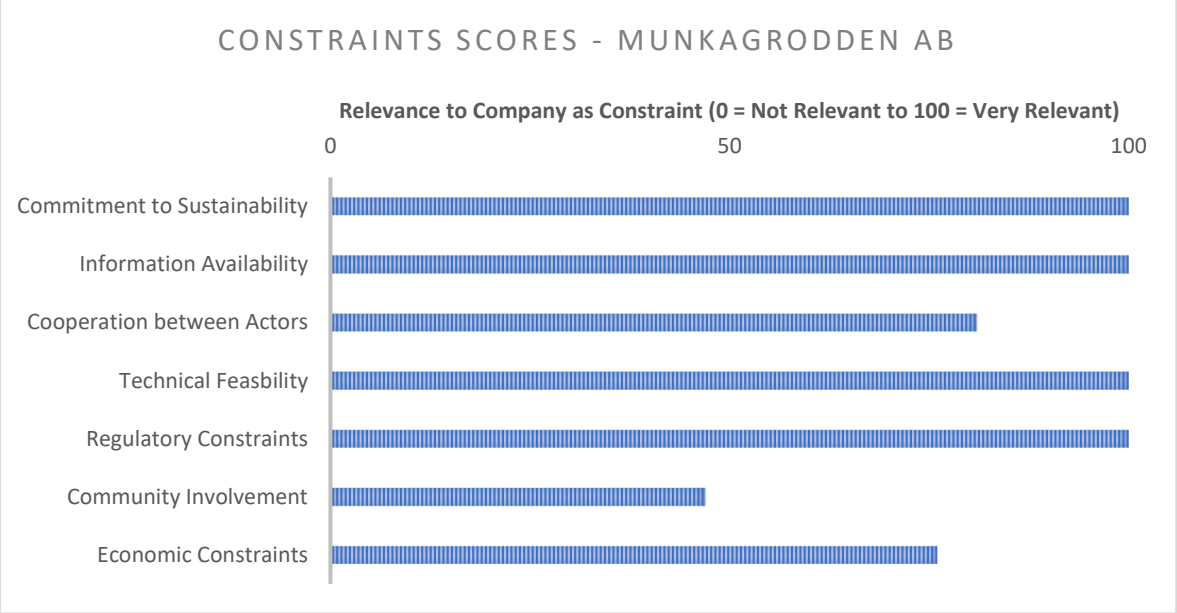

Figure 4-1. Constraints Scores: Munkagrodden AB

Source: Author

The survey responses on the constraints from Munkagrodden AB as seen in Figure 4-1 above showed that they felt others commitment to sustainability, the availability of information, technical feasibility, and regulatory constraints were the most relevant. They scored economic constraints as the second lowest relevant constraint and found a lack of community involvement as the least relevant.

Enablers

The most important enabler was felt to be opportunities to work together with others. They were very optimistic and open about this idea and were excited to be working together with pioneers in Stockholm with innovations on bean sprouts and how to valorize the unused products for plant nutrition. They also discussed how the revenue margins on this exchange were the same as if it were fresh product being sold to store. Therefore, it was a highly attractive venture, especially given the opportunity to not pay to send it as waste. Distance was not mentioned to be an issue for either logistical reasons or for cost.

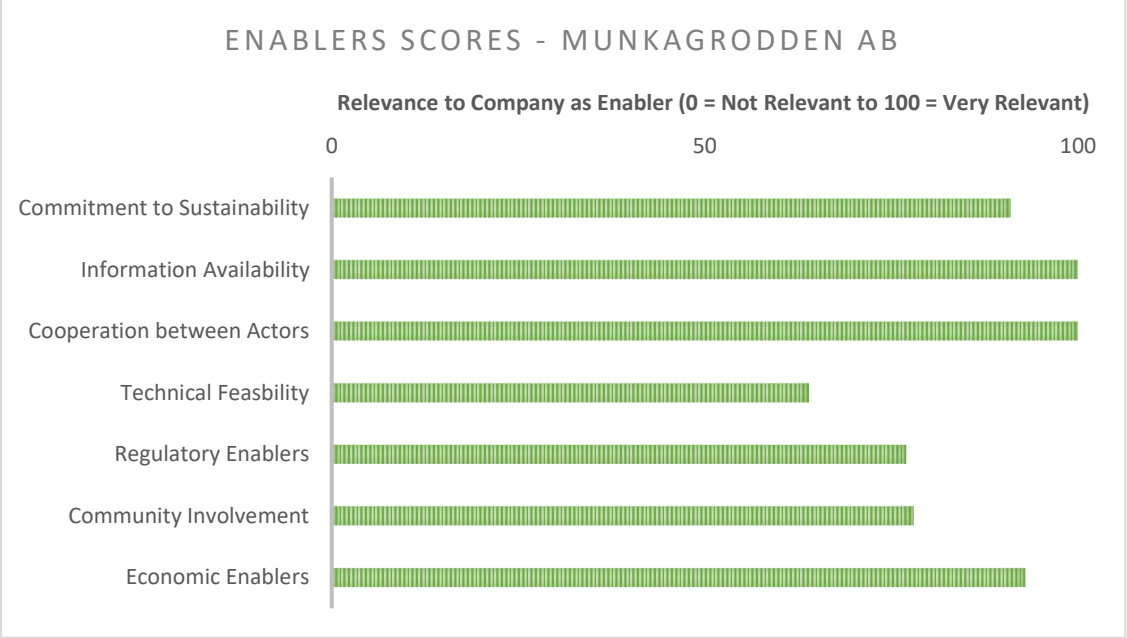

Figure 4-2. Enablers Scores: Munkagrodden AB

Source: Author

The survey responses for enablers in Figure 4-2 above echoed the conversations in the interview that information availability and the cooperation between actors were seen as the main enablers. They also felt commitment to sustainability and economic incentives were relevant enablers.

TKAW

In order to determine each company's TKAW aspects, discussions were had in the interviews, where the terms were defined and related back to the business. Additionally, to provide inputs to the TKAW framework, the survey questions on TKAW asked companies to self-score themselves on each aspect. Therefore, the respective TKAW results will be discussed under each company's TKAW section.

For Munkagrodden AB, the interviewee mentioned that they always preferred to stay open and positive when it comes to *trust*, however stressed that they needed a mutual approach from the other side to also have this work. They prefer relationships with others who are open as well and prefer transparency with supply available each month. On the survey the respondent felt they were neutral (score of 0) when it came to trust compared to others in their networks and felt it could be a constraint if not well developed.

Their *knowledge* on the technical and logistical aspects of industrial symbiosis was higher than the networks they operate in and felt they are not the same as other conventional farmers who have been doings things as they have always done traditionally. On the survey they scored themselves a +1 on knowledge and felt it could more often act as a constraint due to a potential lack of knowledge.

Their *awareness* of potential synergies was discussed as rather average, and they do not have extensive awareness of what other farmers are doing but they are often involved in meetings once a year where they can share in their networks. They scored their awareness as a +1 as well but felt that in general it acted as an enabler.

The respondent's *willingness* was perhaps the most pronounced and they really stressed that they would be highly willing to engage in more such exchanges as the ones they are currently a part of. They mentioned they would be more willing to produce extra sprouts so that even if they cannot sell them all to retailers, through industrial symbiosis exchanges at least there is always a good place for them to go. On the survey they scored themselves highest at +2.

Diffusion

To gain understanding of how each company has been acquiring knowledge and contributing to diffusion of the concept, they were asked about their experiences with diffusion and their absorptive capacity, to get a sense of how they could incorporate new knowledge into their businesses (see Appendix A for interview questions). This was deemed important to discuss as diffusion and absorptive capacity are important components of IS synergy creation as discussed previously in sections 2.4 and 2.5 and may be related to facilitator support which contributed to answering research question 3.

For Munkagrodden AB, the interviewee's experience with diffusion of knowledge has been mostly through attending exhibitions and meeting enthusiastic professionals there who are willing to share information and opportunities. This is how the exchange with the plant nutrition company in Stockholm happened. They are also actively involved in an economic association called SydGrönt and through this they are able to sell their products directly to the grocery trade. Here they also meet other farmers, and it provides a good opportunity for discussions on innovations and current market trends.

Absorptive Capacity

Absorptive capacity was not discussed at length with this company, but they did mention they are always open to new innovations and do not feel their organization is set up in a way that could not make use of new trends or technologies should they arise. They did not feel lock-in was a significant issue, either with their technology or institutional capacity.

4.1.2 Plant-Based Protein Food Product

This company produces plant-based protein products, however; had asked to not include the company name as their responses were their own reflections on the discussion and not representative of the company's. The company operates out of Malmö and currently employs four people. The company has been awarded sustainability awards and has been supported by the EU Climate-KIC for helping transition towards a zero-carbon economy.

Interviewee Role:	Operations Manager
Number of Employees:	4
Location:	Malmö, Sweden

The interviewee has some experience with industrial symbiosis but has mixed feelings about its potentials. They tended to see more of the constraints and challenges involved with setting up such exchanges and were not too optimistic about its potentials for their company. They did mention the spent product normally went to biogas production but that this is currently not happening. They reported a high understanding of circular economy and a high understanding of industrial symbiosis on the survey.

Constraints

As mentioned, this respondent concentrated on the constraints and challenges involved with engaging in industrial symbiosis. They mentioned food safety and shelf-life as a constraint. They also stressed the value of the by-products as not high enough, especially as an inadequate volume of this would not justify the equipment and labour costs of recovery. They also mentioned many farmers do not have the time or resources to do more than they already do and are being as efficient as they possibly can already. Another constraint mentioned was yields, and how they are difficult to predict and keep consistent.

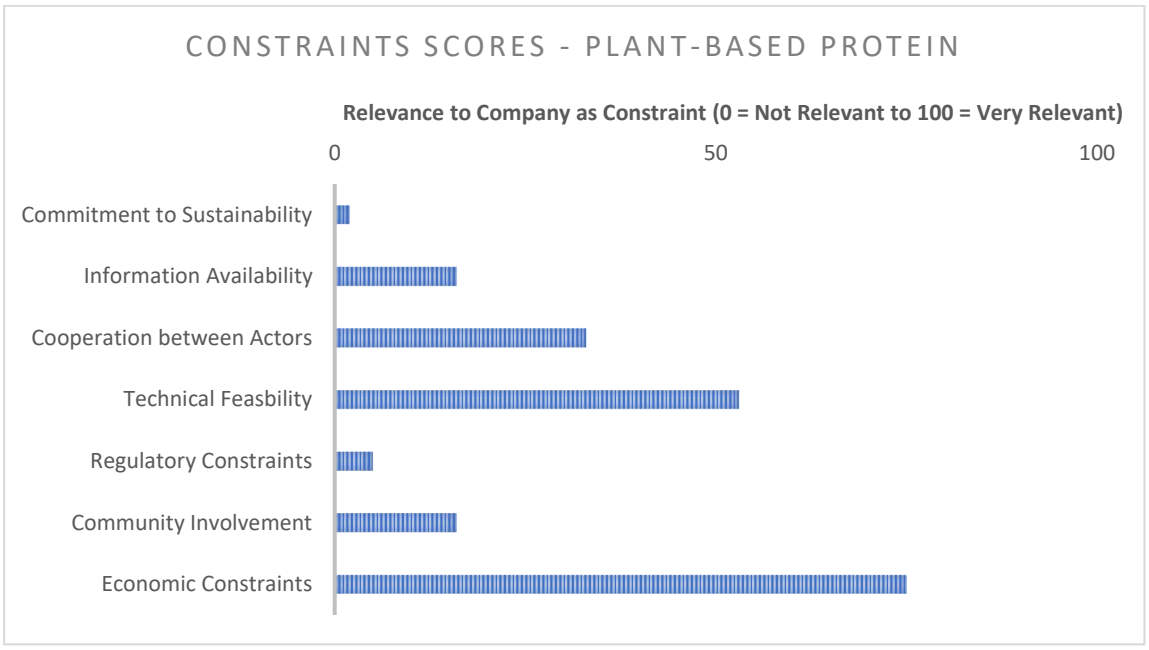

Figure 4-3. Constraints Scores – Plant-Based Protein

Source: Author

The responses of the survey seem to echo the discussion where economic constraints and technical constraints are mentioned as the most relevant. They simply do not see the value in investing in extra time, labour, and machinery to recover a low-value by-product.

Enablers

The discussed enablers were having more information in the networks and finding an exchange that it worthwhile economically.

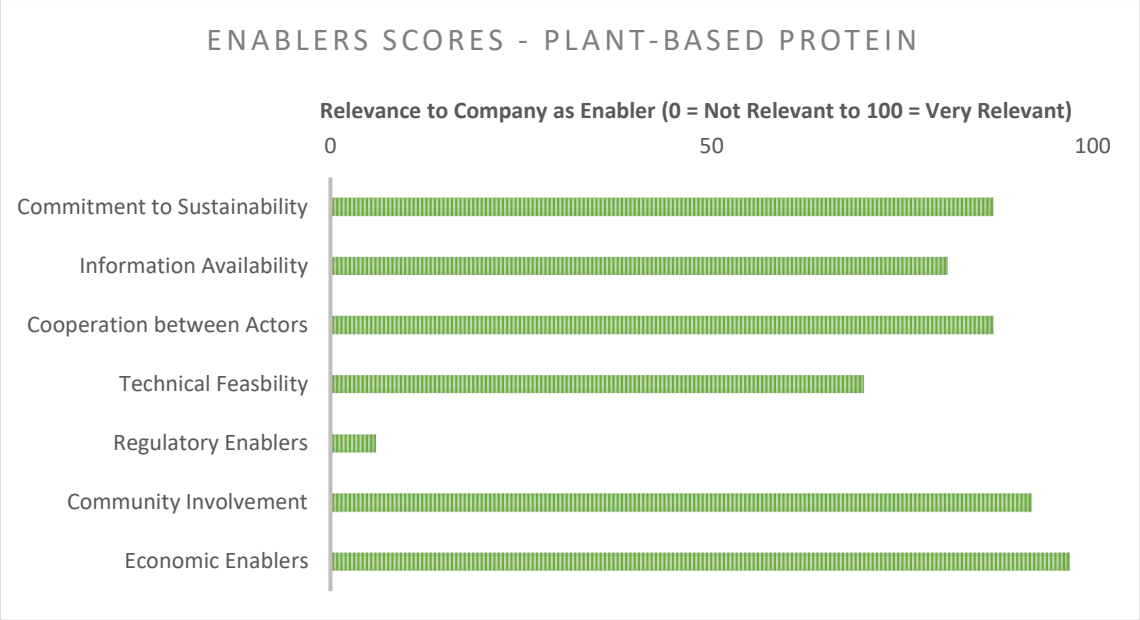

Figure 4-4. Enablers Scores - Plant-Based Protein

Source: Author

The survey responses showed that the respondent felt an economically viable exchange would be most relevant as an enabler, following by community involvement as well as cooperation between actors. They felt that regulatory enablers were not very relevant for setting up industrial symbiosis exchanges.

TKAW

The respondent felt that *trust* needed to be earned and felt that their level of trust in their networks is not constant, and that they feel it is important to have the freedom to trust or distrust other actors. On the survey they scored themselves as a +1 and felt that once trust was established it could act as an enabler.

They felt their *knowledge* about the technical aspects and logistics of industrial symbiosis was high, and felt they were likely much higher than others in their networks. They understand the intricacies of the various raw material types. They scored themselves a +2 on the survey and mentioned their high level of knowledge could act as an enabler.

The respondent mentioned their *awareness* of potential synergies in their network was good and scored themselves as a +1 on the survey and felt it was an enabler.

Their *willingness* was high, and it was mentioned if all pieces fit and it made economical sense, then they would consider entering a symbiotic exchange. They scored themselves a +2 on the survey and felt their high willingness to be an enabler.

Diffusion

The respondent felt an important facilitator for the diffusion of the concept was the waste management companies, who can find new business models and organize symbiotic exchanges better on behalf of their customers because of the scale of material they are handling. They collect double digit tons per month from this company and therefore may find some way to valorize this by exchanging it with another company. They also mentioned they are not aware

of any organizations that would specifically be able to help them if they had questions or needed support to better understand the concept or help overcome technical challenges.

Absorptive Capacity

The respondent felt that the fact they worked for a small company made it difficult to grow their absorptive capacity when their human capital only allows for the day-to-day functioning of the company. They feel that there is a certain level of lock-in and sunk costs with their business and they could not easily absorb or adapt to new innovations. This seems to be more on the financial side as they do feel technically, they would be able to tweak the process to fit new innovations.

4.1.3 DoubleGood AB

DoubleGood AB is the company behind the beverage product Good Idea drinks. They were selected as a viable case study as the Swedish food industry includes beverage companies in their statistics (Swedish Board of Agriculture, 2018). This product is a functional beverage with a patented blend of amino acids and chromium in carbonated water which is good to consume before and after a meal to help balance and regulate blood sugar levels. The product is science-based and focused on health benefits. The company was launched in 2017 first in the United States, but now is also producing in Sweden and headquartered in Lund as of 2020. Production takes place north of Helsingborg, in Mörarp.

Interviewee Role:	Chief Scientific Officer
Number of Employees:	5
Location:	Lund, Sweden

The interviewee was the chief scientific officer. The interviewee discussed that in normal operation circumstances, there is not much waste, or by-products produced, and the aim is to buy as much inputs as needed in their various sizes and to use up all these inputs. However, there have been circumstances where it was difficult to match supply and demand. In the survey, the interviewee reported to have some understanding of circular economy and some understanding of the term industrial symbiosis.

Constraints

Given that this study covered food companies, an important constraint presented was that of food stability and shelf life. The amino acids, and the maltodextrin and chromium used in the product have a labelled one-year shelf-life, and this makes by-product exchange more complex and may limit opportunities. The aromas used in the product also lose power over time. Therefore, logistics planning is key, and to maximize resource efficiency, proper planning with the freight company and even waste haulers must be further prioritized. An example given of when this logistical challenge posed a large output of waste was when large pallets had to be purchased for PET (Polyethylene terephthalate) packaging, and production mismatch meant a lot of this could not be used. There was no plan in place to deal with this and send it to some other company, nor was there a possibility to store it onsite somewhere given the limitations in space. The last major constraint discussed was the cost involved with moving byproducts around and who would be paying for this.

Figure 4-5 below shows the responses from DoubleGood AB on the survey they were sent:

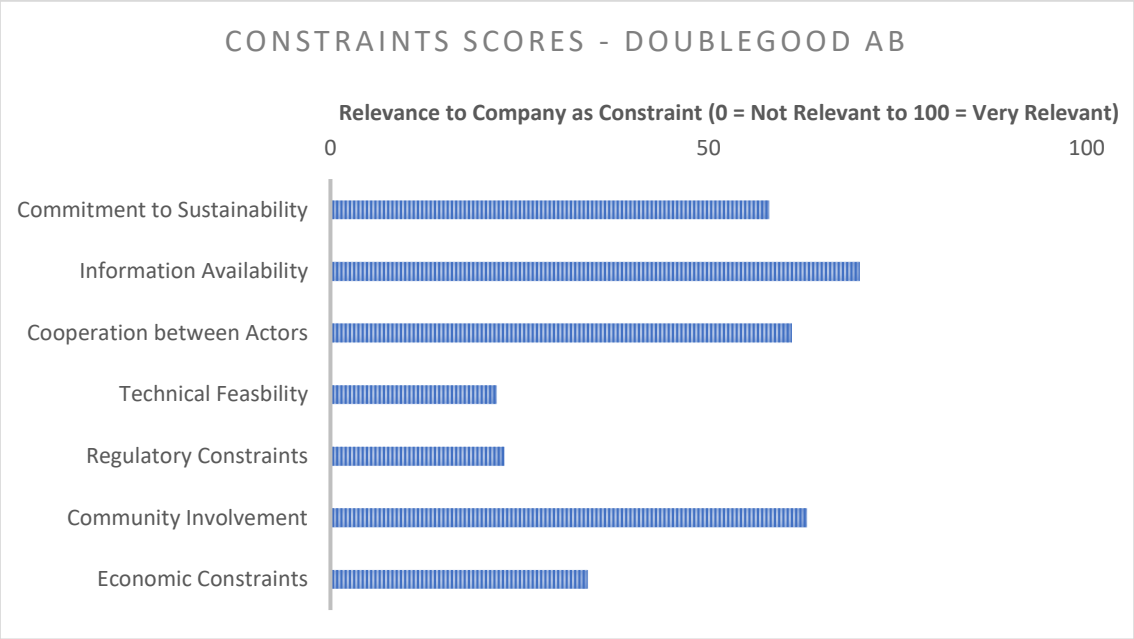

Figure 4-5. Constraints Scores: DoubleGood AB

Source: Author

This shows that while the shelf-life and cost of moving around the by-products was an important discussion point, the interviewee felt other aspects such as information availability, community involvement, and cooperation between actors were seen as more of a constraint. A lack of incentives to collaborate was mentioned. The respondent did mention that many of these aspects can be overlooked when launching a new product, and no specific role at the company has a focus on either of these. In a small company, especially in the start-up phase, other things simply take priority over by-product and waste planning.

Enablers

The most important enabler that the respondent felt would guide them in their way to by-product and residuals exchange with others would be an intermediary partner, or some broker or matchmaker who can facilitate these exchanges. It was discussed that having a facility with extra storage space and engaging a waste handler or hauler who can provide these services would be supportive. A second enabler discussed was stability samples from the resource input providers. While they have a rated shelf-life, in situations with excess products, the suppliers have been very supportive in providing more detailed stability samples to give more confidence in going a little beyond the rated shelf life. This detailed and batch-specific information helps keep resources in use for longer and eliminates the need to send raw inputs to waste. The third discussed enabler was to incorporate a more active role and develop a more proactive strategy when it comes to handling and exchange of residuals. As the company grows, it is envisioned that this could be part of an employee's role as more human capital becomes available for such decision making and strategy development. Finally, proximity was discussed as being an enabler as the company's production is close to Bjuv, which has a large industrial symbiosis focussed production plant with relevant knowledge and experience in this regard. The company is also close to other large beverage producers and packagers and thus feels they have a strong network around them.

The respondent's responses on the seven aspects and how relevant they are as enablers can be seen in Figure 4-6 below:

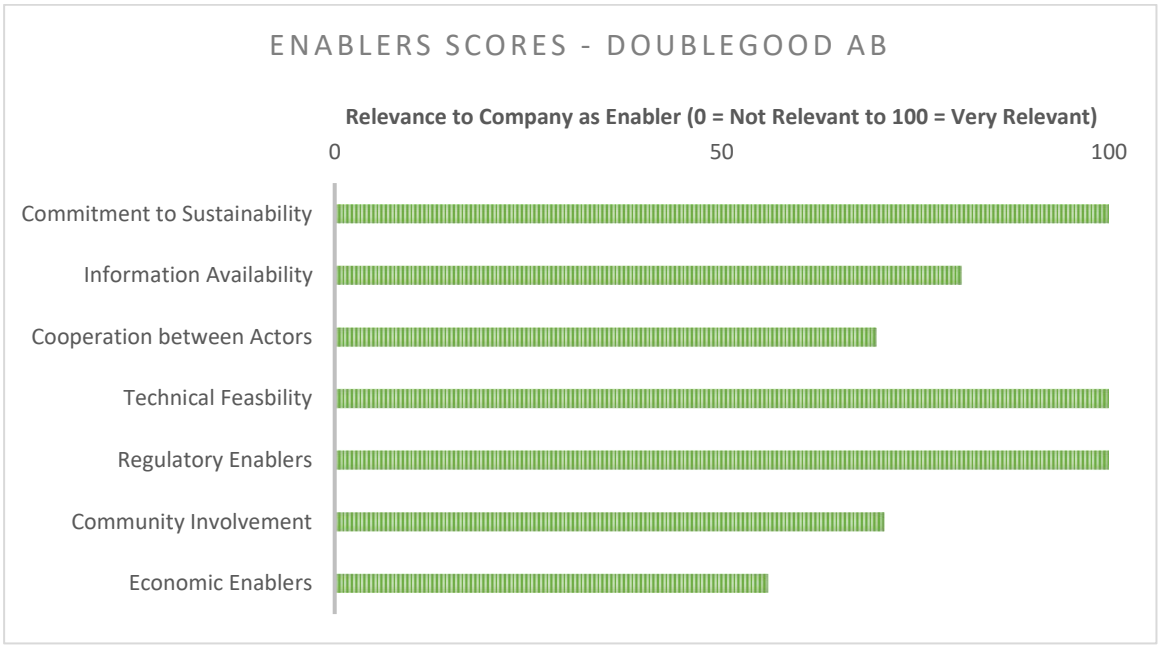

Figure 4-6. Enablers Scores - DoubleGood AB

Source: Author

Here it is clear the respondent felt that each aspect could be an important enabler, with commitment to sustainability, technical feasibility, and regulatory enablers being the predominant ones. Economic aspects were rated as the lowest priority in this case. They commented that support could be given by Miljöförvaltningen, during the annual facility inspections and this would help disseminate knowledge and highlight areas for improvement.

TKAW

The interviewee felt that *trust* at this stage was difficult to gauge, as they are in the start-up phases and have not established too many other contacts. On the survey, they ranked trust in their current or potential networks at a neutral level but did feel it would be an enabler instead of a constraint.

Their *knowledge* about the technical and logistical aspects of industrial symbiosis was low and therefore scored themselves at -1 on the survey. They feel others in their networks have more understanding about this aspect. They listed their lack of knowledge as a constraint.

The interviewee also noted their *awareness* of potential synergies in their network as low, and therefore scored themselves at -1 here as well. They feel their lack of awareness as a constraint to engaging in by-product exchanges. They commented that as they are a start-up, it is hard to consider all aspects and be aware of the networks at this stage.

The *willingness* however was scored high at +1. Given the right conditions and if an exchange were to be mutually beneficial, they would be willing to enter a collaboration and see their willingness as an enabler.

Diffusion

The respondent mentioned the most probable way of diffusion of the concept and knowledge required to set up industrial symbiosis between their firm and others was through their venture group. As they are a group of companies all working out of the same venture, they are in close communication with each other. Many of these companies have similar needs and comparable products, so learning from each other is possible. They also mentioned that municipal inspections can inform companies.

Absorptive Capacity

The product itself has a patent, and this creates some lock-in, and therefore materials cannot easily be changed or substituted due to this being the core makeup of the science-based function of the product. To gain health claim approvals, they would have to go through a lengthy and capital-intensive process requiring lots of new data. So, while the core product itself is rather locked in, the packaging it is sold in has more flexibility and new innovations or information can be useful in this regard. Therefore, the company's absorptive capacity is in some ways limited by the regulatory and approvals process, but new market learnings can still positively affect the business in other areas.

4.1.4 Malmö Chokladfabrik

Malmö Chokladfabrik is a company based in Malmö, Sweden which produces fair-trade and organic chocolate. It is free of nuts and other allergens and values this all the way down its supply chains. They also support Hand in Hand which is a charity helping to create entrepreneurship opportunities in Africa and often involved in transitioning to planet-positive agriculture through regenerative and circular agricultural practices.

Interviewee Role:	CEO
Number of Employees:	12
Location:	Malmö, Sweden

The interviewee and survey respondent is the company's CEO. Currently they are sending their spent cacao shells to a company turning it in garden soils. They also sometimes send any unused nibs to a brewery, but most nibs can be used internally to make chocolate. Major waste streams are spent water from cleaning which is currently sent to the municipal sewer system and any carton and packaging that raw materials arrive in. In the survey, the interviewee reported to have high understanding of circular economy and some understanding of industrial symbiosis.

Constraints

Aside from the scored constraints in the survey, the main constraint discussed to engaging in industrial symbiosis on the receiving end was the food safety requirements and allergen free commitments. The company guarantees its supply chain and production is free from nuts, gluten, soy, and eggs. It is also certified organic, so conventional non-organic raw material could not be handled in the same facility. Figure 4-7 below shows the constraints scoring survey responses:

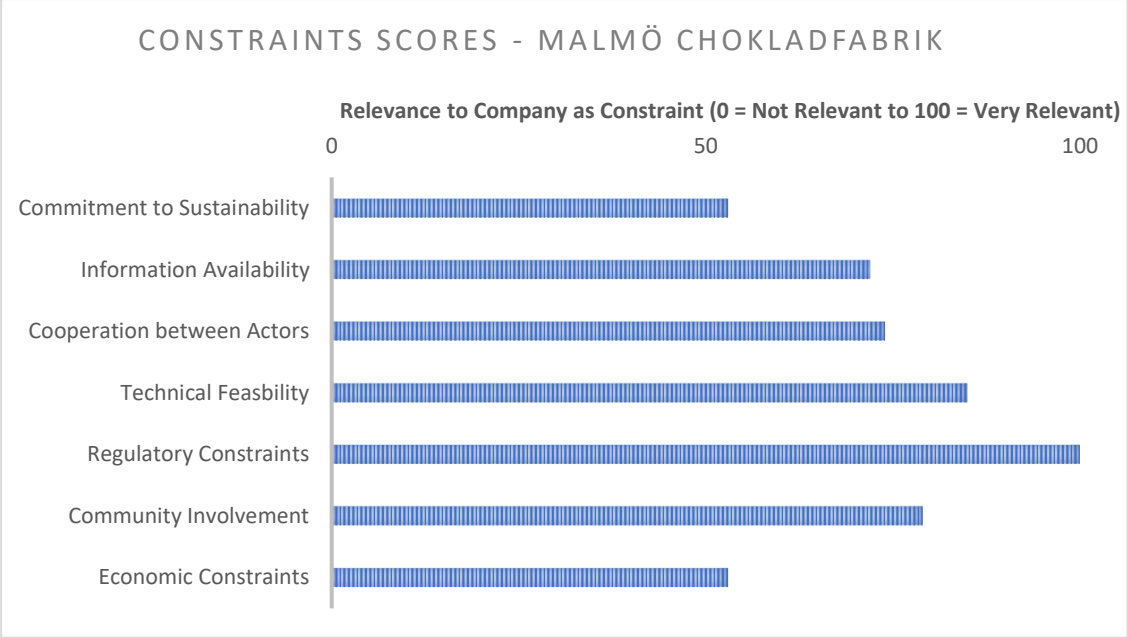

Figure 4-7. Constraints Scores - Malmö Chokladfabrik

Source: Author

From these responses it is clear regulatory and technical constraints are felt as the most relevant and this had to do with the organic certification, allergen free promise and wastewater from the cleaning processes during switch over.

Enablers

The main enabler discussed was that Malmö Chokladfabrik aims to be a positive force in the community, and therefore would like to engage more with other businesses and actors in the area to achieve this. They are a values-based and ethically driven company and are looking for opportunities to improve when they can. Through cooperation with others, it was mentioned that access to information would improve. Based on the survey responses in Figure 4-8 below, these values are reflected in the highest scored relevant aspects and economic related incentives are not a defining driver for this company regarding IS.

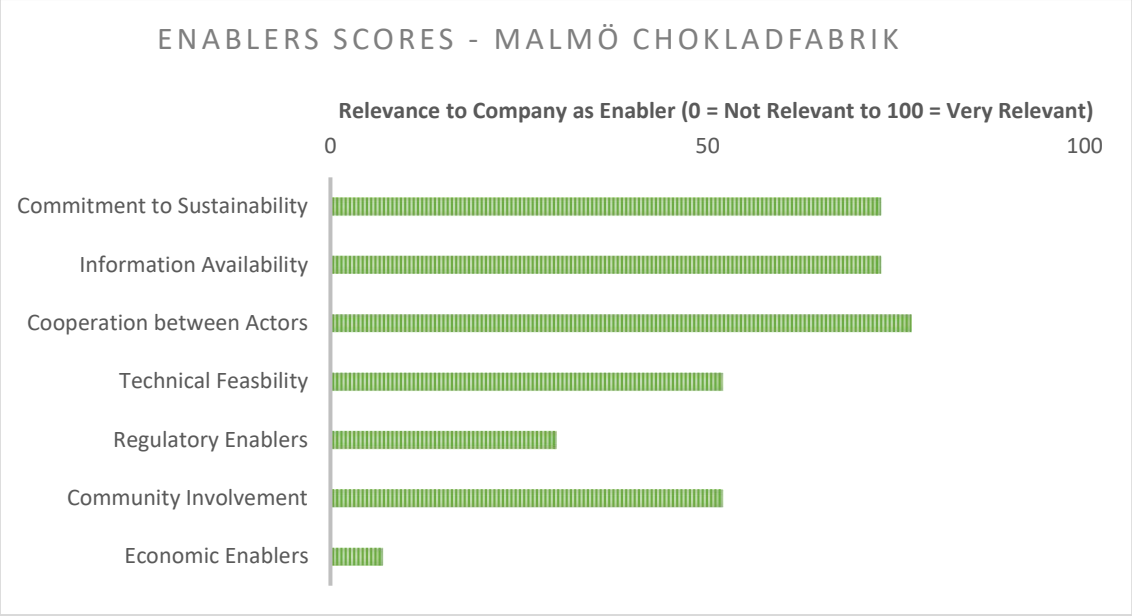

Figure 4-8. Enablers Scores - Malmö Chokladfabrik

Source: Author

TKAW

The respondent felt that *trust* was easier to receive and feel when in person. They were opportunistic about it and feel it is beneficial to their local networks. Through high trust in their contacts, they have managed to find other good relations with relevant stakeholders. On the survey they scored themselves highest on trust with a +2 and felt in general it has acted as an enabler in their networks.

Their *knowledge* and the technical and logistical aspects of industrial symbiosis were lower, and they felt neutral on this regard. They have started a company before based on circular economy principles and sharing economy, but do not have too much technical capacity on industrial symbiosis. They scored themselves a 0 which is a neutral score and have mentioned their lack of knowledge as a potential constraint.

The respondent also mentioned their *awareness* of potential synergies in their networks as low and scored themselves a -1. They were not too aware of other potential opportunities other than the ones they are already participating in and feel their lack of awareness as a constraint.

Their *willingness* however remained high, and they felt highly enthusiastic about the idea should an opportunity present itself. They scored a +1 and felt their willingness an enabler to enter collaborations or exchanges with others.

Diffusion

The concept of diffusion was discussed, and the respondent felt the best place for them to go was to their various industry groups for knowledge and support. They mentioned Organics Sweden, which is a club for organic companies within the food sector. There are often suppliers coming together here for dialogue and mutual knowledge exchange. They also have felt Livsmedelsakademin has been a helpful facilitator for them and mentioned BusinessSweden and Invest in Skåne when they are looking for help with exports. They also mentioned Livsmedelsforetagen, which is a union organization.

Absorptive Capacity

The respondent mentioned that absorptive capacity is something they often think about, as there is more innovation in products, new product demands, and fast-moving markets. For a small company, they mentioned it is important to stay ahead of this and gather the latest information.

They are always looking to stay flexible, and this included buying their own printer so they can adapt their labels quicker due to shifting realities and demands in the market. They also mentioned that while their product composition itself inside the packaging cannot change as quickly, the packaging allows them greater flexibility.

4.1.5 Saltat Ferments

Saltat Ferments was the only micro company studied where the owner and producer of the company is the same person, being the sole employee of the company. This company specializes in producing fermented products based on seasonally available ingredients. They work primarily with local small farms and support small independent businesses. They do not certify as organic but are very adamant about sourcing from farmers who use organic non-pesticide farming practices. They sell in local shops in Malmö, Stockholm as well as Copenhagen.

Interviewee Role:	Owner/Producer
Number of Employees:	1
Location:	Malmö, Sweden

They self-support their own shop through their own sales. Any expired products from local shops can be turned into dehydrated fermented powders and resold, so there is some element of internal circularity already happening. On the survey they mentioned they have some understanding of circular economy and some understanding of industrial symbiosis.

Constraints

They are very optimistic about growing their business and do not presently see additional constraints to potentially entering an industrial symbiosis exchange other than the time constraints since it is just the owner who is doing all the work currently.

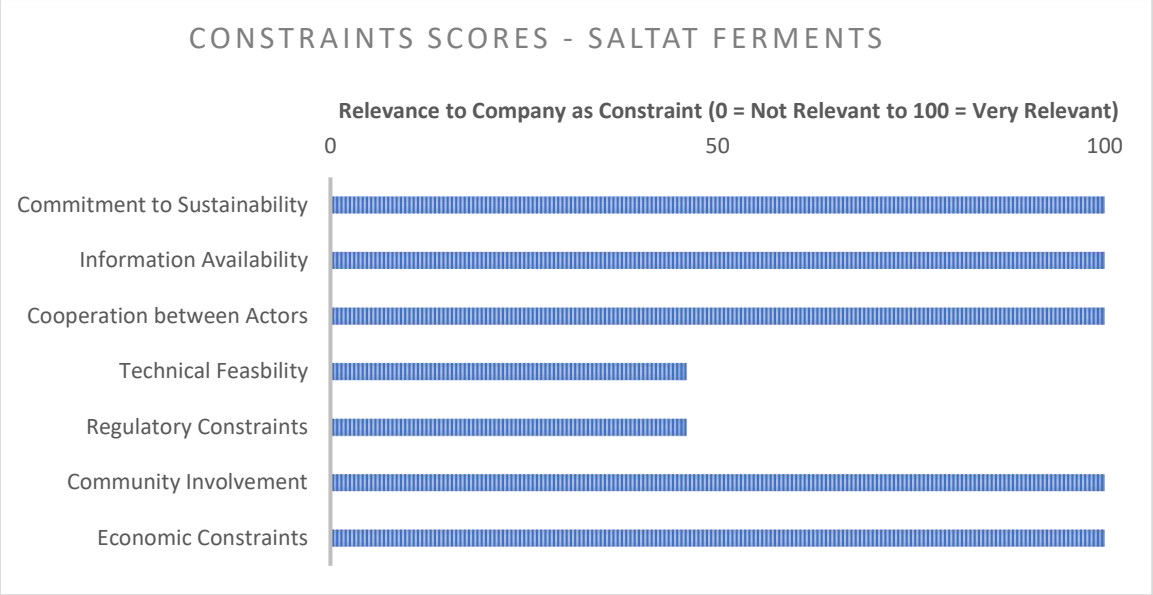

Figure 4-9. Constraints Scores - Saltat Ferments

Source: Author

On the survey they mentioned all factors as being potentially very relevant constraints to their business but scored technical feasibility and regulatory constraints as the least relevant. They feel they have enough capabilities to navigate the technical hurdles and can find support if need be.

Enablers

The discussion centered on how optimistic they would be to develop an industrial symbiosis exchange. They currently work with local farmers and are actively involved in the urban farming community of Malmö. They already use some of the ingredients that are not fresh enough to sell direct to consumers for their inputs on their fermented products and in this way are somewhat engaged in industrial symbiosis. This has been mostly done through self-facilitation. They feel internal cycling within the systems is an important part of eco-efficiency.

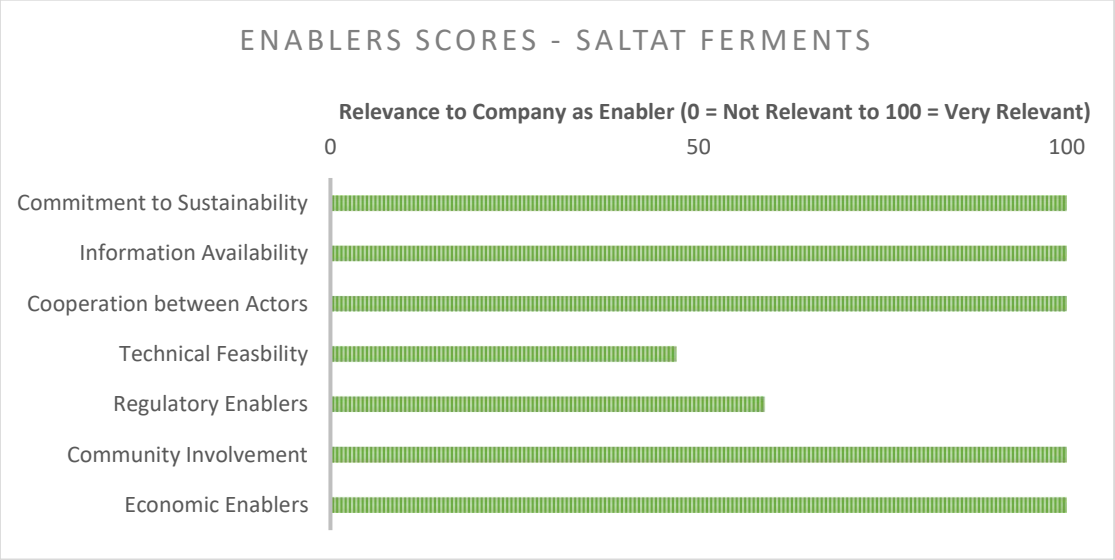

Figure 4-10. Enablers Scores - Saltat Ferments

Source: Author

When responding to the survey they again felt that all aspects were also relevant enablers but did not believe technical and regulatory aspects were as relevant to them.

TKAW

The respondent from the company had high *trust* in the actors in their networks and described how they often meet in the winter to pre-plan the year and collaborate in various communication channels to meet demands and supply quality products. This collaboration leads to high trust between the actors. On the survey they ranked themselves as +2 and mentioned trust is an enabler to their organization.

They felt their *knowledge* about the technical and logistic aspects of industrial symbiosis was high, especially when compared to others in their networks. They scored themselves a +2 and felt it was an enabler for their company.

Their level of *awareness* of potential synergies in their networks are high, due to close communication channels and working together with restaurants and networking with different chefs in the city. They ranked themselves a +2 and felt their awareness was an enabler.

They had high *willingness* to engage in more symbiotic exchanges and thus ranked themselves a +2 and mentioned their willingness as an enabler.

Diffusion

They first heard about industrial symbiosis through academia, and from there took an interest in it. They often work together with other farmers, restaurants and really value networking as a means to knowledge diffusion. They learn about the equipment other small businesses use and any innovations this way. They mentioned one place they would likely reach out to if they needed additional support would be the municipality and see if that can lead them towards more answers.

Absorptive Capacity

The business is still very small, and therefore the focus is on growth and new opportunities. It is more difficult to deal with extra costs of incorporating new innovations into the business, however, they feel time wise they can handle these transitions and would prioritize these ventures to grow their business.

This concludes the results of the five case companies. The following section will input these findings into the TKAW analytical framework.

4.2 TKAW Analytical Framework

The following section applies the case study companies' TKAW values into the analytical framework presented in section 2.7 to analyze how the different companies would fit into this framework and test whether the framework is a suitable way to apply empirical TKAW values.

It is important to start with the fact that these scores were self-reported scores by the case study companies themselves, and therefore can only be considered in this way. The process of characterization was used as described in section 2.7.2 to convert each company's social aspect values on TKAW to quantifiable inputs for the framework. The companies self-scored using the Kunin face scale responses as shown in the Appendix B survey TKAW questions. These were converted to numerical values to assist with placing the companies into their relevant positions in the framework.

The scores range from a -2 to a +2 with the higher score meaning more self-reported strength in this aspect. Figure 4-11 below shows how the conversion from Kunin face scales on the survey were converted to numerical values.

Figure 4-11: Kunin face scale to numerical score conversion

Source: Author

The TKAW framework only seeks to present the data as it came in. One exception had to be addressed, as Saltat Ferments self-scored +2 in all aspects, the interview results had to be considered, and they were chosen as the awareness leader because they mentioned this is their strongest point and they felt they had very high awareness and understanding of the industrial symbiosis concept.

Munkagrodden AB had the highest Willingness score, with a +2. They were overall very enthusiastic about taking on opportunities should they present themselves and are therefore the **willingness leader** in the framework.

Table 4-1. Munkagrodden AB TKAW Table

Aspect	***Score***	***Enabler or Constraint***
Trust	0	Constraint
Knowledge	1	Constraint
Awareness	1	Enabler
Willingness	2	Enabler

The Plant-Based Protein Food Product respondent was the most knowledgeable about the technical aspects and the concepts of circular economy and industrial symbiosis and are therefore the **knowledge leader** in the framework

Table 4-2. Plant-Based Protein TKAW Table

Aspect	***Score***	***Enabler or Constraint***
Trust	1	Enabler
Knowledge	2	Enabler
Awareness	1	Enabler
Willingness	2	Enabler

DoubleGood AB self-scored rather low throughout all aspects, and therefore they were the case that would likely remain outside of the network until another knowledge or awareness leader can bring them in. This worked in line with the model presented by Ghali et al. (2017) which describes that companies may fall outside the framework network, but have avenues for entering through the support of other TKAW leaders. Therefore, leaders can diffuse knowledge outside of their direct networks as well. They were the only case company not able to be a leader in one of the TKAW aspects.

Table 4-3. DoubleGood AB TKAW Table

Aspect	***Score***	***Enabler or Constraint***
Trust	0	Enabler
Knowledge	-1	Constraint
Awareness	-1	Constraint
Willingness	1	Enabler

Malmö Chokladfabrik was the **trust leader** of the case companies. This was in line with their interview as well as they had mentioned their high trust in their contacts in networks has been fruitful in the past and they are most focussed on working together and collaborating with others for the good of the community.

Table 4-4. Malmö Chokladfabrik TKAW Table

Aspect	***Score***	***Enabler or Constraint***
Trust	2	Enabler
Knowledge	0	Constraint
Awareness	-1	Constraint
Willingness	1	Enabler

Finally, as mentioned before Saltat Ferments self-scored high on all aspects. Since they alone could not be leaders in all aspects, as this would not work in the framework or help establish a network of synergies, they were chosen as the **awareness leader** due to aspects they stressed in the interview which focussed on their excellent networking in the industry, how well versed they were in understanding the concepts and how they were actively on the lookout for more opportunities for eco-innovations as a growing company.

Table 4-5. Saltat Ferments TKAW Table

Aspect	***Score***	***Enabler or Constraint***
Trust	2	Enabler
Knowledge	2	Enabler
Awareness	2	Enabler
Willingness	2	Enabler

4.2.1 Case Studies Placed into TKAW Framework

To conclude the TKAW scoring, the companies that were able to be scored as aspect leaders were placed into their respective positions based on the tables listed in the previous section. This shows that the framework was able to apply empirical collected data on each individual company's TKAW responses on the survey, use the process of characterization to convert survey responses to quantitative values and finally, determine whether each company takes a leader or follower position.

The following Figure 4-12 shows each case company placed into their respective TKAW leading position, apart from DoubleGood AB who is a dependent follower outside of the network.

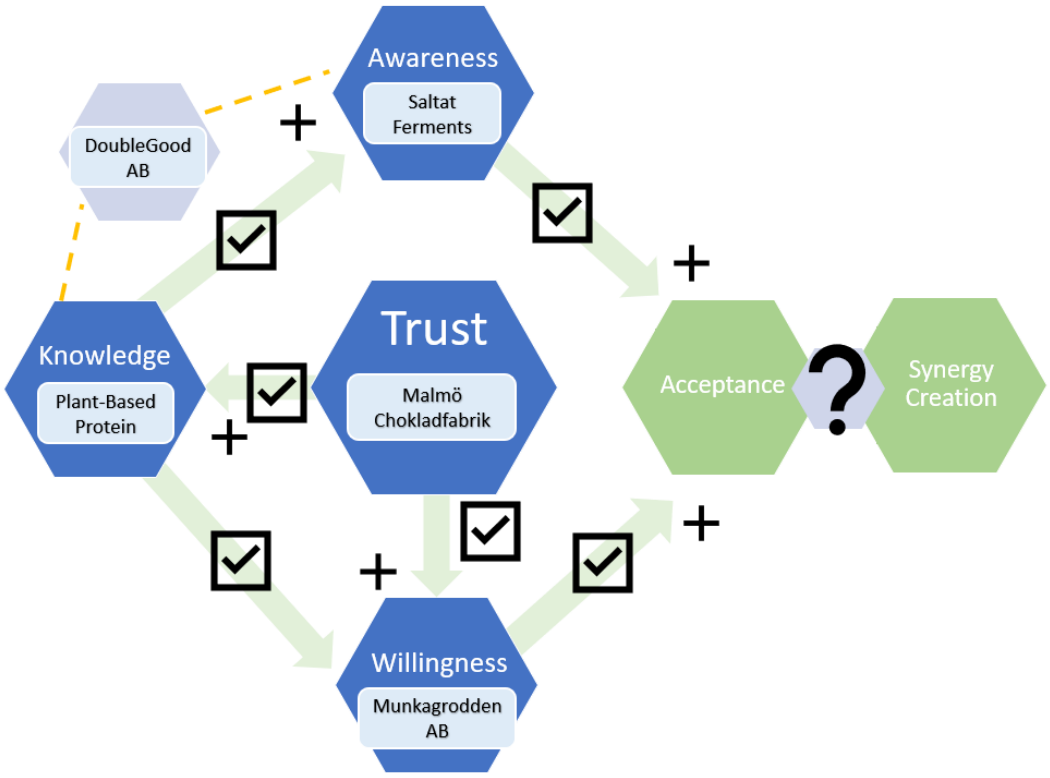

Figure 4-12. Completed TKAW Framework

Source: Author

As each position has a leader, this means that based on this analytical framework, it would be possible for the network to function and have diffusion of knowledge and an opportunity to find synergies. The final step would be acceptance, where if an opportunity presented itself, the relevant companies would have to make the decision to accept the match or not based on shared economic and technical information. This was not included as in this study technical and economic matches have been left out and therefore do not have enough information to conclude on the final step of acceptance. This is marked by the large question mark between the two green nodes of acceptance and synergy creation in the previous Figure 4-12.

One challenge encountered by the study was that of incorporating companies with higher capacity for resource flow linkages and to find a way to better measure a company's capacity to influence change in their networks. An example of this was that while Saltat Ferments self-scored high on all aspects and was knowledgeable and willing to further develop their business towards potential IS opportunities, it was recognizable that a small one-person company may not have the resources or time to significantly influence their networks. Nevertheless, all the cases were useful proxies to test the analytical framework with empirical data, and thus still yielded results in line with the aim of the study.

This same approach could be applied to more companies' data leading to a higher complexity of inputs and therefore would be more suitable for inputting into an actual computer model such as an agent-based model to simulate outcomes and matches. This study sought only to test the framework with a small number of case companies as access to a computer simulated model was not possible and was outside the scope of this work. Next, to contribute to answering research question 3, the following section describes conversations had with facilitators about how they are able to support ambitions by companies to enter into IS networks.

4.3 Discussions with Facilitators

This section will present a summary of the discussions that were had with facilitators in line with the goal of answering research question 3 of the thesis. The interviews were more exploratory than the interviews with the case study companies, but followed the same themes of trust, knowledge, awareness, and willingness (TKAW). The aim was to capture some external thoughts on SMEs working toward IS in Sweden from the perspective of facilitators and how they may play a role.

4.3.1 CircLEAN Launch

An important piece of supporting industrial symbiosis is support from governmental organizations as discussed earlier in Chapter 2. The European Commission on February 23rd, 2021 launched CircLean, through an online event and roundtable discussion. CircLean is a European network of businesses and SMEs for IS. It aims to be a facilitator platform that looks to mobilise industries and relevant stakeholders to seize opportunities and overcome challenges when approaching industrial symbiosis. While this is not specific to Sweden or Skåne, the food industry in this region can benefit from the support of the EU and therefore this initiative.

One major enabler and goal was to set up an Industrial Symbiosis label to promote credibility and transparency. This would be managed by the CircLean network. Another major initiative is to create an online tool to work as an assessment, matchmaking, and evidence gathering platform to support industrial symbiosis transactions. Finally, the initiative seeks to create and pilot a common methodology to measure and report on resource exchange benefits. These three components seek to be enablers to help establish more industrial symbiosis with the network members. The initiative is in line with the Type 5 "virtual" industrial symbiosis and the intention is to create possibilities amongst members that are not always co-located or not aware of each other. Constraints that were discussed during the event were the number of applicable uses for potential resources, the matching of supply and demand of resources, and finally actually measuring and rewarding environmental achievements through these efforts.

Finally, a discussion about trust unfolded in the chat section of the event, and there were some notable takeaways from this discussion. Most participants held the common belief that facilitators are a key part of overcoming trust related challenges. One attendee mentioned that given the right information, at the appropriate time through facilitation efforts, trust can be overcome. Through the discussions a common agreed upon definition of trust was presented:

"The confidence in a resource partner's ability to deliver the wastes/by-products to specification, volume, price and time. The confidence in someone using the resources to do so in a responsible way. The trust in governance that the synergy can persist long enough to justify investment and the confidence in not using shared information or knowledge opportunistically" (CircLean, 2021).

This definition served as the basis for the definition discussed with case companies during interviews and was in line with the definition used by Ghali et al. (2017). The event ended with a call for interested stakeholders to sign up on the platform and help with shaping the development of the label, the online tool, and the common methodology. Next, a discussion with a private facilitator will be presented.

4.3.2 Kvadrilj Private Consultancy

To gain some interdisciplinary insight into the role facilitators play in establishing industrial symbiosis between stakeholders, discussions were had with a private consultant that runs a consulting agency named Kvadrilj, as well as working with Livsmedelsakademin Skåne a food industry organization, for Packbridge a cluster industry organization for packaging, and for IUCSYD an industry development organization for Skåne. The following section is written based off the reflections during this interview.

Last year, the four organizations came together to facilitate a circular food value chain workshop including primary producers, retailers, and consumers. The findings of this workshop were discussed as well as how these organizations play a role in facilitating industrial symbiosis exchanges in Skåne. The consultant's main reflection was that the food industry in Skåne still works in silos, with many in the industry following a traditional and conservative business approach. There is an overall lack of communication between stakeholders, even if willingness is often high. The ways in which a facilitator can get involved were discussed to be introducing more information into the food value chains. It is because of a lack of information that companies sometimes overproduce, sometimes in very high volumes over the actual demand. This causes an excess of product that is not entered back into the value chain as there is a lack of information about it, and it goes to waste. On top of this, grocery stores that are consumer facing follow the demands of consumers by stocking shelves much more than the actual demand to create the perception of abundance which consumers demand. There have not been enough intermediaries and receiving companies included in these value chains to deal with this wasted supply or turn them into industrial symbiosis resource sharing opportunities.

The interviewee from Kvadrilj also felt that packaging was an important part of providing information and to keep food from being wasted by extending the shelf-life of the products. Appropriate packaging can therefore provide its intended use of extending shelf life, and then be re-used in some other value chain. However, this is another piece that seems to be missing in the industry, as much of the plastic does not find a second life. Another concept discussed was having large companies and SMEs work together to find solutions. The SMEs can present innovations and new business models to different consumer groups and create new sales channels for by-products or waste. Having the larger companies pitch their challenges and finding ways for smaller companies to solve these challenges can be a forum for knowledge diffusion and innovation, so long as the outcomes are mutually beneficial. Finally, trust was discussed as an important enabler and constraint and the interviewee mentioned one of the most important roles of a facilitator is to help create this trust between firms. One challenge is misinterpretation of claims, and this can impact the trust between the companies. There are also challenges with a lack of evidence-based claims. In a business-to-business setting, trust is easier to achieve as the aim is to create shareable value and common gain. The interviewee mentioned that local authorities are increasingly becoming responsible for ensuring collaboration between companies to reduce waste and environmental pollution.

This concludes the results chapter, and the next Chapter 5 will offer a discussion on the findings in relation to those found in the literature review.

5 Discussion

This section serves to present some reflections on the findings from the case studies and discussions with facilitators and collate these with the existing literature reviewed earlier. It then also serves to offer a reflection on the research methodology and limitations of the study.

5.1 Collating the Findings

This thesis sought to contribute to understanding of constraints and enablers to IS for SMEs and how aspects of trust, knowledge, awareness, and willingness (TKAW) can be gathered from case studies and used to test a conceptual model developed for future simulation through agent-based modelling. As per Bichraoui et al. (2013) these aspects are more difficult to assess and solve, and thus this research looked to find one way towards addressing this challenge.

In Chapter 2, Table 2-3 served as a summary of the key findings in the literature review related to the research questions of the study. In this Discussions chapter, the same table will be presented in three separate parts for each research question and additional findings from the empirical study will be added on and discussed.

For research question 1, regarding SME specific enablers and constraints to achieving IS, the findings were based on the information presented in the interviews as well as the scoring in the surveys. These scores can be seen in more detail in Appendix C, where they were also averaged out to find commonalities between the five case companies. Table 5-1 below presents the new findings which were additional to those found from the literature review.

Table 5-1. RQ 1 Findings

Research Question	*Key Findings*
RQ 1. What are the SME specific constraints and enablers to industrial symbiosis in Skåne, Sweden?	Overall, the seven aspects by Golev et al. (2015) are a useful summarization and categorization of IS constraints and enablers **Enablers:** Becoming part of a regional network (Pigosso et al., 2018) Higher absorptive capacity (Pigosso et al., 2018) Meta-knowledge on network's TKAW aspects (Ghali et al., 2017) **Constraints:** Being in a business-to-business setting (Ormazabal et al., 2016) Limited institutional capacity and resource availability (Boons & Spekkink, 2012) Supply and demand mismatch and reliance (Oberle et al., 2019) Limited governmental support (Pigosso et al., 2018)

Additional findings from case studies	**Enablers:** Cooperation between actors and information availability were seen as highest priority Regulatory aspects were scored as the lowest relevance Potential value of by-products important Ethical and value-based company cultures act as motivators **Constraints:** Food related aspects such as shelf-life, organic certification, allergen, and cross contamination discussed as constraints In small companies, other things take over priority over by-product and waste planning

The case companies felt their limited institutional capacity and resources were an important constraint as per the literature review. Supply and demand mismatches were also echoed by the companies. Others stressed the importance of governmental support. The additional findings were not contradictory to the literature review findings, and instead brought further understanding to their own experiences as SME companies in the agri-food sector in Skåne. Thus, the findings contribute by further contextualizing constraints and enablers to the study's specific scope. They do also support the argument presented earlier in Section 1.1 by Sterr & Ott (2004) that information transparency and cooperation are most important to development of an IS network.

For research question 2, the TKAW model proved to be a possible way to capture and quantify in some way how the case companies felt about the aspects of trust, knowledge, awareness, and willingness. The model ended up working and being complete, with one case company becoming an aspect leader in all four of the social aspects, while one fell outside of the network as a follower needing support. This was not expected or planned and shows that even with a small sample of companies it provides a useful tool to navigate how companies may fit into networks and where they can provide support.

Table 5-2. RQ 2 Findings

Research Question	*Key Findings*
RQ 2. How can trust, knowledge, awareness, and willingness (TKAW) aspects from empirical study be applied to a proposed analytical model to support industrial-symbiosis creation?	Allows to understand and model diffusion of knowledge and concept (Tao et al., 2019) Increases meta-knowledge of TKAW amongst members allowing for "shorter mental distance" (Ashton & Bain, 2012) Adds real-world empirical values to TKAW instead of existing fixed theoretical values (Ghali et al., 2017)

	Tests the applicability and compatibility of empirical data from SMEs interested in IS to the TKAW model framework by Ghali et al. (2017) Provides a foundation upon which further study through modelling techniques can be done (Batten, 2009; Rincón-Moreno et al., 2020)
Additional findings from case studies	Overall willingness was high from all case companies Trust was an important aspect to all companies Process of characterization allowed for quantification of TKAW aspects through a survey form Each TKAW aspect ended up with an aspect leader Theoretical network was able to be developed

The analytical framework therefore ended up being a useable model, and a simplified precursor or snapshot input to a more complex modelling approach such as agent-based modelling. It was the first known empirical collection of the TKAW aspects related to industrial symbiosis on SMEs and therefore the method of how it was used in this study could act as an inspiration for future development in agent-based modelling.

Finally, the findings on research question 3, regarding support from facilitators showed some potential facilitators as more relevant for these case companies. Table 5-3 below summarizes the additional findings:

Table 5-3. RQ 3 Findings

Research Question	*Key Findings*
RQ 3. How are SMEs efforts to enter IS networks and increase TKAW aspects supported by facilitators?	Sharing of institutional resources, knowledge and economic benefits (Boons et al., 2017; Golev et al., 2015) Increased co-operation between actors (Golev et al., 2015) Supporting development of absorptive capacity in firms (Pigosso et al., 2018) Increased awareness, communication and build-up of trust (Mirata et al., 2017)
Additional findings from case studies	One example of self-organized industrial symbiosis was found at Munkagrodden AB where no facilitator was involved

	Industry associations seemed to be the most relevant facilitator for the case companies and most likely to help diffusion of knowledge and concepts Venture groups or partner organizations can act as a facilitator EU-wide CirClean facilitator platform in early stages

One case company echoed findings in the literature review that they felt their waste management company could be a helpful facilitator in brokering places to send their by-products. The consensus was that the companies felt local authorities or government bodies could be useful facilitators but had not felt supported by them. This has potential policy implications for Sweden's development and dissemination of their National Plan for Circular Economy. Outside of Sweden, the EU-led CirClean initiative is in the early stages, and only just now developing their online tools and labelling scheme to help be a facilitator in the market. The discussion with the private consulting facilitator echoed findings in the literature that trust was an important aspect and facilitators can help overcome shortcomings. This last research question however could be further studied to find more context on facilitators specifically supporting SMEs, as the empirical study only yielded limited views on this.

5.2 Reflection on Methods and Limitations

This section will review and reflect upon the chosen research methodology and any limitations of the study with further research opportunities presented alongside the discussion. The **research design** was motivated by the need for more empirical data collection identified as a research gap when studying areas related to TKAW. In this way, the best way to collect such empirical data was through a collection of multiple case studies. A higher number of cases with more complex resource flows and higher capacity for resource exchanges to achieve industrial symbiosis may have contributed to the **validity** of the study and is a potential for further research. However, the aim was to test how the TKAW analytical framework could be used with empirical data and study specific implications that SMEs face and therefore the results still showed validity in relation to this aim. The challenges faced with studying SMEs were known at the start of the study, with lower capacity available to dedicate to detailed discussions on complex issues. The opportunities that presented themselves ended up being beneficial to this study, as well as to the contribution of knowledge to the practitioners themselves. Despite their limited time, they were open, approachable, and very willing to help. While other cases did not come to fruition, the cases studied ended up being acceptable proxies to test the analytical framework. Limitations to findings other cases included companies' challenges during the Covid-19 pandemic, how comfortable respondents were with discussing detailed TKAW social aspects in English instead of Swedish, some companies being part of larger conglomerate companies outside of the scope of the study, and finally limited time. With case study research, and especially qualitative research it is sometimes argued that it is difficult to achieve **generalizability** (Gustafsson, 2017), but given the findings were examined under an analytical framework, there is still an adequate amount of 'analytical generalization' which as per Yin, (2014) is about making projections about the transferability of findings from an evaluation, based on a theoretical analysis of the factors producing outcomes and the effect of context. This same study on Swedish firms may not be transferable to other national or regional operating cultures due to variations in trust dynamics in other businesses, governments, or facilitating agents. The aim was to analyze the core elements of these cases, use them as inputs to test the framework and come to an understanding about overall constraints, enablers, TKAW aspects and reflections on facilitators. This same theoretical analysis can then be applied to other cases to compare contexts in future research.

Regarding additional **theoretical focus**, the study may have benefited from deeper examination of the constraints and enablers as per the resource-based view and the resource-dependency view. These lenses however require a much deeper study into the internal workings of the case companies, with information needed about their institutional capacities, and internal firm resources (Barney, 1991). Given the limited time and availability of the interviewees, and an already full agenda to answer the research questions, this leaves space for opportunities to conduct additional research in the future.

A challenge with performing qualitative research comes to interpretation on the variation of data that is collected which may affect the **reliability** of the results (Creswell, 2014). One of the analytical limitations of this study was thus using a survey form that included scales to collect responses. This left each respondent some room for interpretation of the questions (Warmbrod, 2014). To combat this and help bring all respondents to the same understanding, it was decided the survey only be sent out after the semi-structured interview was completed, so each respondent clearly understood what was being asked of them, what the various terms meant, and how the responses would be used. Despite this, it may have proven challenging to decide on how to score themselves on aspects such as trust, knowledge, awareness, and willingness on a scale. For this reason, these questions that were used to quantify these aspects were presented using the Kunin face scales as seen in Appendix B, where the respondent had a better way to select a score based on their feeling, and not an arbitrary number.

To best understand the outcomes of the study, it is also important to understand what the study **did not aim** to do. The study did not intend to provide a representation of the population of agri-food companies in Skåne, and thus a qualitative study design was chosen instead. This allowed for purposive sampling of available companies that were interested and somewhat knowledgeable about IS and the opportunities it can provide. The study therefore should be understood with this level of bias applied. Other agri-food companies with no knowledge of IS may not have been able to reflect on their own aspects of TKAW in relation to resource-sharing networks and therefore, could not serve as useful proxies to testing the analytical framework. The study also is not intended to be used as a direct input to a future agent-based model. The complexity of such data collection needs to be much higher, and there are more detailed calculations that need to occur to simulate behavioural interactions and decision making within the networks. This study intended to provide a snapshot of how the TKAW framework could be used, how TKAW aspects and discussions could be measured and evaluated and finally used to determine a probabilistic placement of companies into their respective positions in the framework. Therefore, the positions should not be understood as discrete, and should another researcher develop another way of capturing TKAW aspects from case studies and characterizing them in a different way, they may end up with other results.

Finally, following the conclusion of data collection and analysis there was a realization that some form of measuring or scoring of the case companies' **abilities or capacities** to influence change in their theoretical network was needed. This could have perhaps better described how a small one-person company could have enough ability to diffuse the concept and set up network connections even if they were very willing, with high knowledge, trust, and awareness. This ability or capacity to effect change may be an important variable to better complete the analytical framework in future study. Its importance as well as the importance of the other aspects could also be measured and validated with a sensitivity analysis to see how the variables effect the outcomes given the same assumptions and values. Finally, the analytical framework served as a first step of empirical data collection related to TKAW aspects and serves as the basis for further input into more complex modelling applications.

6 Conclusions

This thesis sought to contribute to understanding of constraints and enablers to IS for SMEs and how aspects of trust, knowledge, awareness, and willingness (TKAW) can be gathered from case studies and used to test a conceptual model developed for future simulation through agent-based modelling. The purpose of the study was to address the gaps in understanding of social aspects TKAW roles in IS network creation in relation to SMEs and recommend future research potential.

To address this aim and operationalize the study, a literature review was conducted followed by qualitative empirical data collection from five case study companies through semi-structured interviews and a survey. These were then analyzed using coding to find common themes and core concepts, as well as applying the findings to an analytical framework. This was done to answer the following research questions:

RQ 1) What are the SME specific constraints and enablers to industrial symbiosis in Skåne, Sweden?

RQ 2) How can trust, knowledge, awareness, and willingness (TKAW) aspects from empirical study be applied to a proposed analytical model to support industrial-symbiosis creation?

RQ 3) How are SMEs efforts to enter IS networks and increase TKAW aspects supported by facilitators?

The findings in relation to **RQ 1** were as follows: The identified **constraints** for SMEs included operating strictly within a business-to-business setting, having limited institutional capacity and resource availability; supply and demand mismatches and reliance; limited governmental support; food shelf-life; organics certifications; allergen strictness and cross-contamination worries; and finally, the fact that in small companies' by-product and waste planning are not top priorities. The identified **enablers** were found to be participating in regional networks; having a higher absorptive capacity; having a meta-knowledge on their networks TKAW aspects; increased cooperation between actors; increased access to information; a higher potential value of by-products; and values-based and ethically driven company cultures.

To answer **RQ 2**, the interviews and surveys were key inputs to a **TKAW analytical framework** developed. Each TKAW aspect ended up having a company leader, while one company remained outside the network. The framework logic process was able to be used with collected empirical data. This was unexpected, and a good indicator that even with a random selection of actors, there is an opportunity to study potentials for co-operation and synergy creation. Trust was an important aspect to all companies, knowledge and awareness levels varied, while overall willingness was high from all case companies. This undertaking applied real-world empirical values to the TKAW aspects instead of fixed theoretical values and therefore tested the applicability of empirical data to the TKAW framework and thus informs further study using more complex modelling applications such as agent-based modelling.

The findings for **RQ 3** were that facilitators can help with trust building, knowledge diffusion, but also need development and ways of incorporation into networks. Noted relevant facilitators were industry organizations as well as venture groups that share similar business goals, structure, and visions. The case companies felt local authorities and governments could be more of an active facilitator and this could have implications for Sweden's National Plan for Circular Economy which mentions industrial symbiosis as a key pillar. Finally, an EU-wide facilitator platform launched recently called CircLean aims to support SMEs' efforts in Europe to achieve industrial symbiosis through the development of an online platform for knowledge, a common methodology and a labelling scheme.

The thesis achieved the aim it had set out to study, however; a range of **limitations** were encountered that must be acknowledged. The most substantial limitation was that of the complexity of resource flows of the case companies which made discussions about various industrial symbiosis opportunities somewhat limited. Overall, this did not impact the aims of the study, as it was not meant to find technical or economical matches but instead provide inputs to TKAW aspects and analyze potential interactions among the companies based on these inputs. The interpretation of the scoring in the surveys by the case companies served as another main limitation. This may have made it challenging for respondents to uniformly interpret the scales and apply them to complex aspects such as trust, knowledge, awareness, and willingness. Using Kunin face scales for this and clearly communicating the intention in the interviews and definitions of terms prior to the surveys helped mitigate some of these worries. Finally, another limitation was having no way of measuring the capacity or ability for the case companies to actively participate in the networks.

The contributions of the thesis are targeted at three main audiences. The first one being **practitioners**, as discussing ways of becoming more aware of industrial symbiosis opportunities, increasing their knowledge on the concept, and identifying common enablers and constraints can help practitioners across the agri-food-sector in Skåne get ahead of regulatory or legislative efforts from governments. It can also inform them to better develop their institutional and absorptive capacities well in advance to take advantage of potential resource-exchange opportunities.

Second, the study helps inform **facilitators**, be they industry associations, government authorities or private consultants of constraints and enablers and how they may help companies diffuse in their networks. This can be done by better understanding the importance that trust, knowledge, awareness and willingness play in network creation and diffusion and then supporting and targeting these aspects where they need it most.

Third, the study shows potential for future research in **academia**. Having a way to measure the ability and capacity for the companies to effect change in the networks would increase the robustness of the TKAW analytical framework. The importance of the TKAW aspects could also be input to a sensitivity analysis to better determine how the variables effect outcomes. There is an opportunity for a deeper examination of the constraints and enablers as per the resource-based view which refers to the knowledge, capacities and resources of the company, and the resource-dependency view which offers the perspective of interdependence between companies for key resources. This would require gathering more detailed internal company information. Finally, the most applicable opportunity would be to apply empirical findings as inputs to a modelling application such as agent-based modelling, and better simulate the network diffusion and synergy creation. This study informs these efforts as the analytical framework and its logics ended up being useable with empirical data collection. As these modelling applications have capability to increase complexities on the framework, more case study companies can be included, increasing the empirical data collection. This could also be applied to an active network to validate the model.

Overall, the study offered a unique opportunity to work together with a diverse group of SME case companies in the Skåne agri-food sector to determine important factors to achieve more by-product resource exchanges, test an analytical framework for industrial symbiosis, and look for ways to increase collaboration in their networks to contribute in a small way to a more circular agri-food industry in Skåne.

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Appendix A: Semi-Structure Interview Outline

The interviews that were conducted in this study were semi-structured and therefore offered a high degree of flexibility. However, to satisfy the aims of the data collection, they followed the core theme areas, similar to the survey that was sent out. The questions served as a guide for the author to refer to should the discussion stray too far off topic.

	Establishing a Base
Practicalities	• Do you agree to have this interview recorded? • Your name will remain private • Do you understand the aim of the project? • Provide info about thesis, define IS and SME, describe uses of data
Company Information	• What is your specific role at the company? • What experience do you have with IS? • How did these experiences occur or how do you intend to get involved with IS • Describe your waste and by-product streams and potential opportunities
	Constraints and Enablers
Enablers	• Based on the seven aspects provided, what do you feel act as enablers for your organization? • Do you have any others you may suggest?
Constraints	• Based on the seven aspects provided, what do you feel act as constraints for your organization? • Do you have any others you may suggest?
Diffusion of Concept	• How did you first learn about/come across IS? • How would you gather more knowledge?
	TKAW
Trust	• What is your level of trust of the industrial actors in your current or potential networks?
Knowledge	• What is your knowledge level of IS compared to the industrial actors in your current or potential networks?
Awareness	• What is your level of awareness of potential IS synergies with the industrial actors in your current or potential networks?
Willingness	• What is your level of willingness to enter into potential IS synergies with industrial actors in your current or potential network?
	Facilitators
Support	• Were the exchanges or would potential exchanges be through self-organization or facilitation? • How have facilitators supported your company?

	• Which facilitators do you feel are most relevant to your organization? • How do you feel facilitators can influence trust between members?
	Absorptive Capacity
Capabilities	• How ready do you feel your company is to transform and to assimilate new knowledge to create new value opportunities?
	Closing
Survey	• Explain survey and ask to fill it out
Questions or Concerns	• Do you have any further questions or concerns?

Appendix B - Survey Sent to Case Companies

0% completed

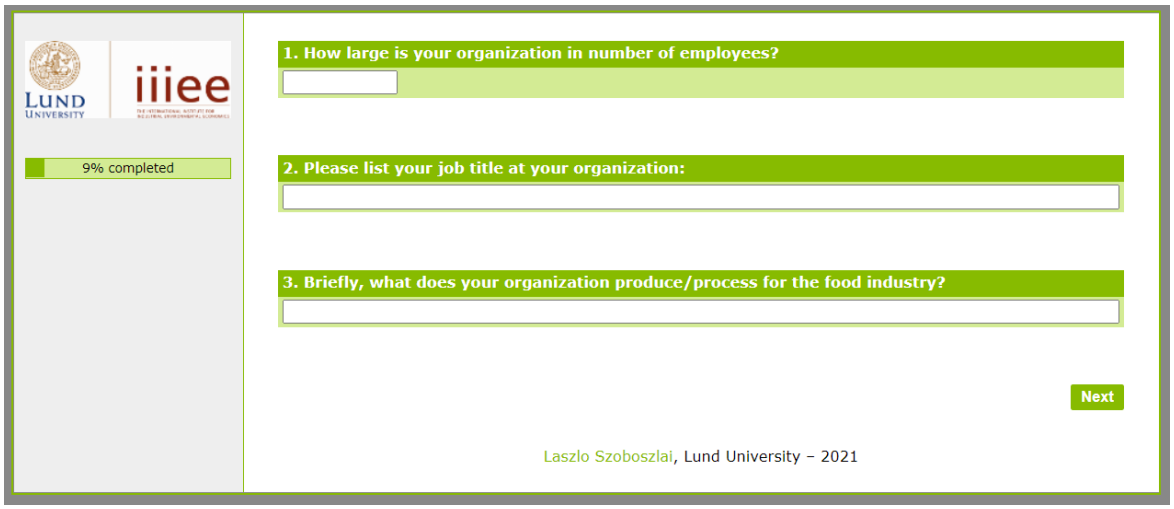
Hej! My name is László and I am a Master's student at the IIIEE (International Institute for Industrial Environmental Economics) part of Lund University in Sweden. I am working hard to complete my thesis on "**Industrial Symbiosis between Swedish Food SMEs**" and would greatly appreciate your input. The aim of the survey is to discuss the constraints and enablers you may face at your organization to implement industrial symbiosis practices (by-product resource exchanges) between other organizations in your networks.

The answers to the survey will be anonymous, and all answers remain confidential. Your participation is voluntary and you may withdraw at any time. Answers will be aggregated, coded and analyzed and the published results will not be able to be traced back to your organization.

Should you have any questions or concerns, please respond back to the email at la0132sz-s@student.lu.se.

Next

Laszlo Szoboszlai, Lund University – 2021



9% completed

1. How large is your organization in number of employees?

2. Please list your job title at your organization:

3. Briefly, what does your organization produce/process for the food industry?

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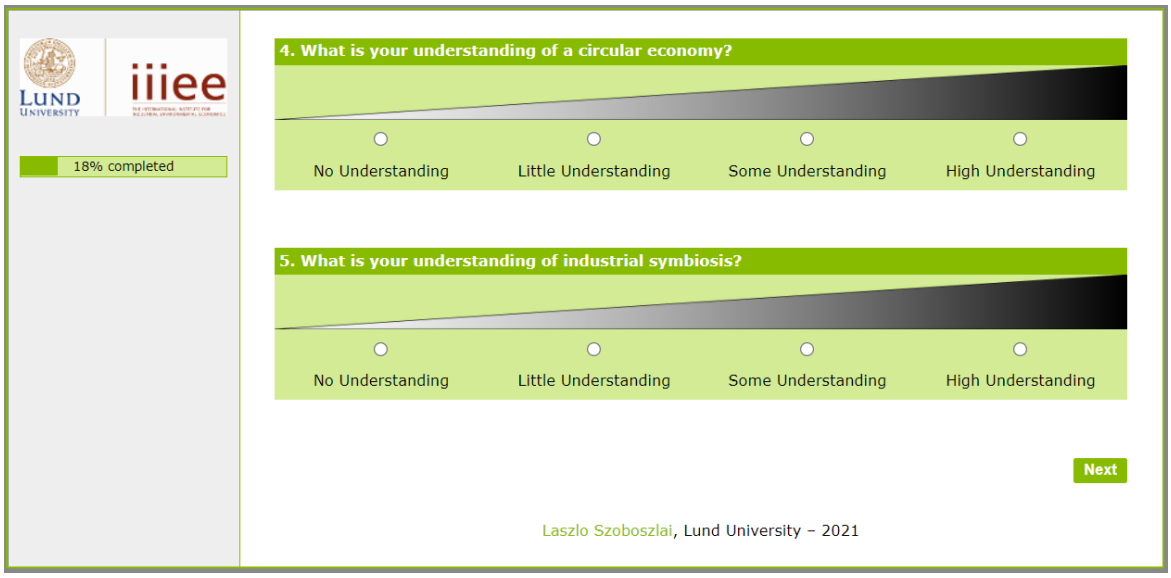

18% completed

4. What is your understanding of a circular economy?

No Understanding | Little Understanding | Some Understanding | High Understanding

5. What is your understanding of industrial symbiosis?

No Understanding | Little Understanding | Some Understanding | High Understanding

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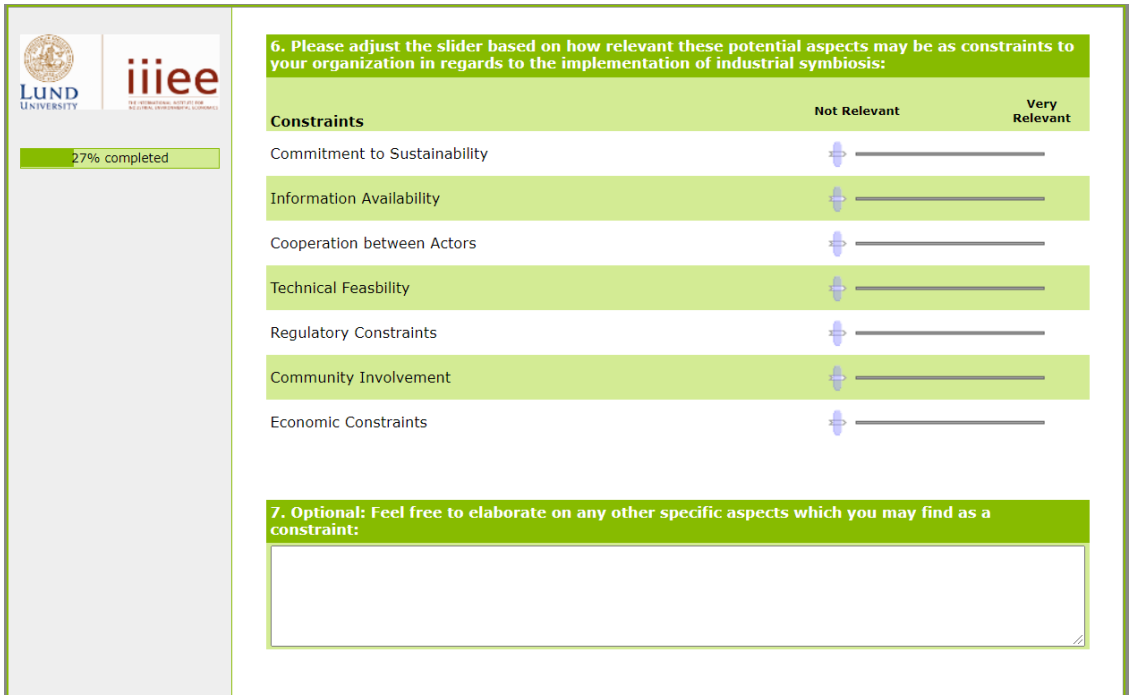
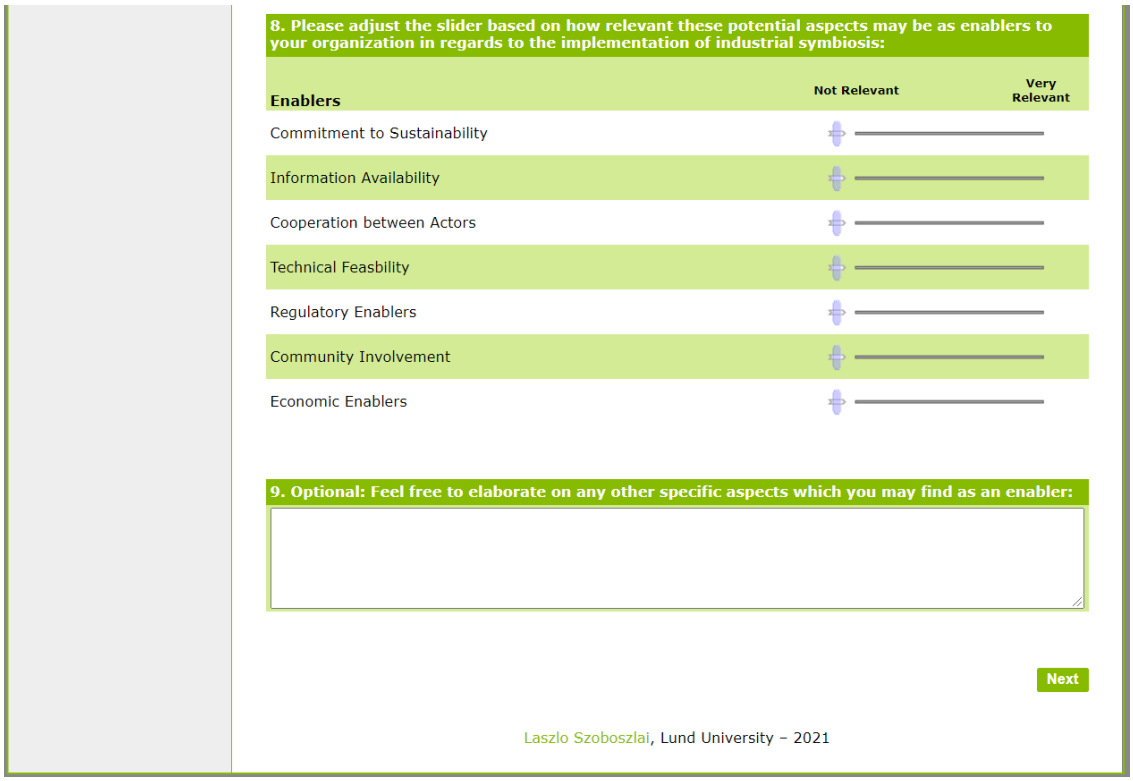

27% completed
6. Please adjust the slider based on how relevant these potential aspects may be as constraints to your organization in regards to the implementation of industrial symbiosis:
Constraints
Not Relevant
Very Relevant
Commitment to Sustainability
Information Availability
Cooperation between Actors
Technical Feasbility
Regulatory Constraints
Community Involvement
Economic Constraints
7. Optional: Feel free to elaborate on any other specific aspects which you may find as a constraint:


8. Please adjust the slider based on how relevant these potential aspects may be as enablers to your organization in regards to the implementation of industrial symbiosis:
Enablers
Not Relevant
Very Relevant
Commitment to Sustainability
Information Availability
Cooperation between Actors
Technical Feasbility
Regulatory Enablers
Community Involvement
Economic Enablers
9. Optional: Feel free to elaborate on any other specific aspects which you may find as an enabler:
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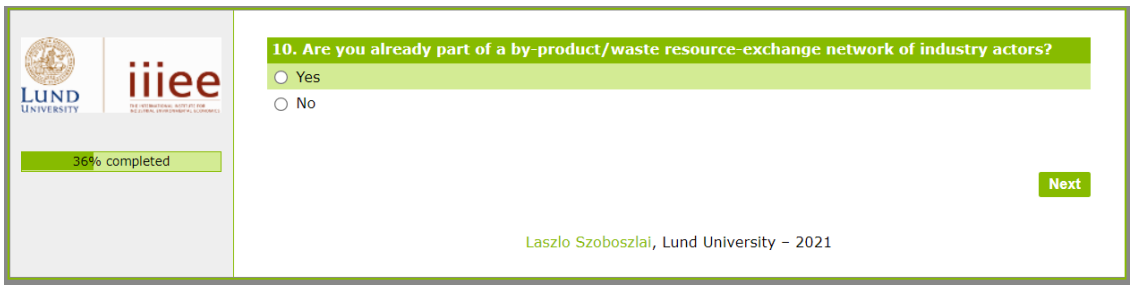
36% completed
10. Are you already part of a by-product/waste resource-exchange network of industry actors?
Yes
No
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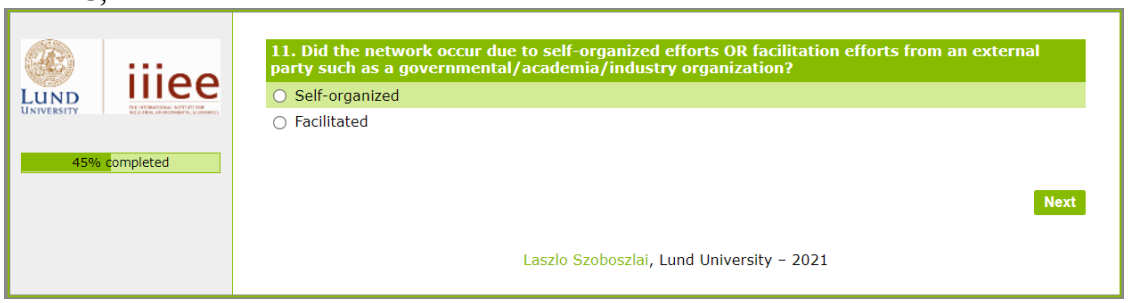
IF YES,


45% completed
11. Did the network occur due to self-organized efforts OR facilitation efforts from an external party such as a governmental/academia/industry organization?
Self-organized
Facilitated
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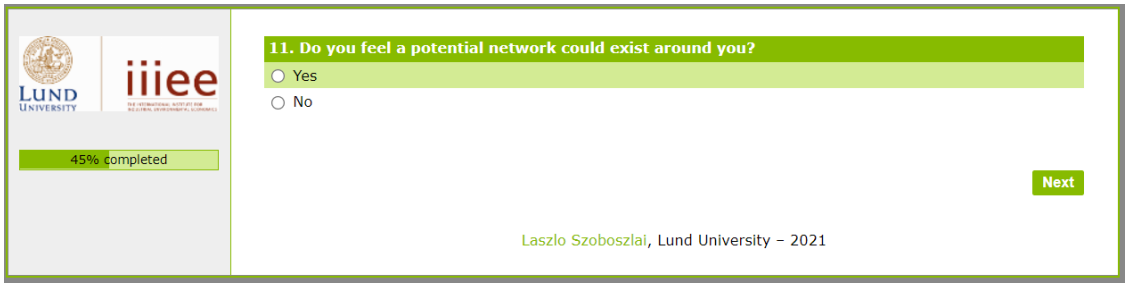
IF NO,


45% completed
11. Do you feel a potential network could exist around you?
Yes
No
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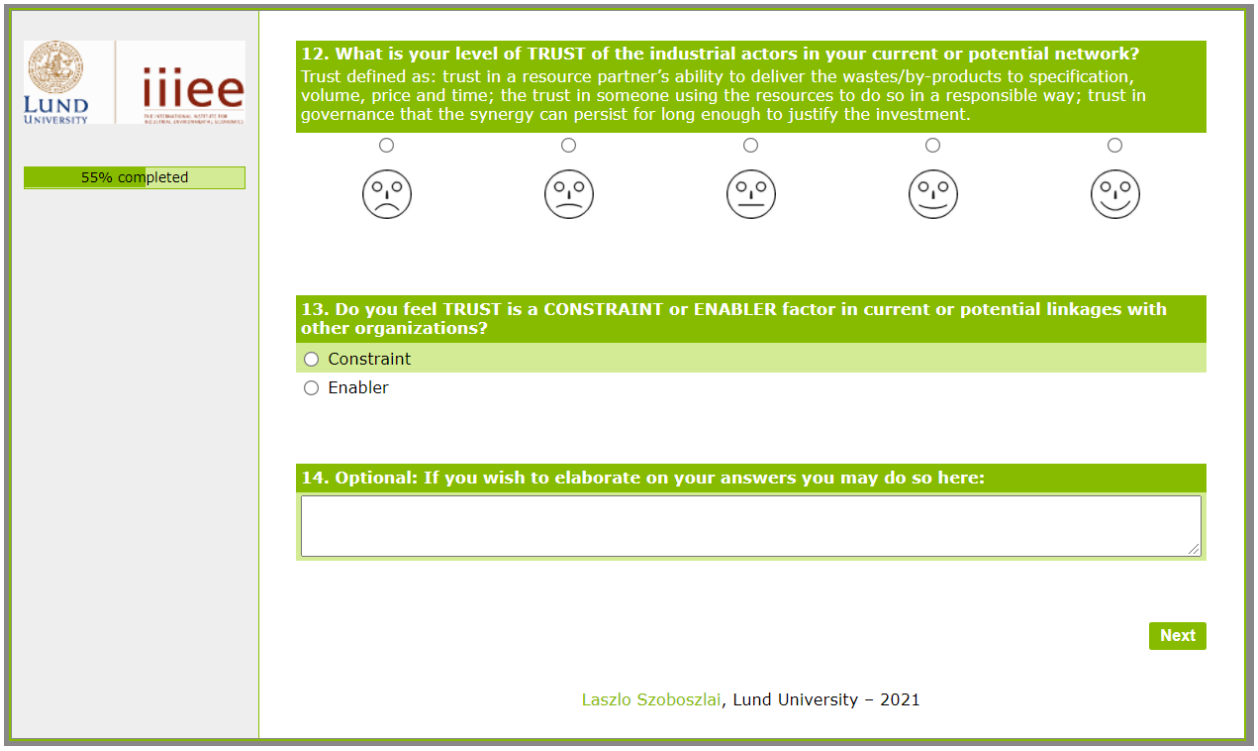
55% completed
12. What is your level of TRUST of the industrial actors in your current or potential network?
Trust defined as: trust in a resource partner's ability to deliver the wastes/by-products to specification, volume, price and time; the trust in someone using the resources to do so in a responsible way; trust in governance that the synergy can persist for long enough to justify the investment.
13. Do you feel TRUST is a CONSTRAINT or ENABLER factor in current or potential linkages with other organizations?
Constraint
Enabler
14. Optional: If you wish to elaborate on your answers you may do so here:
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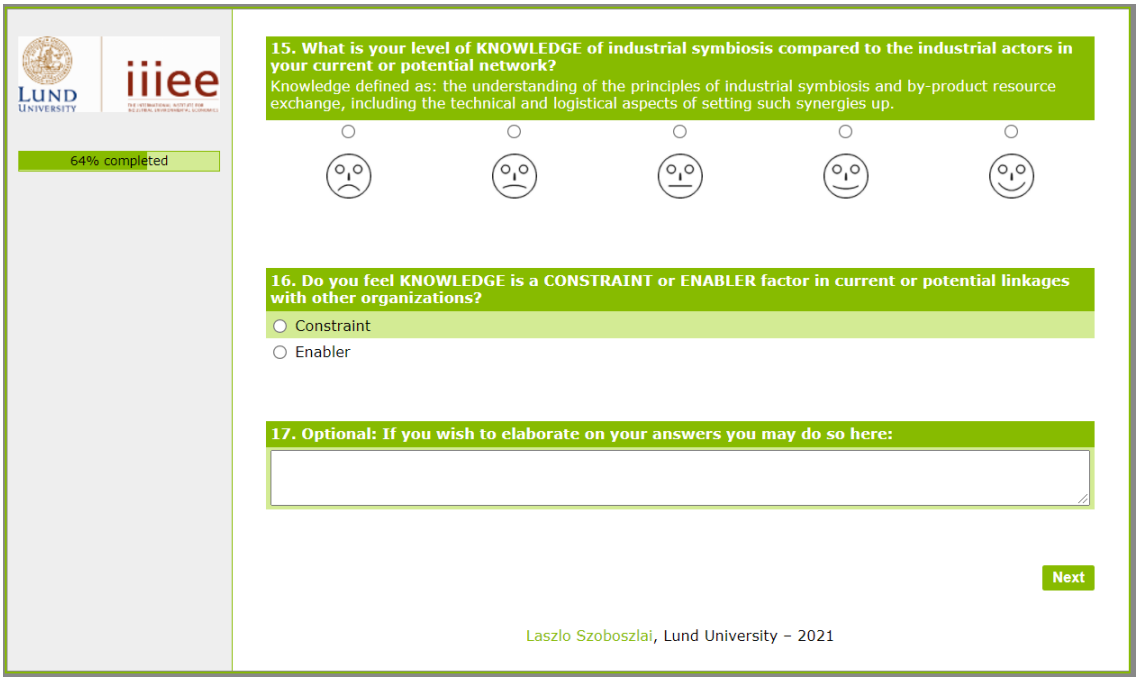
64% completed
15. What is your level of KNOWLEDGE of industrial symbiosis compared to the industrial actors in your current or potential network?
Knowledge defined as: the understanding of the principles of industrial symbiosis and by-product resource exchange, including the technical and logistical aspects of setting such synergies up.
16. Do you feel KNOWLEDGE is a CONSTRAINT or ENABLER factor in current or potential linkages with other organizations?
Constraint
Enabler
17. Optional: If you wish to elaborate on your answers you may do so here:
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73% completed
18. What is your level of AWARENESS of potential industrial symbiosis synergies with the industrial actors in your current or potential network?
Awareness defined as: the ability to identify potential industrial synergies and actors in or outside your networks.
19. Do you feel AWARENESS is a CONSTRAINT or ENABLER factor in current or potential linkages with other organizations?
Constraint
Enabler
20. Optional: If you wish to elaborate on your answers you may do so here:
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82% completed
21. What is your level of WILLINGNESS to enter into potential industrial symbiosis synergies with the industrial actors in your current or potential network?
Willingness defined as: the attitude and desire to enter into potential industrial synergies and commitments with actors in or outside your networks.
22. Do you feel WILLINGNESS is a CONSTRAINT or ENABLER factor in current or potential linkages with other organizations?
Constraint
Enabler
23. Optional: If you wish to elaborate on your answers you may do so here:
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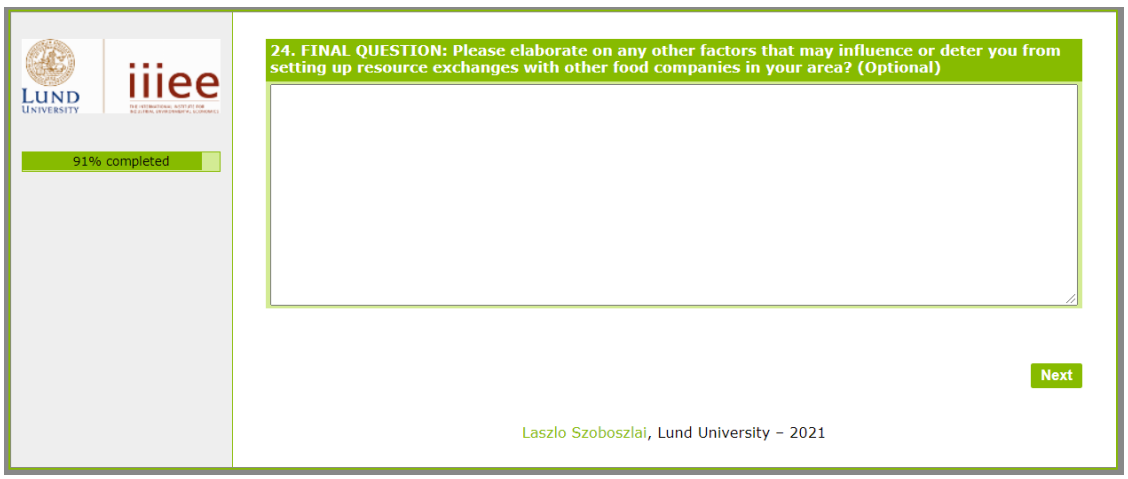
91% completed
24. FINAL QUESTION: Please elaborate on any other factors that may influence or deter you from setting up resource exchanges with other food companies in your area? (Optional)
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Appendix C – Tables of Case Study Constraints and Enablers Scoring

These tables values were generated from the survey as filled out by the respondents. They have been converted to bar charts in Chapter 4 for clarity. They are included here for the reader to access the actual values.

Munkagrodden AB

Constraints Scores

Aspect	Relevance as a Constraint (between 0-100 with higher being more relevant as a constraint)
Commitment to Sustainability	100/100
Information Availability	100/100
Cooperation between Actors	81/100
Technical Feasibility	100/100
Regulatory Constraints	100/100
Community Involvement	47/100
Economic Constraints	76/100

Enablers Scores

Aspect	Relevance as an Enabler (between 0-100 with higher being more relevant as an enabler)
Commitment to Sustainability	91/100
Information Availability	100/100
Cooperation between Actors	100/100
Technical Feasibility	64/100
Regulatory Enablers	77/100
Community Involvement	78/100
Economic Enablers	93/100

Plant-Based Protein

Constraints Scores

Aspect	Relevance as a Constraint (between 0-100 with higher being more relevant as a constraint)
Commitment to Sustainability	2/100
Information Availability	16/100
Cooperation between Actors	33/100
Technical Feasibility	53/100
Regulatory Constraints	5/100
Community Involvement	16/100
Economic Constraints	75/100

Enablers Scores

	Relevance as an Enabler (between 0-100 with higher being more relevant as an enabler)
Commitment to Sustainability	87/100
Information Availability	81/100
Cooperation between Actors	87/100
Technical Feasibility	70/100
Regulatory Enablers	6/100
Community Involvement	92/100
Economic Enablers	97/100

Double Good AB

Constraints Scores

Aspect	Relevance as a Constraint (between 0-100 with higher being more relevant as a constraint)
Commitment to Sustainability	58/100
Information Availability	70/100
Cooperation between Actors	61/100
Technical Feasibility	22/100
Regulatory Constraints	23/100
Community Involvement	63/100
Economic Constraints	34/100

Enablers Scores

Aspect	Relevance as an Enabler (between 0-100 with higher being more relevant as an enabler)
Commitment to Sustainability	100/100
Information Availability	81/100
Cooperation between Actors	70/100
Technical Feasibility	100/100
Regulatory Enablers	100/100
Community Involvement	71/100
Economic Enablers	56/100

Malmö Chokladfabrik

Constraints Scores

Aspect	Relevance as a Constraint (between 0-100 with higher being more relevant as a constraint)
Commitment to Sustainability	53/100
Information Availability	72/100
Cooperation between Actors	74/100
Technical Feasibility	85/100
Regulatory Constraints	100/100
Community Involvement	79/100
Economic Constraints	53/100

Enablers Scores

Aspect	Relevance as an Enabler (between 0-100 with higher being more relevant as an enabler)
Commitment to Sustainability	73/100
Information Availability	73/100
Cooperation between Actors	77/100
Technical Feasibility	52/100
Regulatory Enablers	30/100
Community Involvement	52/100
Economic Enablers	7/100

Saltat Ferments

Constraints Scores

Aspect	Relevance as a Constraint (between 0-100 with higher being more relevant as a constraint)
Commitment to Sustainability	100/100
Information Availability	100/100
Cooperation between Actors	100/100
Technical Feasibility	46/100
Regulatory Constraints	46/100
Community Involvement	100/100
Economic Constraints	100/100

Enablers Scores

Aspect	Relevance as an Enabler (between 0-100 with higher being more relevant as an enabler)
Commitment to Sustainability	100/100
Information Availability	100/100
Cooperation between Actors	100/100
Technical Feasibility	47/100
Regulatory Enablers	59/100
Community Involvement	100/100
Economic Enablers	100/100

Collated Scores of Case Companies and Averages

Constraints

	Munkagrodden AB	*Plant-Based Protein*	*DoubleGood AB*	*Malmö Chokladfabrik*	*Saltat Ferments*	*AVERAGE*
Commitment to Sustainability	100	2	58	53	100	63
Information Availability	100	16	70	72	100	72
Cooperation Between Actors	81	33	61	74	100	70
Technical Feasibility	100	53	22	85	46	61
Regulatory Aspects	100	5	23	100	46	55
Community Involvement	47	16	63	79	100	61
Economic	76	75	34	53	100	68

Enablers

	Munkagrodden AB	*Plant-Based Protein*	*DoubleGood AB*	*Malmö Chokladfabrik*	*Saltat Ferments*	*AVERAGE*
Commitment to Sustainability	91	87	100	73	100	90
Information Availability	100	81	81	73	100	87
Cooperation Between Actors	100	87	70	77	100	87
Technical Feasibility	64	70	100	52	47	67

Regulatory Aspects	77	6	100	30	59	54
Community Involvement	78	92	71	52	100	79
Economic	93	97	56	7	100	71