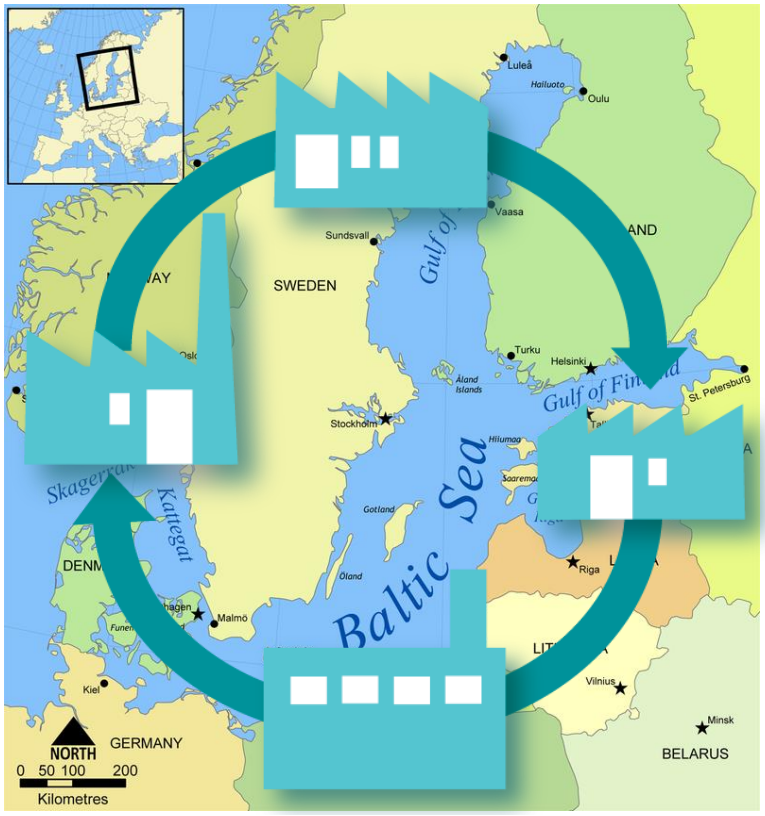
SMEs in the Industrial Sector

Opportunities and Challenges for Industrial Symbiosis in the Baltic Sea Region



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Summary

Industrial symbiosis is one of the many solutions to the global challenges of sustainability and societal resilience. The establishment of industrial symbiosis networks can contribute to environmental, economic as well as social sustainability. The aim of this report is to identify the advantages, challenges, and conditions for small and medium sized enterprises (SMEs) in the industrial sector to participate in industrial symbiosis networks, and to recommend policy measures required for further involvement of SMEs in industrial symbiosis networks. The purpose is to increase the knowledge about what is required for increasing the circularity of companies' energy, water and material streams.

This report has been commissioned by the Swedish Agency for Economic and Regional Growth and was finalised in April 2020, as a part of their engagement in the EU project *Baltic Industrial Symbiosis*. The work has been carried out by a team of experts from Policy in Practice, Cajalma and IVL Swedish Environmental Research Institute. The analysis, conclusions and recommendations in the report are the expert's own, based on the study carried out within this assignment.

Baltic Industrial Symbiosis (BIS) is a pan-Baltic project that aims to accelerate the development of industrial symbiosis and also the development of SMEs through increased cost-effectiveness in production. The BIS project is a part of the Interreg Baltic Sea Region Programme 2014-2020 and is funded by the EU, Norway and The Russian Federation.

The focus of this report is SMEs in the industrial sector in the six countries involved in the BIS project (Sweden, Norway, Denmark, Finland, Russia and Poland). A literature review and an interview study have been carried out to compare the existing information with the current scenario and to identify knowledge gaps. The primary target group of this report is members of the BIS project wherein the report intends to enhance the knowledge about involvement of SMEs in industrial symbiosis networks. Other target groups are business development actors, policy makers, and public agencies in the countries around the Baltic Sea.

The advantages, challenges and conditions identified in this report have been classified into the following three categories:

- **Environmental and technological factors**, which include production processes, feedstock, transports, by-products, waste products and the natural prerequisites of the location of the companies and their surroundings.

- **Economic factors**, which include business models, investments, customers, regulations, and costs for alternative resource management of the flows in the collaboration. Factors which provide the conditions for how the companies choose to conduct their business.

- **Social factors,** which include available competences within the companies and the society, culture and behaviour, experience, and capability to collaborate within the companies, within the industrial symbiosis network, and other stakeholders in the society which the industrial symbiosis network is or could be dependent on.

The analysis of the literature review and the interviews shows that **economic and environmental gains** are the main advantages for SMEs to participate in industrial symbiosis networks. In many cases, the economic and environmental concerns pull in the same direction. When they do not, the interviews in this

study suggest that economic gains are the main drivers for many SMEs. Furthermore, **synergies other than by-product exchanges,** such as the opportunity to share infrastructure or knowledge were identified as additional benefits of being part of an industrial symbiosis network, especially for SMEs. The interviews as well as literature have identified that industrial symbiosis offers **new business opportunities** to SMEs by enhancing the company's credibility and visibility in existing as well as new markets. Most companies have not noticed any disadvantages in being part of an industrial symbiosis network. The two disadvantages mentioned by the respondents were interdependence of companies and enforced transparency.

Regulations and regulatory procedures have been identified as a significant challenge for SMEs. For example, one respondent mentioned in the interview that big companies can accept long regulatory processes, however the SMEs do not have resources for long waiting times. Differences in policy instruments between countries, for example, subsidies related to biogas, also distort competition on an international level. **The focus on core business and a lack of additional resources were identified as other critical challenges for SMEs**. SMEs might not have the capability to invest their limited resources (in terms of time, money, or workforce) for development projects that lie outside their core business, especially if the project has a long payback period.

Social factors are identified as some of the strongest enabling factors for an SME to participate in industrial symbiosis networks. These enabling social factors include, but are not limited to, close collaboration and trust, a non-hierarchal decision-making structure and innovative mindset within an organisation, industrial symbiosis as a priority at the top management level, and societal awareness.

The analysis has shown **strong similarities in enabling and hindering factors across countries,** among the interviewed companies. Respondents identified technical expertise, the possibility to share additional resources, economic and environmental advantages, and the willingness to innovate as enabling factors for participation in industrial symbiosis. Regarding the challenges to participate in industrial symbiosis, the companies in both regions identified dependency and the consequent vulnerability, enforced transparency, a conservative mindset, the risk of losing focus on core business, and time-consuming regulatory procedures as challenges.

No major differences have been identified with reference to different types of exchanges i.e. material, energy and water. Technological factors, nevertheless, have been mentioned as more important for energy exchange, in terms of limitations on geographical distance.

Policy and digitalisation could be the tools to aid the development and growth of industrial symbiosis networks. The difference between policy and digitalisation is that **policy is described as mainly targeting external factors, while digitalisation primarily targets the internal factors**. Digital tools are currently mostly used in operation and control of resources, according to the interviewed companies. Further possibilities for digitalisation, especially in connection to identifying opportunities and developing new business models, have been identified in the report.

Based on the conclusions in this report, we recommend policy makers and public agencies in the countries around the Baltic Sea region to continue working together due to strong similarities across countries. We also recommend promoting networking activities among various stakeholders of industrial symbiosis, for example among companies, intermediary organisations and potential investors in order to strengthen the entire value chain, both on the regional and local level. It is important to continue supporting development projects that further resource efficiency and environmental

sustainability among SMEs in the Baltic Sea Region and if possible, provide economic support for introduction of new products on the market. We recommend that policies, regulations, grants and subsidies should be harmonised across regions, nations and the European Union in order to enable fair competition. We also suggest spreading knowledge about the benefits of digitalisation, especially in connection to identifying new opportunities and developing new business models, so that the companies can recognise further possibilities.

The report has recognised that complicated, or long regulatory procedures are a significant challenge for SMEs. However, identification of specific regulations and how to adapt them in order to make it easier for SMEs is beyond the scope of this report. For future work, we therefore recommend a further in-depth analysis to identify which regulations are perceived as complicated, and how to ease these procedures.

Sammanfattning

Industriell symbios är en av flera lösningar på de globala hållbarhetsutmaningarna och samhällets resiliens. Att etablera nätverk för industriell symbios kan bidra till miljömässig, ekonomisk och social hållbarhet. Målet med rapporten är att identifiera fördelar, utmaningar och förutsättningar för små och medelstora företag (SMF) inom industrisektorn med att vara en del av nätverk för industriell symbios och att rekommendera policyinstrument som främjar ökat deltagande för SMF i industriell symbios. Syftet är att öka kunskapen om vad som krävs för att öka företagens cirkuläritet gällande energi-, vatten- och materialflöden.

Denna rapport är beställd av Tillväxtverket och färdigställdes i april 2020 som en del av myndighetens medverkan i EU-projektet *Baltic Industrial Symbiosis* (BIS). Arbetet har utförts av ett expertteam från Policy in Practice, Cajalma and IVL Svenska miljöinstitutet. Analys, slutsatser och rekommendationer är experternas egna, baserade på studien som gjorts inom detta uppdrag.

BIS är ett Östersjösamarbete som syftar till att snabba på utvecklingen av industriell symbios och mer kostnadseffektiv produktion inom SMF. BIS-projektet är en del av Interreg Baltic Sea Region Programme 2014–2020 och finansieras av EU, Norge och Ryssland.

Fokus i den här rapporten är SMF i industrisektorns i de sex länderna som deltar i BIS-projektet (Sverige, Norge, Danmark, Finland, Ryssland och Polen). En litteraturstudie och en intervjustudie har genomförts för att jämföra befintlig information med nuvarande fall och därigenom identifiera kunskapsgap. Den primära målgruppen för rapporten är medlemmar i BIS-projektet. Rapporten avser att förbättra kunskapen om SMF:s deltagande i industriell symbios. Övriga målgrupper är aktörer inom företagsutveckling och myndigheter i länderna runt Östersjön.

Fördelarna, utmaningarna och förutsättningarna som identifieras i denna rapport har kategoriserats enligt följande:

- **Miljömässiga och tekniska faktorer,** vilket inkluderar produktionsprocesser, råvaror, transporter, biprodukter, avfallsprodukter and de naturliga förutsättningarna för företagens lokalisering och deras omgivning.

- **Ekonomiska faktorer,** vilket omfattar affärsmodeller, investeringar, kunder, reglering och kostnader för alternativ resurshantering av flödena i samarbetena. Även de faktorer som skapar förutsättningar för hur företagen väljer att genomföra sin verksamhet.

- **Sociala faktorer,** vilket inkluderar tillgänglig kompetens inom företagen och samhället, kultur och beteende, erfarenheter och förmåga att samarbeta inom företagen, inom nätverket för industriell symbios och med andra intressenter i samhället som nätverket för industriell symbios kan vara beroende av.

Analysen av litteraturgenomgången och intervjuerna visar att ekonomisk och miljömässig nytta är de främsta fördelarna för SMF med att delta i nätverk för industriell symbios. I många fall drar ekonomiska och miljömässiga strävanden åt samma håll. När de inte gör det är de ekonomiska drivkrafterna starkare för SMF, enligt denna studie. Studien har även identifierat andra synergier än utbyte av restflöden. Till exempel är möjligheten att dela infrastruktur och kunskap till särskilt stor nytta för SMF. Såväl intervjuer med SMF som litteraturstudien identifierar att nya affärsmöjligheter uppstår genom att

företagens trovärdighet och synlighet ökar på både befintliga och nya marknader. De flesta av företagen har inte upplevt några nackdelar med att ingå i ett nätverk för industriell symbios. De två nackdelar som nämns är dock ökat beroende av andra företag och en påtvingad transparens kring exempelvis de strömmar som delas i symbiosen.

Förordningar och regleringar har identifierats som en betydande utmaning för SMF. Till exempel nämndes att stora företag kan hantera långa tillståndsprocesser, medan SMF inte har tillräckligt med resurser för att hantera långa väntetider. Skillnader mellan olika länders policyinstrument, till exempel stöd till biogas, snedvrider den internationella konkurrensen. Fokus på kärnverksamhet och brist på resurser är en avgörande utmaning för SMF. SMF kan även sakna kapacitet att lägga sina begränsade resurser (tid, pengar och arbetskraft) på utvecklingsprojekt utanför kärnverksamheten, särskilt om dessa projekt har lång återbetalningstid.

Sociala faktorer har visats vara några av de starkaste möjliggörande faktorerna för att SMF ska delta i nätverk för industriell symbios. Nära samarbete och förtroende, en icke-hierarkisk beslutsorganisation och öppenhet för nya lösningar inom en organisation, samt att högsta ledningen prioriterar industriell symbios och samhällsansvar, är exempel på de möjliggörande sociala faktorerna.

Analysen av intervjuerna visar att det finns stora likheter i de olika länderna i möjliggörande och hindrande faktorer. Företagen svarade i intervjuerna att teknisk expertis, möjlighet att dela resurser, ekonomiska och miljömässiga fördelar samt strävan efter förnyelse är möjliggörande faktorer för att delta i industriell symbios. När det gäller utmaningar angavs ökat beroende och därmed utsatthet, påtvingad transparens, konservativa förhållningssätt, risk att ta fokus från kärnverksamheten och tidskrävande tillståndsprocesser.

Inga större skillnader har identifierats gällande olika typ av flöden som utbyts, dvs material, energi och vatten. Tekniska faktorer i termer av geografiskt avstånd har dock angetts som mer betydelsefullt för just energiutbyte.

Policy och digitalisering kan vara verktyg för att stödja utvecklingen och framväxten av nätverk för industriell symbios. Skillnaden mellan policy och digitalisering är att policy främst riktas mot externa faktorer (utanför företagets egen verksamhet, så som lagstiftning och styrmedel) medan digitalisering stöttar interna faktorer (inom företagets egen kontroll, exempelvis optimering och uppföljning av verksamhet och processer). Enligt de intervjuade företagen används digitala verktyg i nuläget främst för drift och kontroll av resursanvändning. Framtida möjligheter med digitalisering beskrivs i rapporten, särskilt kopplat till att identifiera möjligheter och utveckla nya affärsmodeller.

Utifrån slutsatserna i denna rapport rekommenderar vi att beslutfattare och myndigheter i länderna runt Östersjön fortsätter att arbeta tillsammans eftersom det finns stora likheter mellan länderna sett till företagens utmaningar och behov. Vi rekommenderar att nätverksaktiviteter mellan intressenter för industriell symbios främjas, till exempel mellan företag, intermediärer och potentiella investerare för att stötta hela värdekedjan både regionalt och lokalt. Det är viktigt att fortsätta stödja utveckling mot ökad resurseffektivitet och miljömässig hållbarhet för SMF i Östersjöregionen, och om möjligt erbjuda ekonomiskt stöd för marknadsintroduktion av nya produkter. Vi rekommenderar att policies, förordningar, bidrag och subventioner harmoniseras mellan länder och inom EU för att möjliggöra konkurrens på lika villkor. Vi föreslår också kunskapsspridning gällande fördelarna med digitalisering, särskilt kopplat till att identifiera nya samarbetsmöjligheter och utveckling av nya affärsmodeller, så att företag lättare kan se möjligheterna.

Rapporten har identifierat att komplicerade eller långa tillståndsprocesser är en betydande utmaning för SMF. Kartläggning av vilka specifika regelverk och hur de borde anpassas för att underlätta för SMF har dock inte ingått i arbetet med denna rapport. För framtida arbete rekommenderar vi därför att en fördjupad analys görs för att identifiera vilka regleringar som upplevs som komplicerade och hur förfaranden kan förenklas.

1 Introduction

Within the programme *Digilift*, the Swedish Agency for Economic and Regional Growth (Tillväxtverket), has the assignment to address digitalisation opportunities in small and medium-sized enterprises (SMEs). The Digilift stimulates increased digitalisation in SMEs in the industrial sector and service providers closely linked to industry. Through Digilift, the Swedish Agency for Economic and Regional Growth also participates in the EU-project *Baltic Industrial Symbiosis* (BIS), which is financed through the Baltic Sea programme. A deliverable within the BIS project is a knowledge-based report with relevant policy measures related to industrial symbiosis and SMEs in the industrial sector, which is presented in this report.

1.1 Background

This chapter presents an overview of the development of industrial symbiosis concept and a short description of the project *Baltic Industrial Symbiosis*. The latter part of the chapter describes the aim and the scope of this study.

1.1.1 Industrial Symbiosis

Industrial symbiosis is a research topic within the field of industrial ecology which focuses on inter-firm collaboration to create competitive advantages through resource exchanges. Within this context, no firm is seen as an island but interacts with other firms to create mutual benefits and valorised processes [1-3]. Marian Chertow [1], the most cited researcher in the field, defined the topic as:

"Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity."

The term 'industrial symbiosis' first appeared in the literature on economic geography to describe the organic relationships between dissimilar industries, employing wastes as input [2]. Similar concepts were also explored around the same time by various researchers, such as eco-industrial parks, zero waste, combined production, by-product synergies, integrated biosystems [3], [4]. Since the early 1990s, scholars have attempted to develop concepts to examine resource reduction through sharing and exchanges. At this time, some seminal developments reintroduced industrial symbiosis, most prominently the Kalundborg network in Denmark [5]. The topic has seen significant advances in recent years, evolving from studies of "uncovering" examples of industrial symbiosis networks worldwide [6], to including a large suite of academic disciplines to understand the contextual development, sustainability, dynamics, facilitation tools, and business models [3], [7], [8], [9].

The term 'industrial symbiosis' implies that the *industrial* production and practices are of primary importance. However, this limitation is not exclusive as exchanges may extend beyond the industrial setting. This can include synergies with surrounding systems to include agriculture, horticulture, forestry, fisheries, municipal and urban systems [10], [11]; extending the bounded geographical proximity is generally associated with the concept [12], [13]. Figure 1 shows an example of synergies between firms, regional sectors and urban systems from the Händelö industrial symbiosis network in Sweden.

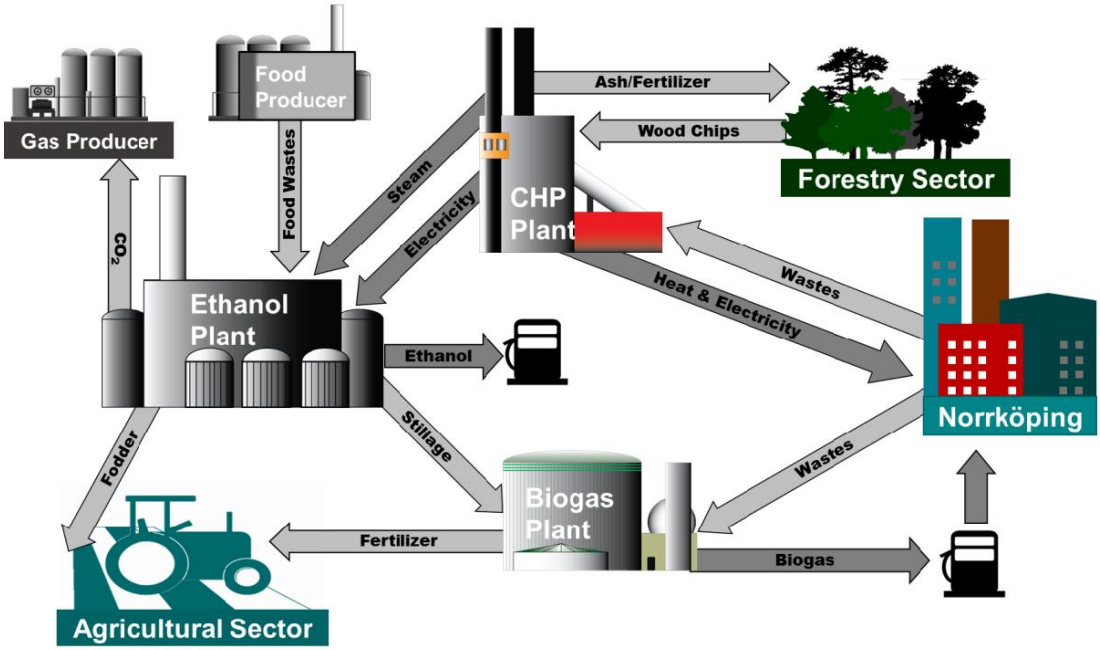

Figure 1 ***Example of synergies from the Händelö industrial symbiosis network in Sweden*** *[14]*

The industrial symbiosis topic stems from the symbiotic relationships seen in the natural environment, where organisms, or species, exchange energy and materials for mutual benefits. These exchanges of resources, energy, utilities, and knowledge between firms are fundamental to industrial symbiosis and are the major mechanism for industrial symbiosis to allow for cross-sectoral and multi-stakeholder resource, knowledge and innovation exchanges.

1.1.2 Baltic Industrial Symbiosis

Baltic Industrial Symbiosis (BIS) is a pan-Baltic project that promotes industrial symbiosis in the region. The aim of the project is to accelerate the development of industrial symbiosis and also the development of SMEs through increased cost-effectiveness in production. The BIS project is part of the Interreg Baltic Sea Region Programme 2014–2020 and is funded by the EU, Norway and the Russian Federation.

The project will increase the opportunities for a large number of SMEs to strengthen their competitiveness through increased resource efficiency, new business opportunities, developed value chains and green/circular business models. Findings from the project, such as business cases and policy learning, will be presented at a Baltic Industrial Symbiosis Roadshow to inspire replication of industrial symbiosis cluster development in Estonia, Latvia, Lithuania, Poland and Russia.

The project is coordinated by the Symbiosis Center Denmark in Kalundborg, Denmark and has a timeframe of four years. The project includes partners from Denmark, Finland, Norway, Poland, Russia and Sweden.

1.1.3 Aim and scope of the report

The aim of the report is to identify the advantages, challenges, and conditions for SMEs to be a part of an industrial symbiosis network and to recommend policy measures required for further involvement of SMEs in industrial symbiosis networks. The purpose is to increase knowledge about what is required for increasing the circularity of companies' energy, water and material streams. The focus of the study was SMEs in the industrial sector in the six countries involved in the BIS project (Sweden, Norway, Denmark, Finland, Russia and Poland). A literature review and an interview study have been carried out to compare existing information with the current scenario and to identify knowledge gaps.

The primary target group of this report is members of the Baltic Industrial Symbiosis Project wherein the report intends to enhance the knowledge about involvement of SMEs in industrial symbiosis networks. The other target groups are business development actors, policy makers, and public agencies in the countries around the Baltic Sea region.

1.2 Methodology and limitations

The advantages, challenges and conditions identified in this report have been classified into the following three categories:

- **Environmental and technological** factors, which include production processes, feedstock, transports, by-products, waste products and the natural prerequisites of the location of the companies and their surroundings.
- **Economic** factors, which include business models, investments, customers, regulations, and costs for alternative resource management of the flows in the collaboration. Factors which provide the conditions for how the companies choose to conduct their business.
- **Social factors,** which include available competences within the companies and the society, culture and behaviour, experience, and capability to collaborate within the companies, within the industrial symbiosis network, and other stakeholders in the society which the industrial symbiosis network is or could be dependent on.

Each of the above factors could be further classified into internal and external factors. **Internal factors** are those factors that can be directly attributed to internal conditions in a company or the group of companies in question. **External factors**, on the other hand, are external factors that cannot be controlled by the companies themselves.

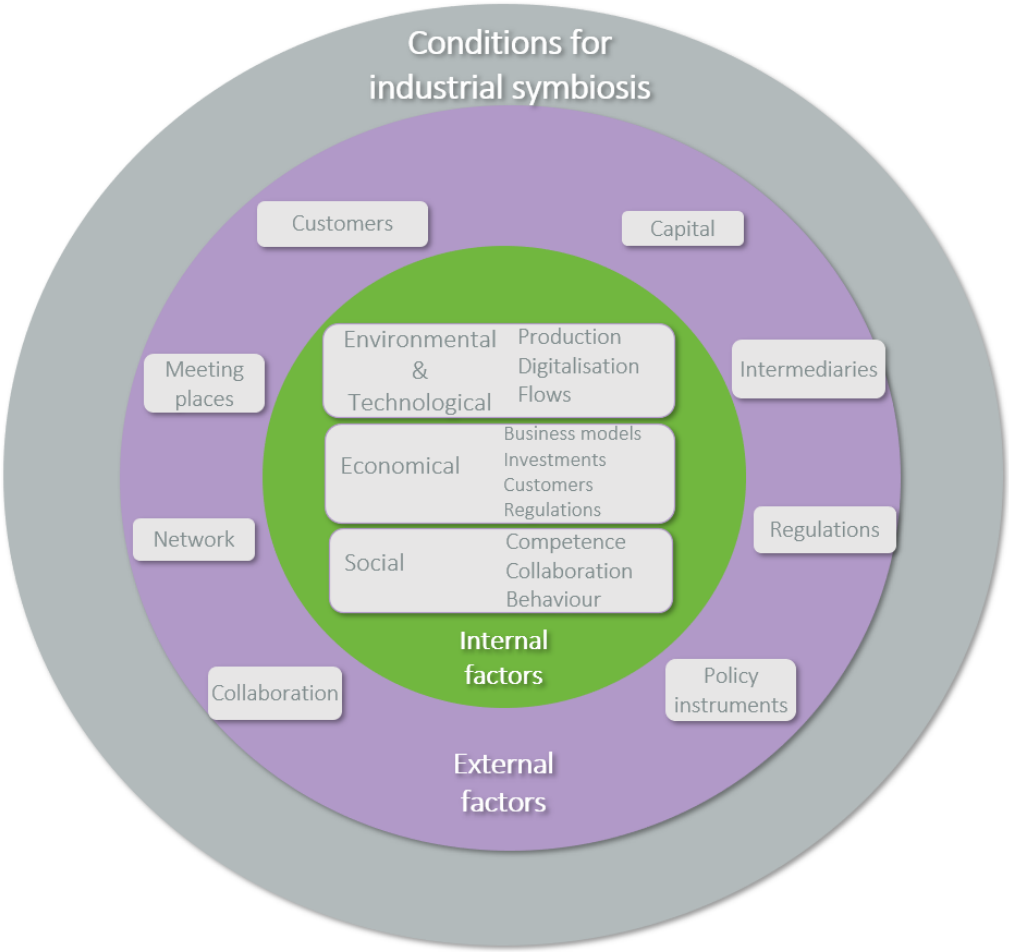

Figure 2. Internal and external factors in the context of industrial symbiosis

The analysis carried out within this report is primarily based on **internal factors.** The purpose of focusing on internal factors is to find the general knowledge that is possible to transmit and reproduce among different companies and countries. We assume that the functional principles for the emergence of an industrial symbiosis network with regards to flows of water, energy and materials, are possible to generalise between different companies, while the national and institutional conditions are more heterogeneous. The knowledge about internal factors would be useful to facilitate the emergence of industrial symbiosis across nations.

The external factors consist of conditions that are important to the emergence and development of a symbiosis, but which the companies included in the symbiosis do not themselves control. This includes, for example, the risk capital, intermediaries such as universities, the culture of collaboration and interpersonal trust found in the regional and national context, regulations and policies. Figure 2 above gives a few examples of internal and external factors.

The study has been carried out in two parts: a literature review and interviews with selected SMEs. The sections below describe the methodology and limitations of each part.

1.2.1 Literature review

The literature review consisted of knowledge compilation of existing reports and policy proposals relating to industrial symbiosis, with a focus on identifying advantages, challenges and enabling factors for SMEs to participate in industrial symbiosis networks and the role of digitalisation in this context. The shortlisting of reports under this literature review was carried out in the following steps:

1. **Specification of search keywords in dialogue with Tillväxtverket:** This was done in order to maintain the chosen focus of the study and obtain qualitative results. Due to time limitations, a shorter list of crucial keywords was prioritised to get effective search results. The search engines used are Google and Google Scholar. The list of keywords can be found in the Appendix.

2. **Identification of relevant material**: From the search results obtained using the selected keywords, the reports were selected based on the relevance of their title, summary or abstract and full text.

In addition to the reports identified by using search keywords, a snowball methodology was used to further find relevant material for the study. Snowball methodology means that more reports were identified from the citations of the already selected reports.

Analysis of the material: The selected reports were then analysed by the experts to select relevant information required for this report. The information from these reports is presented in Section 2.1 of the report. The relevant information was divided into the following categories:

- Opportunities, challenges, existing conditions to participate in industrial symbiosis networks
- Opportunities, challenges, existing conditions to participate in industrial symbiosis networks, specifically for SMEs
- The role of digitalisation in industrial symbiosis
- Policy suggestions
- Information related to circular business models and industrial symbiosis networks

1.2.2 Limitations of the literature review

The scope of literature was limited to available literature from the countries around the Baltic Sea, including Sweden, Denmark, Norway, Finland, Poland and Russia. In order to further clarify, the studies are limited to those in which 1) either the main author of the report belongs to one of these countries, or 2) a case study from one of these countries is analysed in the report. The review was limited to reports written in English and published during the time period 2010-2019.The keywords were selected according to the aim of the project, and therefore it is possible that the search results did not display reports that did not contain the selected keyword even though the reports might contain relevant information for the purpose of this report.

Two reports have been included in the study despite not meeting the defined scope. The first report is a study on organisational factors for the industrial symbiosis network in Landskrona, Sweden written by Jan-Erik Starlander. This report was published in 2003 and therefore is out of the defined time period. However, the report contained relevant information since 18 of the 19 interviewed companies were SMEs. The second report is a study of industrial symbiosis as a business model for a circular economy

written by Baldassarre, et al. (2019). The main author of the report is from the Netherlands; however, Nancy Bocken from Lund University had co-authored the paper and due to the high relevance of this topic within the project, it was included in the literature review.

1.2.3 Interviews with SMEs

Interviews of selected SMEs were carried out in the project in order to understand how companies perceive their opportunities, challenges and obstacles to participate in industrial symbiosis, and their view of the possible contribution from digitalisation.

The SMEs that were contacted during the project were known through previous contacts by either one of the partners of the BIS project, the team who has written this report, or were identified as a relevant company during the literature review. The interviews were carried out as semi-structured interviews, by phone or skype. Each interview took about 30 to 60 minutes and was conducted in Swedish, English or in a Scandinavian language mix, depending on the preference of the respondent. Therefore, the citations are translated and not exact.

The selection of respondents for the interview study was carried out by dividing the geographical area into two regions, one with Finland, Poland and Russia and the other region with Sweden, Norway and Denmark. In each region, at least one company in each country has been interviewed and at least one company that works with each of the three studied flows, i.e. material, energy and water.

A total of 20 SMEs were selected for interviews. The distribution of companies is as follows:

- Geographical distribution 13 of the 20 interviewed companies were from the western region i.e. Sweden, Norway, Denmark.
- Participation in industrial symbiosis networks: 12 of the companies are a part of existing industrial symbiosis networks while the others are in discussion/willing to become part of an industrial symbiosis network.
- Types of flows: 16 of the companies exchange materials, 9 companies exchange energy, and 4 companies exchange water. (Some companies exchange two types of flows such as both material and energy, and two companies were found to have an exchange of all three types of flows).
- A consulting company who facilitates industrial symbiosis networks in multiple regions was also interviewed.

The types of flows represented by the interviewed companies could be further classified as:

- Biomass to fertiliser/biochar/biogas
- Industrial wastewater to biofuel, biogas and/or warm water
- Biomass to food/pharmaceutical ingredients
- Ethanol to chemicals and biofuels
- Lime, a by-product from pulp and paper industry, to fertiliser
- Recovery of metal sulphates from by-products for further utilisation in the industrial sector
- Waste-to-energy for further energy utiliation in the industry
- Reuse/recycling of construction materials
- Recovery of textile waste into new raw materials

Almost half of the companies interviewed in the project utilise side streams of biomass as a raw material. Some of the companies are involved in more than one core business, such as recovery of biomass as well as lime from the pulp and paper sector.

The broad distribution of companies over geographical areas, types of flows, and their current participation in industrial symbiosis networks was selected in order to be a representative sample and provide the opportunity to draw relevant conclusions from the interviews.

1.2.4 Terminology

In this report the terminologies have been used in the following context:

- **Industrial Symbiosis** is a research topic within the field of industrial ecology which focuses on the study of industrial symbiosis networks.
- **Industrial symbiosis network** refers to the network/collaboration between firms to create competitive advantages through resource exchanges. In this report, we focus on exchanges of streams such as material, energy and water.
- **Small and medium-sized enterprises (SMEs)** consist of enterprises having less than 250 employees.
- **By-products, residual material and waste stream** are used synonymously for material that is output from an industry and/or process.
- **Exchanges, streams and flows** are used synonymously for material, energy and/or water that is exchanged between companies or industries within an industrial symbiosis.
- **Raw material** is material that is input to an industry and/or process.
- **Cluster** is a geographic concentration of interconnected companies.

2 Results

In this chapter the results from the interviews and the literature study are presented in separate. In the analysis of the results the findings from the literature and the interviews are combined and presented in the succeeding chapter 3.

2.1 Literature study

A total of 21 reports were shortlisted for a more thorough review. This section compiles the content of these reports in order to highlight the advantages and challenges for SMEs, and the role of digitalisation as a tool to enhance engagement in industrial symbiosis. The final part of this section gives an overview of suggested policy instruments as mentioned in the shortlisted reports, which would enhance the participation of companies in industrial symbiosis networks.

2.1.1 Advantages to participate in an industrial symbiosis network

The results of the literature review suggest that participating in an industrial symbiosis network has the potential to create several advantages for the companies. The advantages identified from the literature have been categorised into economic, environmental and social opportunities.

New **economic opportunities** have often been found in the literature for resource exchanges in terms of increased revenue and improved cost-efficiency in the company [16-18]. It was identified in the reports that industrial symbiosis creates an opportunity to develop new markets with new revenue streams, some of which could be new niche markets, thereby increasing the profitability of the companies [15]. One of the reports mentioned that collaboration with another company offers the advantage of sharing the risks [16].

From the **environmenta**l perspective, the literature suggests that the exchange of resources naturally enhances the resource efficiency of the network. Depending on the resources exchanged, environmental benefits have been mentioned in terms of potential savings in water usage, emissions (e.g. GHG emissions) and/or waste produced in the company's processes [17]. Material exchange of the company's waste products poses an opportunity for the company to divert its waste flows from landfills and reduce its environmental impact. Material exchanges may allow a company to utilise secondary raw material, for example, by upcycling the waste from another company, as an opportunity to promote the sustainable use of resources. Therefore, it was mentioned that participation in an industrial symbiosis network improves the company's environmental performance and in turn, results in a green corporate image [15], [18], [19].

Environmental and economic opportunities are usually the main incentive for companies to participate in an industrial symbiosis network. The literature mentioned that industrial symbiosis networks yield added **social benefits** such as the opportunity to build new partnerships with other local companies and job creation in society [17], [20]. For example, when one company utilises another company's waste as a raw material in its own process, this increases the acceptability of, and creates new markets for, secondary raw materials, thereby promoting sustainable choices in the society [16].

A report by Interreg Europe written under the SYMBI project interviewed 48 industrial symbiosis cases across seven European countries to understand how they view the success of an industrial symbiosis network. According to the report, industrial symbiosis networks are considered successful by 67% of the respondents if improved resource efficiency is achieved in the region. Thereafter, 57% of the cases

consider promoting the use of sustainable bio-energy resources as an important success factor, while 50% of the cases emphasise reducing greenhouse gas emissions. This showed that environmental advantages were the most important success factors. The second type of advantages noticed during the SYMBI project were greater economic benefits such as reductions in production costs (52% of cases), increases in profits and revenues (44% of cases), and openings of new markets for secondary raw materials (38% of cases). [16]

Therefore, the literature suggests that the environmental, economic and social opportunities together lead to possibilities of business development in the engaging companies, for example, achieving higher environmental targets would enhance the company's green corporate image. This leads to better credibility among the existing customer base and offers prospects to attract new customers, according to the reports.

Opportunities for increased visibility for SMEs participating in industrial symbiosis

The literature on SMEs identified that the main incentives for SMEs to participate in an industrial symbiosis network are the environmental and economic opportunities mentioned above. Better environmental performance may improve a company's brand image and resource exchange brings in new business opportunities with new revenue streams [18], [20]. Starlander also identified that an industrial symbiosis network allows for increased economies of scale and that some companies identified common purchasing as an attractive area of collaboration.

Furthermore, several authors, see for example [19], [20] suggest that industrial symbiosis networks could offer added advantage to SMEs in terms of increased visibility in the following ways:

- Partnerships with larger, better-established companies could improve the credibility of an SME, especially offering legitimacy in the context of public criticism.
- Participation in an industrial symbiosis network could allow extension of the customer base and therefore approach new markets
- The global recognition of industrial symbiosis offers the possibility to gain visibility in an international environment thus helping the company to expand to new geographical markets.

2.1.2 Challenges to participate in an industrial symbiosis network

The challenges identified in the literature for companies to participate in industrial symbiosis networks are described below. These have been categorised into technological, economic, and social factors.

A lack of available **technology** that would allow the upcycling of the waste streams into resources was identified as one of the challenges [19], [21], [22]. This was specifically noted in a case of energy exchanges [25]. This could mean a lack of the technology itself, or that the price of the available technology is too high to allow for an economically feasible symbiotic development. Another related barrier identified in the literature is the lack of technical capacity and expertise in the companies to implement solutions.

From an **economic** viewpoint, a potential challenge would be high investment cost and a long possible payback period of the technology [19]. Domenech et al. [22] identified that the companies often consider only direct waste disposal costs and do not take into account that 'social' costs of their waste products such as the cost of wasted resources, energy, and increasing demand of primary raw

materials, which might cause them to disregard the benefits of forming an industrial symbiosis network.

Another cost-related barrier identified is that waste and by-product streams might have lower economic values in comparison to conventional substitutes and virgin materials [15], [19]. For instance, recycled plastic often has a higher price than virgin plastic. Another example noted in a European Commission report [15] is that some countries offer subsidies on biogas, which might hinder the development of material valorisation of bio-wastes due to the possibilities of higher financial returns with energy recovery.

Costs related to transportation are highly relevant and are often the reason industrial symbiosis networks are geographically limited. Transportation costs have been reported as a potential restricting factor in wood waste, food waste, construction and demolition waste, and non-scrap metal waste owing to their relatively high volume to value ratio [15], [17].

Companies may also be hesitant to spend extra time and resources in identifying opportunities, organising and implementing industrial symbiosis networks since there is no guarantee at the beginning for new opportunities or gains. The upfront costs for participating in industrial symbiosis networks (e.g. membership fees) could hinder a company from participating in such networks [17], [19].

The **social** factors relate to the capabilities and willingness for collaboration. This could involve a company's own reluctance to share information with other companies due to confidentiality issues. For example, the pre-requisite for the formation of an industrial symbiosis network is an identification of possible synergies, which requires mapping of resources among different companies and sharing of information. The company might perceive it as a risk due to the uncertainty issues linked to collaboration among multiple companies [17], [19], [21], [24].

Starlander [20] identified that developing new relationships requires efforts and might act as a barrier for new collaboration. He noticed a reluctance from companies in Landskrona in changing from a current service provider to one of the companies involved in the industrial symbiosis network, due to the need of developing new relationship from scratch. One of the studies identified a lack of knowledge or competence about upcycling of resources within the company as a challenge [25]. Related to this, the need to identify a coordinator for the network who could facilitate development of mutual agreements was often identified as crucial. It can be challenging for the involved companies to decide who should take the role of coordinating the network [15], [22]. A lack of cooperation between different government departments and engagement of stakeholders was also identified as a critical challenge specifically for Denmark [26].

Kurvde et. al [25] identified that the importance of some of the barriers could differ according to the type of resource being exchanged. For material exchange, a lack of knowledge and competence about the upcycling of products within the company and in sharing information with other companies were identified as major barriers. For energy exchanges, the primary barrier was identified to be technical barrier in terms of the need to exchange resources within a limited geographical area.

Magnified challenges for SMEs

In the case of SMEs, a focus on core business may lead to a lack of motivation to explore industrial symbiosis networking opportunities with other companies. It was identified that the challenges encountered by SMEs related to spending their own time and resources into organisation and implementation of industrial symbiosis networks was more significant compared to larger companies [17], [18], [19], [20], [26].

The lack of **economic** resources was identified as a critical factor in the CESME White Book [26]. SMEs might not have the capability to invest their limited economic resources towards establishment of an industrial symbiosis initiative, both in terms of organisational costs such as membership fees and required capital investments [27]. Furthermore, small local companies might not be able to compete on price with their much larger competitors, and this creates a competitive disadvantage for SMEs to be involved in an industrial symbiosis network with nearby companies. Starlander [20] identified that most of the companies would be willing to change from their current supplier or service provider to a company in the network, but only if the price for a provided service is the same or lower, implying that SMEs would find it difficult to collaborate unless they offer a competitive price.

Regarding the **social** factors, SMEs might not have an extensive contact network with other companies, research institutions or universities [20]. Missing information such as lack of awareness of potentially profitable new opportunities was identified as a critical factor for SMEs in Finland [26]. It can be difficult for SMEs to find business partners who would be willing to collaborate as SMEs could be viewed as high risk partners [18].

New value chain configurations require a diverse set of capabilities and it has been recognised that only large companies will be able to establish such an ecosystem themselves, whereas SMEs need to develop partnerships in order to achieve new business models [28].

SMEs might not be used to regularly collecting and exchanging data regarding their input and output resource flows. Arranging this information would likely require a significant amount of resources [18], [27]. In the case where this information is available, a perceived risk of proprietary information disclosure might hinder the involvement from SMEs, especially the risk of information being accessed by a competitor [20].

In the case when the SMEs are a subsidiary of a larger international group, there is an additional challenge in terms of limited power to make decisions. At the local company level, restrictive standards and requirements might hinder collaboration with other local companies [20].

In conclusion, resource scarcity intensifies the challenges for SMEs to participate in industrial symbiosis networks. This resource scarcity spans over limited or imperfect information, inadequate economic resources, low price competitiveness, lack of an extensive network of partners and insufficient set of competencies required for implementation of industrial symbiosis.

2.1.3 Enabling factors to participate in an industrial symbiosis network

The involvement of SMEs in industrial symbiosis networks might seem to be limited due to a lack of time and resources. However, there are many existing networks that involve SMEs to a great extent.

This section describes the factors that enable a company's participation in industrial symbiosis networks, as identified in the literature. Most of the conditions were mentioned irrespective of a company's size and we assume that these conditions would be highly relevant for the involvement of SMEs as well. The factors are classified into technological, economic and social factors.

On the **environmental/technological** front, the literature mentions that identification of potential synergies requires considerable amount of resources. Therefore, assistance in identifying opportunities for turning by-products into resources would be valuable for SMEs [18], [20], [27]. The following tools have been suggested in the literature to enable identification of potential exchanges:

- An online directory of companies containing valuable pieces of information, such as the geographic location of the companies.
- The Nomenclature of Economic Activities (NACE) code is the European Statistical Classification of Economic Activities and was shown to be a successful tool for identifying the specific companies that could be connected via industrial symbiosis partnerships in the Västra Götaland Region of Sweden. NACE codes group the organisations according to their business activities and therefore are useful to find synergistic opportunities.
- A screening tool generating data sets that can enable sectorial and regional analysis of streams for example, possible local access to critical resources

One of the reports mentioned **economic** factors as enabler for industrial symbiosis. Substantial costs for disposal of by-products, for example, organic emulsion in a chemical company, could act as an incentive for industrial symbiosis networks. During interviews with SMEs in Landskrona, Sweden, Starlander [20] found that several SMEs perceive that industrial symbiosis networks will be a natural evolution of industry, for example, scrap metal recycling company and the waste management company explicitly considered industrial symbiosis as an extension of their current activity. Such perception on business models might act as an incentive for companies to participate in industrial symbiosis networks. [20]

In terms of the **social** factors, collaboration with partners and, company's culture and behaviour were identified as promoting industrial symbiosis. Presence of certain organisations in the region or value chain could act as a catalyst to participate in industrial symbiosis networks [18], [22], [25], [27]. These could include:

- Neighbouring SMEs in the region who would understand the circumstances of SMEs
- A coordination agent (likely an external body) who would facilitate communication and foster cooperation and trust among actors with an independent perspective
- Innovation support organisation who would offer competence exchange and technological advice to build an industrial symbiosis network, for example Kuggcentrum and Mälardalen Industrial Technology Centre (MITC) in Landskrona
- Pressure from the supply chain can act as a catalyst of change to improve efficiency and environmental performance especially for SMEs
- Active local Environmental Department who could impose environmental regulations such as Extended Producer Responsibility that would in turn trigger conditions for establishment of industrial symbiosis in nearby regions.
- Existing symbioses in the same industry to act as role models for industrial symbiosis development

Another important factor that would trigger an SME's participation in an industrial symbiosis network is the organisation's culture and behaviour [20]. If a company has a problem-solving approach and

focuses on development of innovative solutions, it might come up with a solution that involves collaboration with other companies and would be willing to invest resources into achieving the solution. For example, for a company doing flexible printing of packaging materials, the motivation to find an output for its paper waste led to industrial symbiosis networking in the region of Landskrona in Sweden. Similarly, if a company's management has focus on high environmental performance, participation in an industrial symbiosis network to enhance resource efficiency might be prioritised over other initiatives. This is especially applicable in cases when the SME is a subsidiary of a larger group - company policies that promote higher environmental performance/innovativeness would motivate the local subsidiary to take actions in line with the policies [20].

2.1.4 Digitalisation as an enabler for industrial symbiosis networks

Many companies are now shifting towards digital platforms for collection, storage, and analysis of data. Digitalisation can be a powerful tool for businesses to become more efficient and to track their activities, however it comes with a risk of open data and challenges related to data protection and confidentiality. Digitalisation is a key transformational instrument for today's industries, and therefore this section describes how digitalisation could enhance the opportunities that come with industrial symbiosis. Towards the end of the section, the perceived risks of digitalisation and how to overcome them are explained.

In the context of industrial symbiosis, digital tools could be used for the following purposes:

Identifying opportunities

As mentioned in the previous section, identifying which streams could potentially be exchanged with other companies could enhance the involvement of SMEs in industrial symbiosis networks. Digital databases such as an online directory of companies, Nomenclature of Economic Activities (NACE) code by European Union, which makes it easier to find potential matches would therefore be valuable for SMEs [20]. In a report from the MISTRA project [29] a national bioeconomy monitoring system based on automatic data flows for assessing trends and therefore the potential of different renewed production processes is suggested for the bioeconomy sector. Such databases that would provide comprehensive information about products and streams would make it easier to tap into new opportunities, thereby creating new supply chains and closing material loops [29], [30].

Another suggestion in the literature was to create a screening tool to analyse regional streams that would make it less resource intensive for companies to discover potential synergies [27]. Järvenpää et. al [31] has suggested that the online databases could be developed on a regional level and that the regional development actions could then focus on enhancing industrial symbiosis, thereby reducing the resources required by individual companies to find synergistic possibilities.

Operation and control of resources

Digitalisation brings with it possibilities for automation and in the context of industrial symbiosis. It can be used for automatic sorting of waste, allowing enhanced separation and thereby homogeneous quality side streams to be used as resource for other companies [28], [29].

Tools such as sensors or Internet of Things (IoT) enable tracking and monitoring of process streams, allowing transparent access to data for the engaged companies and enhanced possibilities for joint monitoring [26], [28], [32]. The use of digital twins for process units could also help in development of efficient maintenance solutions [28].

Analysing costs and benefits, and environmental impact

Digital tools enable efficient collection of a large amount of data and therefore make it easier to analyse different types of data. For example, in order to optimise resource consumption, product life cycles, or logistics routes. [30]

Business development

Digital tools can enable transparency and traceability in supply chains, thereby enhancing trust among the actors and leading to better business possibilities. The increased transparency enables fair redistribution of the benefits of industrial symbiosis [32]. By offering possibilities to optimise supply chains and industrial symbiosis networks, digitalisation strengthens the networks and promotes further extension of symbiosis [32], [33].

Digitalised data offers an opportunity to recognise trends and patterns such as any changes in customer preferences and behaviours. This acts as a motivation for companies to adapt their business models according to the customer's demand, for example by exploring possibilities for symbiosis in the region. Ruohoma et al. [33] mentioned that regions can increase their attractiveness and development by offering open data for the use of local companies and industrial symbiosis.

Communication between companies

Digital tools can be used for communication between the companies in order to facilitate networking, collaboration and co-creation [30]. In this way, digital communication tools provide more efficient tools for discussion and collaboration in order to enhance industrial symbiosis networks.

Therefore, digitalisation offers multiple benefits to companies by allowing access to valuable information in a transparent and traceable manner. However, digital tools are still seen as novel tools with perceived threats such as misuse of data, proprietary information disclosure, exchange of confidential information, data breaches or risk of cyber-attacks [28], [30].

Such perceived risks are common as with any other new technology. Antikainen et al. [30] identified that co-creation, networking, increasing transparency and providing information could change this perception towards a positive tone and enable acceptance of digital tools. Co-creations involves sharing of expertise and experiences in order to develop better products or services. When both sides have the possibility to gain from each other, they would see this as an opportunity rather than as a threat. Antikainen et al. also suggested that co-creation and networking must be promoted among actors from different sectors and from both small and large organisations. In the long term, co-creation and networking would enhance trust among actors and therefore minimise the risks that come with the use of digital tools. Innovative technological solutions, such as blockchain technology could also be utilised for the protection of data [30].

In conclusion, the availability of data, possibilities of joint monitoring and better communication among actors will be important elements of digitalisation that could enhance the performance of industrial symbiosis networks in the future. The risks of data breaches could be managed by enabling co-creation and networking among different actors and stakeholders to build up mutual trust.

2.1.5 Policy suggestions for emergence of industrial symbiosis networks

In order to increase the establishment of industrial symbiosis networks, support from policy makers is required in order to promote the conditions that would favour industrial symbiosis networking. The policies should be designed on both national and regional levels and on a long-term basis. The policy suggestions identified in literature have been classified into six different categories below.

1. ***Industrial symbiosis on National agenda***

Literature suggests that industrial symbiosis should be included in the policies on national level in order to stimulate regional actors to take actions towards creation and expansion of industrial symbiosis networks. One suggestion is that the responsibility to promote industrial symbiosis should reside with a single government agency so that it can take concrete actions and be held responsible [34]. A long-term public support framework is essential, and a national strategy will act as a signal for the industries to take actions for exploring industrial symbiosis opportunities [24]. For example, industrial symbiosis could be included on the national agenda as a part of a national circular economy strategy or a national industrial symbiosis platform could be established [15], [34].

2. ***Economic instruments***

Economic instruments should be provided at national and regional levels, especially in order to support the initial establishment of industrial symbiosis networks [31]. It is important to offer long-term funding to make the companies feel secure [34]. Incentives could be designed to either directly promote industrial symbiosis, for instance by offering tax reductions or subsidies to companies who establish industrial symbiosis networks, or through indirect stimulation through penalties/bans on landfilling or incineration of certain types of waste [22].

There is funding available at the EU level that could cover industrial symbiosis projects, such as from the Green Public Procurement, and European Structural and Investment Funds. However, these mechanisms are often not utilised to their full extent. Therefore, it has been recommended that the national agencies could promote increased use of such funds as a start [15], [19].

3. ***Regulatory triggers***

The environmental policies must be designed considering the environmental impact of the entire value chain. Local landfilling ban for certain types of waste could be an indirect support mechanism for industrial symbiosis networks. Clear definitions for ‘end-of-waste’ criteria are crucial for companies to understand when their waste materials would be treated as a product or a secondary raw material and consequent implications of such nomenclature [21], [29].

It has been identified that regulatory procedures could act as a barrier for companies trying to collaborate on resource flows, and therefore literature suggests that such regulatory barriers should be identified and adjusted accordingly in order to ease the establishment of industrial symbiosis networks [15], [22], [24], [34].

4. Regional planning initiatives

Regional planning that takes into account the possibilities for industrial symbiosis would create the space required for industrial symbiosis development and thus promote such networks [31]. For example, regional roadmaps with realistic short, medium and long-term objectives could be developed to showcase to the industries that industrial symbiosis will remain on the agenda [29]. Urban planning, such as, planning of an eco-industrial park, is likely to trigger discussions about industrial symbiosis [22], [35].

On the consumer side, regional authorities could generate market demand for certain streams by updating regulations or policies as well as awareness-raising about the new products. Examples include awareness for biogas that is used in transportation [35].

5. *Increased engagement of stakeholders at regional level*

It was identified in Section 2.1.3 that certain actors in the value chain such as innovation centres or a third-party coordination agent could act as catalysts for industrial symbiosis networks. Therefore, the regional authorities could support such stakeholders in order to organise and implement industrial symbiosis networks in the region [19], [35]. Promotion measures that support third party intermediaries would facilitate the development of industrial symbiosis networks as they provide curated interaction, often coming in with technical knowledge and expertise required for the development [22].

The other key stakeholder group consists of potential investors. The regional authorities could aid in identifying and inviting these stakeholders to invest in industrial symbiosis networks [31], [35].

It is also important to promote interactions between different stakeholder groups [31]. Many industrial symbiosis networks have been a result of spontaneous interactions among closely located industries and were self-organised due to high mutual trust and long-term relations among actors. Such industrial symbiosis networks have shown resilience and adaptability over time and therefore it is important to promote networking opportunities that might not directly target industrial symbiosis networking [22].

6. Capacity building

The importance of raising awareness and disseminating knowledge about industrial symbiosis has been mentioned in multiple reports [15], [19], [24], [29], [31], [34]. This would be especially relevant for SMEs since they do not have as many opportunities to network or receive expert advice compared to larger companies. Informational campaigns that highlight good examples and benefits of industrial symbiosis as well as green business model innovation must be supported in order to ensure that the information reaches the companies [21].

The identification of possibilities to exchange streams is an important factor for industrial symbiosis networks. This can be supported on the national level by development of digital platforms to map side streams [15], [34]. The regional authorities could further support the companies in carrying out screening of side streams and facilitating match-making activities [34]. There are several EU projects that have been conducted or are ongoing in this regard, for example STORM by EIT Raw Materials,

SYMBI by Interreg Europe as well as the BIS project [36], [37]. Such support enhances the capacity of companies to establish industrial symbiosis networking.

A report by Ellen McArthur Foundation [24] has also suggested tangible capacity building by stimulating pilot projects in order to encourage innovative solutions, mentioning the need for financing instruments for such pilot projects.

2.1.6 Industrial symbiosis as a business model in circular economy

Baldassarre et al. [38] describe industrial symbiosis as a sustainable business model in the perspective of circular economy. It can be classified as a business model as it involves collaboration of multiple stakeholders for technical innovation, with the aim of improving environmental performance but still with a strong focus on business viability. Baldassarre et al. [38] recognised that a business focus is crucial in an industrial symbiosis network in order to ensure that the stakeholders align with each other and for long-term survival of the industrial symbiosis network. In this perspective, according to the authors, an industrial symbiosis network comprises of circular strategies to match resource flows for increased resource efficiency in an industrial cluster.

Development of an industrial symbiosis cluster in this respect therefore follows the following steps, as described in the report:

1) Defining a value proposition for example reduction of waste
2) Value creation for example turning waste into valuable materials
3) Cross-industry partnerships to capture the value and create economic and environmental benefits.

An industrial symbiosis network encompasses multiple stakeholder groups of varied types, size and culture. Each stakeholder has a specific role to play in order to ensure that the industrial symbiosis network is successful. For instance, the value proposition for the local government would be job creation and sustainable economic development and it could in turn participate in the network by providing land or by ensuring bank loans. The value proposition for a company engaged in the network could be production of value-added products while another company participates with its waste streams.

Therefore, in order to form an industrial symbiosis cluster, business viability is often analysed as a focal point to align stakeholders and create a long-lasting impact and could be perceived as a type of sustainable business model during the discussions on circular economy.

2.1.7 Knowledge gaps

The Nordic countries have many beneficial pre-conditions for the establishment of industrial symbiosis networks. Considerable research has been carried out in these countries to analyse existing symbiosis networks and to propose new ones. Poland and Russia were found to have limited experience and literature on industrial symbiosis. However, it is important to note that the literature search during this study was limited to English language. Most of the literature from these countries showcases good examples of industrial symbiosis from other countries.

Many studies have identified challenges and opportunities of industrial symbiosis. Nevertheless, during the literature search, only three studies were found with an integral focus on SMEs. Therefore, it would

be worthwhile to carry out further studies to understand which triggers would be the most important for SME's participation in an industrial symbiosis network and which are the most critical barriers for SMEs to be involved in an industrial symbiosis network.

2.2 Interview study

In the following chapter the results from the 20 conducted interviews are presented. The questions used for the interviews are presented in the Annex.

2.2.1 Advantages and disadvantages to participate in an industrial symbiosis network

The companies were asked about the advantages and disadvantages that occur as a result of being part of an industrial symbiosis network. The respondents' answers are summarised below.

Many of the companies view better economic results as the greatest advantage of industrial symbiosis. These can occur in terms of increased revenues and/or lower costs. In terms of increased revenues, two of the respondents mentioned that it allows the companies to *"find new products and markets"*. In terms of lowering the operating costs, industrial symbiosis allows the companies to either have a cheaper solution for waste management or obtain cheaper raw materials, or both. For example, lime is a by-product from the pulp and paper industry that is being utilised by some companies to produce fertiliser, thus lowering the waste management costs for pulp and paper mills.

Furthermore, industrial symbiosis networks allow companies to become more resource efficient. For example, a respondent mentioned that they benefit *"by combining deliveries to the customers".* Creating an industrial symbiosis could allow companies to lower their investment costs as some of the existing infrastructure can be shared among the companies. For example, a company that utilises sawmill dust as its raw material mentioned that *"locating close to a sawmill makes it easier to both obtain raw material for their process and to share operational machinery at the mill so that they themselves do not have to invest in the big machines".* One of the companies mentioned that being part of an industrial symbiosis network allows the process industry to maintain its competitiveness and to fulfil the public regulations, thus allowing them to continue their business in the region. One example was that *"without the collaboration the industry may have de-located to another country with less strict environmental regulations, instead new business emerged creating new opportunities and keeping the industry from de-locate".*

The second most frequently mentioned advantage by the respondents were in terms of **environmental benefits:** increased environmental performance of the company itself and/or contribution to a green economy. For example, one of the interviewed companies utilises food waste and views this as a contribution to a circular economy. Another company utilising seaweed for biofuel production mentioned that they offer multiple environmental benefits to the community since *"collection of seaweed reduces the odour problem from seaweed fouling on the beach and reduces eutrophication in oceans".* In addition, when they sell the biofuel to their customers, *"it leads to a reduction in the use of coal, reduction in carbon emissions for the region and is a great way for the company to show social responsibility".*

Seven respondents mentioned **social benefits** that arise with being part of an industrial symbiosis network. In addition to sharing material/energy/water resources, being part of an industrial symbiosis network offers the opportunity to share resources such as staff and their competence. One of the respondents mentioned that *"close collaboration among the companies offers the opportunity to*

exchange experiences with other companies, especially in terms of health and security issues within the industrial plants". Being part of an industrial symbiosis network also enhances positive visibility for the companies, especially if the network is well-known. For one of the interviewed companies, the added visibility brought economic benefits in terms of increased attractiveness for investors. Two of the respondents also mentioned that industrial symbiosis promotes innovation in terms of new products, customers or markets. They view it as a problem-solving approach with *"an opportunity to create advanced solutions together".*

Many of the companies have not noticed any disadvantages in being part of an industrial symbiosis network. There were however **two disadvantages mentioned** by some of the respondents: **interdependence of companies and enforced transparency**.

Five of the respondents mentioned that interdependence of companies could create disadvantages. One of the respondents said that, *"the flows become dependent on each other and how it goes for another company could affect our capacity and vice versa".* The companies *"cannot take independent decisions".* One of the respondents highlighted that the interdependence could also have an impact on the company's image – "*if we are too dependent on other companies, we are vulnerable. If they do something bad, we get the blame as well".* The respondent also mentioned that this is nevertheless a small risk. Talking about how to overcome the disadvantage of interdependence, one of the respondents mentioned that *"we always use 2-3 companies on either end to make the industrial symbiosis network more robust",* meaning that they arrange the networks such that there are 2-3 receivers of the by-products and 2-3 suppliers for the raw material. This minimises the risks related to dependence of one company.

Two of the respondents mentioned that being transparent and sharing information with each other acts as a disadvantage. One of the respondents elaborated that this is not a big issue, however according to their experience, it acts as a barrier to development of business models for new symbiosis networks in new regions. The companies in the other regions expect the same pricing model, even if the regional conditions could be quite different.

2.2.2 Challenges to participate in an industrial symbiosis network

The challenges faced by the respondents in becoming part of an industrial symbiosis network are summarised in this section.

Only four of the respondents identified **environmental/technological** factors as a challenge in creating the industrial symbiosis networks. Variations in either quality or quantity of the streams could create a hindrance in the symbiosis. For example, one of the respondents identified that the *"quality of by-product is important"*. Further elaborating on this, another respondent exemplified that *"if the residue in biomass that we receive is polluted, we would have to consider if our process would break down because of it"*. A company which is dependent on energy flows highlighted that *"if the other company cannot supply us with steam, then we may have to stop our factory"*. The company mentioned that there is an interdependence factor here and the problems could be caused by their own process as well. For example, *"in the biofabrication, our capacity may decrease if the bacteria feel bad, and in this case, we cannot receive all the inflows"*.

Economic factors were identified as a challenge by five respondents. According to two of the respondents, economic challenges can occur from the competition with cheaper, but not as environmentally friendly, alternatives: *"One obstacle has been that other alternatives have been*

cheaper, for example, landfill". Another respondent identified that *"long distances can make it expensive with the transport of, for example, waste"*. One of the companies mentioned that there can be trade-offs between efficiency and profitability and competitiveness. One of the respondents acknowledged that a lack of resources in terms of both time and money is an obstacle for them. Another stated, "risk of losing some focus on core business, which could lead to loss of market share and poor financial results in turn". One of the respondents identified market failure as a risk: *"We will exchange stream with seafood farm, however land-based seafood is not an established market yet, so if the market fails, then we will not be able to exchange the resource"*.

Seven respondents identified **social** factors as obstacles to engagement in an industrial symbiosis. Social perceptions can play a role, for example, a company mentioned that working with residual products *"can be perceived as boring and cumbersome".* The companies might have different perceptions or strategies, which can create problems when collaborating. For example, a company mentioned that the other company they are interested to collaborate with *"is very traditional and sees our business as something new and risky. This makes it difficult to collaborate with them"*. Another obstacle could be the traditional mindset of employees within the company in question: *"We are a traditional wastewater treatment company and employees do not necessarily understand the big picture and are not keen about industrial symbiosis".* Two of the companies identified risks of being transparent, mentioning that *"We want to keep our company secrets"* and *"other companies might make use of the technology/know-how"*. One of the respondents mentioned the lack of competence within the company as a challenge to industrial symbiosis.

Regulatory processes and public support are another category of challenges identified by ten of the respondents. Slow licensing processes create a hurdle: *"For example, for transporting waste across national borders, it takes from three months up to a year to obtain the licence and it must be renewed every year".* One of the respondents elaborated that *"it takes between 3.5 and 4 years to register a new edible product in the EU"* and a major challenge connected to this is the lack of financial resources. There is no financial support available for going through the regulatory processes according to the respondent.

Regarding the food and healthcare industry, three of the respondents highlighted problems with the existing regulations: *"Four different authorities make regulations in our area and these are hard to comply with".* It was highlighted that certain regulations must be simplified for certain common food products, for example, *"rules do not make a difference between proteins from mammals and fish, although fish protein does not spread diseases and does not need to be regulated in the same way as animal protein"* and *"even though some parts of the country already eat spruce and there are already some products in the country made out of spruce, there is still a long regulatory process for getting claims on food ingredients made out of spruce".* Two of the respondents identified that changes in policies are another challenge: *"We are not able to plan for long term due to instability and changing policies in the country*", mentioned one of the respondents. Another challenge is the difference in regulatory processes across countries. For example, one of the respondents exemplified that *"if a company's residual product becomes fertiliser, in some countries it is not allowed to spread it on the fields".*

Some companies identified public support as lacking. The shortcoming could be in the form of financial support, or the absence of an active environmental authority to push the companies to follow environmental regulations. One respondent mentioned that sometimes there is a lack of knowledge about existing environmental permits, and/or how to accurately apply for new ones. One of the companies mentioned that there is a lack of financial support in creating markets of new, usually

expensive, products. Public support that differs between the countries creates distorted competitive conditions, for example, *"Denmark provides production support for biogas and competes out the Swedish biogas. Sweden is now considering also providing production support for its biogas. It instead risks competing for the Norwegian biogas, which also does not receive production support".* One respondent mentioned that some industrial sites in Germany have centralised environmental permits that other companies would be included in. That was an attractive feature when searching for new potential industrial symbiosis collaborations or potentially relocating.

2.2.3 Enabling factors to participate in an industrial symbiosis network

This section summarises the factors that were mentioned as enablers for participation in an industrial symbiosis network by the interviewees.

Only three of the respondents mentioned that **environmental/technological** factors enable their contribution to symbiosis. This was exemplified in terms of availability and access to others' waste streams and the possibility to utilise the secondary product. Another enabling factor mentioned by one of the respondents is the possibility to utilise existing infrastructure at the site, in addition to engaging in exchanges with other companies.

Seven of the respondents mentioned that **economic** factors enable their participation in industrial symbiosis networks. One of the respondents mentioned that the high cost of managing their waste streams led them to explore opportunities of industrial symbiosis. Another respondent highlighted the importance of a business case. The market demand acts as a strong contributor to enabling an industrial symbiosis network – two of the respondents, with reference to their own products, mentioned that the increased demand of *"green products"* and of *"textile fibres"* was the enabling factor for their business. Another respondent mentioned that the potential for decreased economic costs that arises due to sharing of infrastructure with other companies is an incentive to participate in industrial symbiosis network: *"we as a small company cannot invest in big machines".* For some of the companies, their core business model depends on cooperation with other companies, and therefore naturally enables industrial symbiosis. *"Our natural business is to add value to other's side stream products"*, mentioned one of the respondents. Two of the respondents highlighted the importance of economically strong and financially stable partners in the symbiosis, explaining that this *"creates confidence among the customers".*

The importance of **social** factors was mentioned by eighteen of the respondents. Due to many responses and a variety of social factors, these social factors have been further classified into the following sub-categories: close collaboration and trust, culture and behaviour, technical expertise and experience, sharing of additional resources and societal awareness.

Nine of the respondents mentioned that the companies must be willing to have a partnership and cooperate with each other. Five respondents explained why **close collaboration and trust** within the companies is one of the keys to industrial symbiosis such as, *"We consider each other as partners, not competitors"* and *"If you only think about your own advantage it becomes difficult, everyone must understand that everyone in the system must be able to participate"*. It was highlighted that ongoing and well-established contact and trust between the companies makes it easier to exchange ideas between one another.

Eleven respondents mentioned that a company's **culture and behaviour** are important in establishment of industrial symbiosis. The relation between the organisational culture of a company and its participation in industrial symbiosis was pointed out by three respondents. Two of the respondents mentioned that non-hierarchical organisations where everyone contributes to the solution and where it is easy for employees to take decisions is a positive element. One of the respondents highlighted that it is important to have engaging employees in the company. One respondent stated that industrial symbiosis should be prioritised at the top decision level and that goal-oriented planning is an important factor in achieving industrial symbiosis. One of the companies highlighted that since they are a small company, they are adaptive, and this was described as the enabling factor for industrial symbiosis. One of the respondents mentioned that the political engagement within their company was a strong factor to enable industrial symbiosis: *"the political institution owns the company and industrial symbiosis would not have been possible without their engagement from the start"*. Another respondent identified that the *"willingness to innovate"* is important while another said that the company *"must be open to new ideas"*. One of the companies made a remark that importance should be given to research and development: *"we have a strong R&D department and invest 11% of our turnover in R&D activities"*. Another company stated that their "*willingness to take a bigger risk than usual"* enabled them to become part of an industrial symbiosis network.

The **technical expertise and experience** of the employees were mentioned as enabling factors by seven respondents. One of the respondents mentioned that their employees have *"knowledge of different factories, what types of waste and needs they have. We have developed our own database with detailed information on this. High technical knowledge on the conversion of waste into raw materials between sectors enables us to contribute to industrial symbiosis".*

Three respondents highlighted that additional advantages of **sharing resources** other than the by-products could strongly enable a company's contribution to take part in an industrial symbiosis network. This could refer to sharing physical resources (for example, *"Fire safety equipment is located in the main part of the other company's factory, so we do not need to invest in it",* mentioned one respondent) or soft skills (such as *"exchange of experiences around health and safety in projects"* and "*we are open to sharing know-how on cleaner meat products*").

Three respondents mentioned **societal awareness** as a driving force. Two of the respondents gave credit to environmental awareness wherein one of them commented that *"this drives us and our customers to become more environmentally conscious"*. One respondent talked about the international awareness about Nordic technology, mentioning that the Nordic technology has good reputation internationally which gives them a market for their products. Another respondent mentioned that over the last few years he has seen a development that more people are involved in the meeting concerning the waste streams. For example, sustainability managers and communications staff.

2.2.4 New business opportunities and potential for new collaboration

The answers to the questions related to possible development of the business models due to the participation in an industrial symbiosis, varied to a great extent and are presented in this section.

Four of the respondents answered that they develop their business in terms **new products and services** due to the industrial symbiosis networks. For example, one respondent said, *"Now we are an*

engineering company, but we could have a separate service company". Another described that through sharing of resources and sales, they have developed combined products where all have taken part in some part of production.

Some of the respondents (three companies) answered that they saw no new business opportunities from being part of an industrial symbiosis. However, one of the three answered that they will help other small companies to make new business. Furthermore, another respondent answered that a report on the environmental impact and the share of recycled waste products will be communicated to their customers. In this way the industrial symbiosis helps with customer relations and to obtain the customers' environmental demand. Hence, the industrial symbiosis strengthens the business model, even though no *new* business is developed.

The latter impact of being part of an industrial symbiosis, strengthening of the business model, is implied by two others of the interviewed companies as well. The respondents answered, *"Yes, we are growing"* and *"We could have new business, new customers and suppliers, but is would not be new. It would be more of the same"*.

In addition to new products and services, the business development in terms of **new customers** through industrial symbiosis, is pointed out by several of the respondents. Three of the respondents highlight the access to new customers due to the industrial symbiosis and development of customers' relations. For example, one respondent said, *"Through cross-fertilisation of industries, we have found new markets"*. Another respondent said, *"We have found new customers and new types of customers that were not interested before"*. Also, one respondent describes that that a small company has little possibility to have positive visibility, but that the industrial symbiosis network has given them positive visibility.

The opportunities to meet customer demands and strengthening customer relations are highlighted by several of the respondents in different ways, not the least the opportunity to meet the customers' environmental demands and communicate it more easily. Four respondents answer that the demand for green products or the great public interest in environmental issues have been the main enabling factor for participation in an industrial symbiosis. Also, four companies stress the opportunities with digital tools to analyse the environmental impact in order to get a documentation of their level of circularity and an environmental certification. For example, one company are looking at the possibility to get environmental certificates for waste products.

Additional opportunities to develop the customer relations, using digital tools in the context of industrial symbiosis, is pointed out by one company. The respondent described, *"We do active marketing directly to consumers using digital channels – this indirectly helps to enhance industrial symbiosis network as companies adapt to consumer demand".*

In addition, several of the respondents (five companies) answers that they will apply the experiences from the industrial symbiosis to develop industrial symbiosis collaboration at other industrial sites. Some of the companies already have several sites where they duplicated the collaboration model, and others are discussing new industrial symbiosis collaborations or see a great potential for it.

One interview question was about the potential for **new or elaborated collaboration**. Two of the respondents answered that there were no such opportunities. Most of the others mentioned several opportunities. Two mentioned potential for further energy collaboration and two mentioned potential

for further material collaboration. In addition, two of the respondents highlighted the opportunity to add more companies to the existing industrial symbiosis. One respondent stressed the potential for improved collaboration between industry and academy in order to make research come to practical use. Furthermore, two respondents highlighted the opportunity to share other kinds of resources in addition to energy, water and material flows. Examples of resources that were mentioned were, cars, digital platforms, competences such as project managers, and machines.

2.2.5 Digitalisation can further industrial symbiosis networks

The interviewed companies had rather different views on the importance and possibilities connected to digitalisation. Three companies stated that they see no further use for digitalisation besides using regular computers for office work and meetings. But most of the respondents described a more developed view and shared several examples of how they use digitalisation now, as well as ideas about the possibilities connected to further digitalisation in the future. In this chapter their answers are divided into five categories and subdivided further to highlight if the solution is used now or if it is seen as a future possibility.

Identifying opportunities

Four of the respondents discussed digitalisation in connection to identifying opportunities. One respondent described using digital tools to identify business opportunities, by making it possible to map, buy and sell waste streams. Another company acted as a facilitator by analysing streams and possibilities among various companies and creating symbiotic business models between them. That company described the need for detailed information about the contents of the waste products, down to a chemical level, to be able to find the correct matches for each company. The company described that they have developed a database to gather such information: "*Between two companies there is also a need for professionals, who can solve problems and analyse the opportunities. We have made our own database of interesting companies [their wastes and contaminations]. It is a simple but big database".* The respondent also warned against the creation of big and compulsory databases with information about the content of the wastes of each company in relevant sectors. The motive, according to the respondent, being that these cannot be detailed and reliable enough to answer the questions needed to be able to judge the opportunities in a reliable way. "*Every by-product is a little bit different. It won't be sufficient with big data, you can't generalise about it"*, mentioned the respondent.

Other companies viewed the possibilities in a more positive way, however, these companies speak from the experience of working with different kinds of waste materials than the company (cited above) that warned against such ambitions. "*Last September we launched the app. This platform is unique in the world by bringing together the building sector and landfill sites. The building contractors can register what they want to get rid of and within 48 hours they get an offer for their wastes"*, mentioned another respondent.

A couple of the respondents stated that they recognise the possibilities of using digital tools to identify business opportunities in the future, even if they are not currently using the tools for this purpose. One company stated that there are probably good possibilities to collaborate with another company nearby. However, that requires the other company to invest in digital tools to analyse and measure the contents of their waste. If they are not willing to do that, no collaboration will take place.

Operation and control of resources

Five of the interviewed companies described using digital solutions to support the operation and control of resources and another six companies stated that they considered that an opportunity to develop further in the future. Three companies described using sensors, cameras and/or digital systems for monitoring and evaluation of production processes, as well as measurement of the amount and contents of their raw materials, wastes and by-products. One company expressed, "*Every tenth second our system collects data of our production process, which is transferred to the customer as information".* There was also one company that described using digital tools in logistics, tracking and storage handling and another company that at the time of the interview was initiating a project to rationalize logistics and implement tracking of their shopping.

When elaborating on future possibilities, six companies described a few projects that have started, in line with the digital solutions that are already in place in other companies. They also described possibilities in the further sharing of processes and monitoring of data with other companies. For example, to facilitate having a plant that is located far away from the main office and sharing more real time data with their customers to facilitate closer collaboration.

Analysing costs and benefits, and environmental impact

Five of the interviewees described using digital solutions to analyse the environmental impact as well as analysing the content of the streams in the symbiosis network, either now or as a future possibility. One interviewee said, "*We have several monitoring systems and we weigh and analyse the waste to know the dry matter content and the amount of nutrients [in the waste]".* Another stated, "*We automatically measure the amount of carbon dioxide that isn't released from our processes but is instead buried as biochar*".

The respondents emphasised the marketing potential of measuring the environmental impact. The possibility of getting automated documentation of environmental impact and being able to use this in getting green certificates was considered appealing. Furthermore, getting documentation that meets the demand from government agencies in regulatory issues was mentioned by three of the interviewees.

Business development

The use of digital channels as an active marketing tool was described by one of the interviewed companies. This company sells its products to other businesses who could further utilise it as a raw material in their processes. The digital marketing is aimed towards the final consumer, and not directly towards the company's customers. The respondent described that marketing in digital channels serves to enhance the industrial symbiosis network as the involved companies become better at adapting to consumer demand.

There is business potential in highlighting the benefits of using a product from an industrial symbiosis network. This was described by one company regarding their product for the agricultural sector, that is produced as a result of an industrial symbiosis network: "*We are developing an optimisation program for agriculture to optimise farmer's production – so we can see the link between our product's use and their yield, and to adjust crop rotation*".

Another company that works in the construction sector described developing a project for digital design of buildings where the customer can take part and try different designs. In the future, they would like to invite other companies they cooperate with, in the ambition of delivering joint solutions to the customers' demands. Furthermore, one company describes wishing for the creation of advanced systems for procuring green electricity as well as open data on streams of wastes that are open for bidding.

Communication between companies

Besides e-mail, invoice systems, regular office programs and online meeting services, a couple of the companies described using digital tool to communicate with other companies. One of the companies mentioned that there is communication, information, data sharing and sales presentations on a shared web in an industrial symbiosis network that collaborates in foreign markets. In another case, there was communication on machine level in an integrated digital solution between the cooperating companies. Another respondent hoped for a future solution where the result from the weighing of the waste materials is integrated with the documentation systems that their customer keeps to comply with government regulations.

2.2.6 Support and incentives for emergence of industrial symbiosis networks

In the following section, the answers have been divided into the following categories: economic, regulatory, and knowledge or informational.

Many of the respondents (thirteen respondents) mentioned economic support as a facilitator to further enhance collaboration. For example, several of them mentioned subsidies or economic support for market introduction of new products or new technology, or for introduction of existing technology to new markets. One respondent suggested, *"To get more support to enter a new market, especially in non-mature markets. It takes 5 years if entering a non-mature market and that is a big financial risk and investment".* Another mentioned, *"To prepare technology to market, there we have support, but we need support to take it to the market and be completely commercialised, there we have no support. The government funds until ready for market, but then in the commercial step, there is nothing. You want the technology to be used and it will be risky in the beginning. You need to find a way to handle the risk."* In addition, an example of publicly financed industrial clusters was mentioned, and it was suggested to give economic support to organisations with a catalytic role for collaboration between SMEs.

An economic incentive which was mentioned by one of the respondents, was to increase tax on fossil products in order to promote non-fossil alternatives which are produced within the cluster.

Regarding regulatory incentives, environmental legislation was mentioned by seven of the respondents. Harmonising the support between countries in the same region was suggested in order to make fair competition possible. However, the most suggested regulatory measure to support increased collaboration, was to simplify and speed up the environmental permit process. This is particularly important to small companies. One respondent said, *"Big companies can accept long processes. But start-ups have no time for long waiting times".*

In addition to economic and regulatory support, some respondents mentioned support to knowledge and innovation as an important key to increased collaboration, particularly support to development projects was mentioned. For example, *"We have small economic muscles and small opportunities to put effort into development projects".* Knowledge and innovation projects are particularly challenging for small companies with limited resources. Hence, a key could be to support their development projects.

Lastly, informational support, such as networking and dialogue about challenges and opportunities was mentioned. Market studies to link companies and customers was also suggested.

3 Analysis of results

3.1 Enablers and challenges to participate in an industrial symbiosis network

The enablers and challenges for SMEs to be involved in industrial symbiosis- networks have been identified in both the literature and during interviews. These have been classified into economic, environmental/technological, and social factors. This section of the report further delves into the factors in order to analyse the differences and similarities based on internal/external nature, geographical location, and types of resources exchanged.

Social factors are the main enablers while regulatory procedures are a major challenge

It is quite clear from both literature review and interviews that improved economic and environmental results from engagement in industrial symbiosis are given higher importance than social factors. However, it is interesting to report that, when the companies were asked about factors that enable or hinder their participation in industrial symbiosis, the social factors were mentioned by most of the respondents, and more frequently than other types of factors. This shows that factors such as an innovative approach and employee engagement within the company, social engagement among companies, and societal awareness would play a major role in enabling establishment of symbiosis networks.

Regarding the challenges to establish and benefit from industrial symbiosis, regulatory factors seem to play the crucial role according to the interviewees. The absence of enabling social factors, such as trust among the companies and a lack of innovative mindset, was identified as a challenge by seven of the respondents while regulatory processes were mentioned by ten of the respondents. It is however important to note that the critical factors identified in this study cannot be generalised. Which factor plays the central role is highly dependent on the company's own nature and on the nature of the surroundings. Therefore, while one company may identify willingness to collaborate as a key, another might point towards the presence of a good quality stream. The following part of the chapter is an analysis of the results obtained from the literature review and interviews.

3.1.1 Internal and external factors

This section analyses the results in terms of internal and external factors. Internal factors are those factors that can be directly attributed to internal conditions in the company, or the group of companies, in question. The external factors consist of conditions that are important for the emergence and development of a symbiosis, but which the companies included in the symbiosis do not themselves possess.

The internal and external factors are further divided into enabling factors and hindering factors (i.e. challenges). These factors are summarised in Table 1.

	Enabling factors	Hindering factors
ECONOMY		
Internal	• Economic (more cost-effective to handle waste, share investments) • Business model (find new products and customers by being part of the value chain)	• Risk of losing focus on the core business • Traditional business model and mindset • Limited resources (time, money, workforce)
External	• Innovation support • Competitive and able to survive despite strict environmental regulations	• Unfair competition (different support systems in different countries) • High transport costs in case of long distances
ENVIRONMENTAL/TECHNOLOGICAL		
Internal	• Waste into resources • Share infrastructure and machinery	• Variations in quality or quantity of streams that need to be exchanged
External	• Environmental benefits • Active authorities create new markets through regulations	• Laws and regulations (complicated procedure, unclear terminologies)
SOCIAL		
Internal	• Technical expertise and experience • Easy to collaborate (trust) • Innovative and adaptable • Industrial symbiosis prioritised at the company's highest level	• Dependency/vulnerability • Enforced transparency and the risk of stealing of ideas • Lack of competence • Acceptability – residuals may seem "boring"
External	• Interest for green solutions • Willingness of other actors to cooperate	• Market is not "ready"

Table 1 Internal and external factors identified in the study

3.1.2 Comparison between literature review and interview study

The interviews have highlighted many points that were identified in the literature, indicating the credibility of both parts of this study. The interviews have helped to further clarify and provide examples to the statements mentioned in the literature. There have, nevertheless, been some deviations between the literature and interviews. In this sections we compare the literature review and interview study to emphasise the main findings.

Economic and environmental advantages

The interviews showcased that many of the companies view economic benefits as the greatest advantage of industrial symbiosis. The literature has mentioned many benefits of industrial symbiosis, however only one of the reports delved deeper into the prioritisation of these factors. The report from SYMBI project identified that environmental performance was perceived as the major success factor for industrial symbiosis. This contrasts with the result from the interviews putting economic revenue before environment. However, it should be noted that the SYMBI project analysed different types of companies, not just SMEs. An indication here is that SMEs might view economic benefits as crucial due to the limited resources in the companies, and therefore place higher importance to economic benefits

as compared to environmental benefits. Another pattern identified from the interview study is that the private companies have a focus towards economic gains whereas public companies tend to emphasise environmental gains. Regardless, it is quite clear from both the literature review and the interviews that improved economic and environmental results are given higher importance than social factors.

Social factors seem to be the strongest enablers of industrial symbiosis networks

The social factors are significant enablers for the formation of industrial symbiosis, as these were the most frequently mentioned in the interviews. When asked about the hindering factors, the absence of social factors was not identified as frequently, implying that they are probably easier to overcome. This relates to a suggestion from the literature that many industrial symbiosis networks have been a result of spontaneous interactions among closely located industries and were self-organised due to high mutual trust and long-term relations among actors.

On the other hand, in case of absence of such collaboration among the companies, facilitation by an intermediary, or regional authorities, could act as enablers in order to build trust among the participants. Regardless of how the network is formed, the opportunity to build network with other local companies has been identified as an advantage in both the literature and the interview study.

Both literature and interview results indicated that SMEs benefit by getting enhanced visibility. This was further elaborated in the interview by one of the respondents who mentioned that there was an increased interest from potential investors that occurred due to the company being a part of the industrial symbiosis network. Two of the respondents mentioned that industrial symbiosis allowed them to access new markets and customers, which again could be a result from increased visibility of the company. This opportunity of access to new revenue streams was also identified during the literature review.

Two opportunities related to social factors that were identified in the literature review did not come up during the interviews. These were job creation in the society and the increased acceptability of secondary raw materials. This is likely because these societal opportunities may be seen from the perspective of a third party such as citizens or local authorities, rather than from the engaged company's perspective.

3.1.3 Comparisons between regions and types of exchanges

More similarities among internal factors as compared to external factors across regions

A regional analysis based on the two regions (one with Finland, Poland and Russia and the second with Sweden, Denmark and Norway) shows that there are more similarities among internal factors as compared to external factors, which was expected. Respondents from both the regions identified technical expertise, possibility to share additional resources, economic and commercial advantages, and the willingness to innovate as enabling internal factors for participation in industrial symbiosis. The only common enabling external factor was environmental benefit. Regarding the challenges to participate in industrial symbiosis, both the regions identified dependency and the consequent vulnerability and transparency, conservative mindset within a company, and the risk of losing focus on

core business as internal challenges. The common external hindering factor identified by both the regions is complicated/long regulatory procedures.

For example, regarding the possibility to share other resources in addition to the exchange of streams, both the regions (one with Finland, Poland and Russia and the second with Sweden, Denmark and Norway) identified soft skills such as sharing of experiences as well as sharing of hard resources such as existing infrastructure and machinery. One of the respondents elaborated that this is highly relevant for SMEs since sharing of substantial infrastructure costs could give them a significant competitive economic advantage.

Both the regions mentioned challenges related to regulatory procedures, especially in terms of long time periods to obtain permits. Delving deeper into this, the respondents from Norway, Sweden and Denmark were more focused on how the regulations are formulated and interpreted. The respondents from Finland, Poland and Russia identified that instability in politics hinders them from long-term planning and that there is a lack of financial support for SMEs when going through the long regulatory procedures.

With reference to social factors, the acceptability of working with waste streams was identified as a challenge by the western region only, wherein one of the respondents mentioned that working with residual products *"can be perceived as boring and cumbersome".*

The differences between regions stated above are just examples that came up as a result of the 20 interviews conducted in this study. These findings are not necessarily possible to generalise, as the factors can sometimes vary within each region, or even within each company.

Technological factors are important for energy and water exchange

This project has considered three types of exchanges – materials, energy, and water. No major differences have been identified with reference to different types of exchanges. The literature mentioned that technical barriers plays a more important role in energy exchange in terms of the need to exchange resources within a limited geographical area or a lack of an economically feasible technology. During the interviews, one of the respondents mentioned that materials are easy to transport and therefore geographical location is not a challenge for material exchange.

The importance of geographical proximity for water exchange did not come up in either the literature or the interviews. However, it is likely that water exchange requires proximity due to high transport costs.

3.2 Digitalisation and public policy

As concluded in previous chapters, there are several enabling and hindering factors to establishing an industrial symbiosis network. In many cases, the hindering and enabling factors are also different sides of the same coin. When you have it, its enabling, when you do not have it, it is hindering. In that way they can be thought of as critical, or crucial, factors. They are important and by enhancing the access to them, to some companies this will be removing a hinder and to others it will be further enabling their business and operation. In this chapter the critical factors are discussed from the perspective of policy measures and digitalisation and how these can be used as keys to unlock the possibilities inherent in these critical factors.

3.2.1 Digitalisation

Digitalisation can be a key to enable resource-efficient analysis of the costs, benefits and environmental impact of the industrial symbiosis networks. As shown in previous chapters, the enabling factors in the economic dimension consist of cost-effectiveness and finding the right business model, which could be supported by using digital tools. On the other hand, the risk of losing focus on the core business is perceived as a challenge as it may be hard for SMEs to spare the resources needed for development of industrial symbiosis networks. The use of digitalisation in minimizing these challenges is well-established in both the literature review and the interviews.

The literature study also shows that digitalisation can contribute to business development by making the streams transparent. In turn, it makes it easier to trust the other parties involved and assess a fair redistribution of the benefits of the industrial symbiosis. None of the interviews shows this to be happening already. Instead they talk about using digitalisation to promote and enhance sales from the industrial symbiosis network, as well as analysing the benefits of their products for the individual customer (for example farmers), and give advice on even better ways to increase their production and minimise environmental impact (for example by crop rotation). By making the benefits tangible in this way, digitalisation opens the interfaces between the economic, social and environmental dimensions, strengthening the industrial symbiosis network as a business model and as a circular affair.

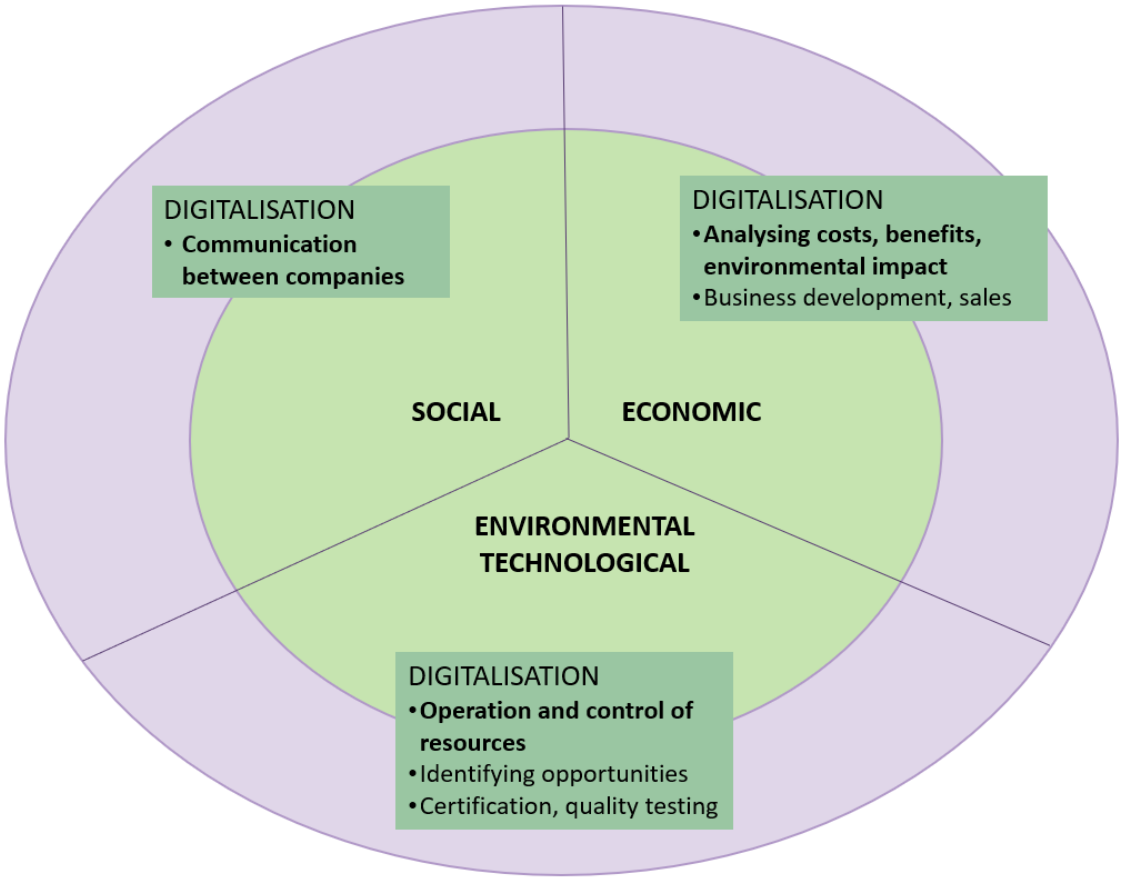

Figure 3. The possibilities of digitalisation to enhance industrial symbiosis networks from the economic, environmental/technological and social dimensions.

To open the interfaces between the social and the economic dimensions from the environmental side, digitalisation can contribute by optimising operation and control of resources, identifying opportunities and aid in quality testing and certification processes. This use of digitalisation is documented by the literature study and in the interviews as well. The operation and control of resources is one of the most common areas for digitalisation described during the interviews. But there are several companies that are discussing, or having recently started to use, digitalisation for identifying opportunities as well. The literature also describes certification and quality testing, but this is mainly seen as a future possibility during the interviews. These uses all have a clear environmental benefit but open the interface to the economic dimension by highlighting the economic opportunities and benefits of the industrial symbiosis network. They open the interface to the social dimension by creating tangible management information and transparent data that can be shared between the involved companies to build trust as a basis for collaboration.

The literature study provides several examples of how digitalisation can facilitate communication between companies to enhance networking, collaboration and co-creation. According to the interviews, this is still an area in need of maturing. The companies describe using regular office programs, web-meeting services, joint homepages and digital invoicing and in one case communication on a machine level between the companies. But many of the opportunities that digitalisation brings are yet undeveloped or used only in a rudimentary fashion. Our analysis shows that there is a gap between the possibilities of digitalisation mentioned in the literature review and the solutions used by the interviewed companies. This suggests that there is still untapped potential in furthering digitalisation, which could be important in creating, as well as maintaining an industrial symbiosis network. By facilitating communication, in which we include the sharing of data and knowledge, digitalisation can enhance trust, transparency and joint development of ideas, which opens the possibilities for creating an industrial symbiosis network. In this way, digitalisation opens the interfaces with the economic and environmental dimensions from the social side by facilitating communication.

3.2.2 Public policy measures

Like digitalisation, policy measures can open the interfaces between the economic, environmental and social dimensions. These policy measures are summarised in figure 4 and elaborated in the following paragraphs.

Public policy measures that target the economic dimension

Among the public policy initiatives described in the literature study, economic instruments and market creation are examples of policy measures that address the economic dimension. The literature study identifies several ways of funding, including tax reductions or subsidies to companies who establish industrial symbiosis networks, or penalties/bans on landfilling of certain types of waste. During the interviews, financial support is identified as one of the most popular policy suggestions, for example, as a support for the first customers to minimise the risks related to a new product. There are also respondents commenting on the need for monetary support to enter foreign markets and create a demand for a product or service that is new to that region. These are examples of what the respondents themselves regard as relevant policy suggestions from the economic side. That way they may open the interface with the environmental and social dimensions by making the industrial symbiosis network possible and/or economically attractive.

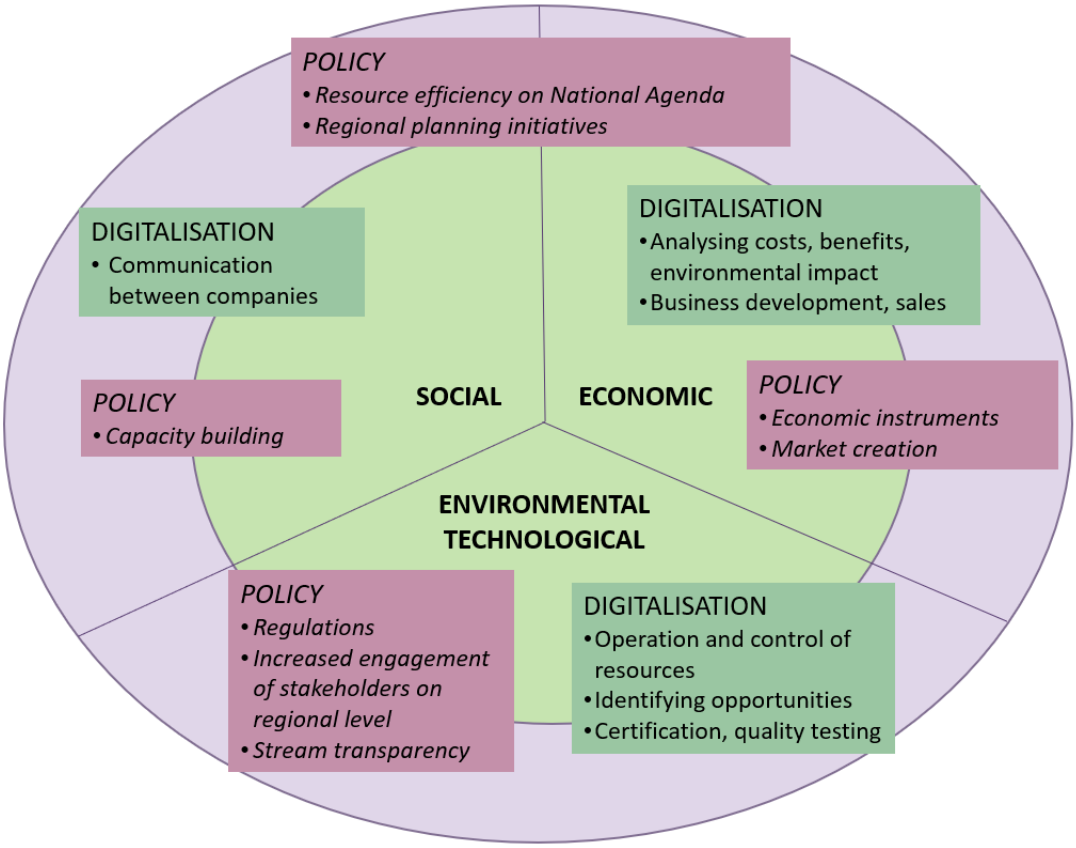

Figure 4. The possibilities of digitalisation to enhance industrial symbiosis networks from the economic, environmental/technological and social dimensions.

Policy measures that target the environmental dimension

From the environmental dimension policy measures are a key factor. According to the literature study policy measures can unlock the potential for industrial symbiosis by improving environmental regulation. A few examples include the enacting of 'end-of-waste' criteria to raise awareness in relevant industries of when waste materials can be treated as a product or a secondary raw material. During the interviews regulations and regulatory processes are identified as the main hindrance to establishing new industrial symbiosis networks. This means that a substantial supportive effect can arise from harmonising regulations between different countries, identifying and changing non-optimal regulations as well as easing different regulatory processes.

Another policy measures that pinpoints the environmental dimension is increased engagement of stakeholders on the regional level and support initiatives that further stream transparency. According to the literature study, policy can initiate and enhance industrial symbiosis networks by identifying industries that could potentially transform into an industrial symbiosis network and support existing innovation centres or third-party coordinating agents to aid such initiatives. However, this is not mentioned during the interviews.

The respondents instead talk about initiatives to further stream transparency and to facilitate the connection of waste materials with buyers. A couple of companies have already taken measures in this

direction, while others view it as a future potential. To open the interface with the economic and social dimensions from the environmental side, one potential policy measure is improved regulations. Other policy measures include initiatives to increase stream transparency as well as the engagement of stakeholders on the regional level. That is by making it lawful and administratively easy to cooperate in an industrial symbiosis network. These policy measures also build trust and networking possibilities. Another important factor is that they highlight the environmental and economic benefits of connecting existing industries in the region and their streams.

Policy measures that target the social dimension

The literature study shows the importance of building capacity for the establishing of industrial symbiosis by e.g. disseminating knowledge and raising awareness about industrial symbiosis networks. That is particularly relevant for SMEs since they have less opportunity to network and receive expert advice than larger companies. None of the interviewed companies mention this, probably since they already know enough to be a part of an industrial symbiosis network or are in the proximity of an established industrial symbiosis network. In other words, they are not part of the target group for such information, even though it may well be significant information for other companies.

There are however other measures that build capacity, for example matchmaking activities and the stimulation of pilot projects with innovative solutions. The latter being one of the policy measures mentioned in the interviews as well. These measures are examples of how to build capacity to trigger the establishment of industrial symbiosis networks. The common element is their focus on the social dimension, which in turns opens the interface to the economic and environmental dimensions. This is done by creating awareness and presenting an arena in which networking can take place and the first introductions and meetings between potential partners can occur.

Policy measures that target all dimensions simultaneously

Finally, there are a couple of policy measures that target all the dimensions simultaneously, but on a more strategic level. One is policies on the national level, for example by creating a national strategy on circular economy and resource efficiency, in which industrial symbiosis could play a part. Another policy measure that target all the dimensions simultaneously is to decree regional planning initiatives that accommodate the spaces needed for industrial symbiosis networks. A third policy measure is deciding on regional roadmaps to showcase that industrial symbiosis will remain on the national agenda, as well as generating market demand for streams that are present in the regional context. None of these measures are mentioned by the interviewees, who speak mostly of initiatives with quick and tangible results. Nevertheless, bringing resource efficiency to the national agenda and introducing regional planning initiatives can function as the underpinnings for all the other policy initiatives and therefore deserves to be mentioned as well.

3.3 Knowledge gaps

The following knowledge gaps were identified in this study:

- Investigation of the specific regulations that are hindering industrial symbiosis is required. For example:
    - Which grants and subsidies distort competition?
    - Which are enabling without distorting competition?
- More knowledge is needed within the companies about the potential benefits of digitalisation
- Knowledge among existing industry facilitating agents on the regional level as to which industries are potential candidates to enter or establish industrial symbiosis networks.

4 Conclusions and recommendations

Industrial symbiosis is one of the many solutions to the global challenges of sustainability and societal resilience. Industrial symbiosis is ideally formed in the intersection of social, environmental and economic dimensions. The establishment of industrial symbiosis networks is a step towards contributing to all the three dimensions of sustainability.

This report has analysed experiences of SMEs in relation to industrial symbiosis networks, and their views on the advantages, challenges and enabling factors to participate in such networks. This was carried out in two parts: a literature review and interviews with 20 selected SMEs. The focus of the study was SMEs in the industrial sector in the six countries involved in the Baltic Industrial Symbiosis project (Sweden, Norway, Denmark, Finland, Russia and Poland). The report presents an analysis of critical factors that are inherent to an industrial symbiosis network, that can enhance the participation of SMEs in these networks. In this context, public policy and digitalisation are key. Both can be used to further development and growth of industrial symbiosis networks, but in different ways. One key finding from this report is that public policy is described by the companies as mainly targeting external factors, while digitalisation primarily targets internal factors. The main conclusions of the report are summarised below:

- **Economic and environmental gains** are the main advantages for SMEs
    - The interview study showcased that many of the companies view economic benefits as the greatest advantage of industrial symbiosis. The literature has identified both economic and environmental gains as important advantages. In many cases the economic and environmental concerns pull in the same direction. When they do not, the interviews in this study suggest that to many SMEs economic gains are the main drivers.
- **Synergies, other than by-product exchanges**, are additional benefits of being part of an industrial symbiosis network, especially for SMEs. These synergies include:
    - Infrastructure synergies such as sharing of operational machinery
    - Knowledge synergies such as sharing key personnel and consultants as well as sharing knowledge of how to better deal with, for example, health and safety issues
    - Partnership synergies such as increased credibility and visibility through partnerships with larger, better-established firms
- The interviews as well as literature have identified that industrial symbiosis offers **new business opportunities** to SMEs in the following ways:
    - Achieving higher environmental targets enhances the company's green corporate image, leading to better credibility among the existing customer base and an opportunity to attract new customers
    - Development of new products and services allows extension of the customer base and a reach to new markets

- The global recognition of industrial symbiosis offers the possibility to gain visibility in an international environment thus helping the company to expand to new geographical markets.

- An interesting social benefit of industrial symbiosis identified in the report from SYMBI project is acceptability of secondary raw materials. For example, when one company utilises another company's waste as a raw material in its own process, this increases the acceptability of, and creates new markets for, secondary raw materials, thereby promoting sustainable choices in the society [6].

- Majority of the companies have not noticed any disadvantages of being part of an industrial symbiosis network. According to the companies that have experienced disadvantages, these consist of the increased interdependency between the companies and the enforced transparency.

- **Regulations and regulatory procedures have been identified as a significant challenge** for SMEs. For example, one respondent mentioned in the interview that big companies can accept long regulatory processes. SMEs, however, do not have resources for long waiting times. Differences in policy instruments between countries, for example, subsidies related to biogas, can distort competition.

- **The focus on core business and a lack of additional resources within an SME were identified as critical challenges for SMEs**. SMEs may not have the capability to invest their limited resources (in terms of time, money, or workforce) for development projects that lie outside their core business, especially if the project has a long payback period.

- Social factors are identified as some of the strongest enabling factors for an SME to participate in industrial symbiosis networks. These factors include:

    - Close collaboration and trust - It was highlighted that ongoing and well-established contact and trust between the companies makes it easier to exchange ideas between one another and reduces the risks related to transparency and interdependency

    - Presence of intermediaries/facilitators – Certain organisations such as innovation support organisations and active environmental authority in the region that could act as a catalyst to participate in industrial symbiosis networks

    - Culture and behaviour – A non-hierarchal decision-making structure, innovative mindset, industrial symbiosis as a priority at the top management level, and engaging employees were identified as promoters for establishment of industrial symbiosis networks

    - Technical expertise and experience - Knowledge about different types of waste streams and on conversion processes of waste to raw materials is important in order to establish new industrial symbiosis networks.

    - Societal awareness – Environmentally conscious customers are a driving force for companies to enhance their sustainability targets via establishment of industrial

symbiosis networks. Pressure from the supply chain can also act as a catalyst to improve efficiency and environmental performance especially for SMEs.

- Another significant enabling factor that would lead to establishment of industrial symbiosis networks is the **identification of possibilities for exchange of streams**. SMEs usually do not have resources to carry out a mapping of side streams and therefore projects that support match-making activities are important.

- The analysis shows **strong similarities in enabling and hindering factors across countries,** among the interviewed companies. Respondents identified technical expertise, the possibility to share additional resources, economic and environmental advantages, and the willingness to innovate as enabling factors for participation in industrial symbiosis. Regarding the challenges to participate in industrial symbiosis, in both regions the companies identified dependency and the consequent vulnerability, enforced transparency, a conservative mindset, the risk of losing focus on core business, and time-consuming regulatory procedure as challenges.

No major differences have been identified with reference to different types of exchanges i.e. material, energy and water. Technological factors nevertheless have been mentioned as more important for energy exchange, in terms of limitations of geographical distance.

- **Digital tools are used mostly for operation and control of resources**, according to the interviewed companies. There are further possibilities in digitalisation, especially in connection to identifying opportunities and developing new business models.

Based on the above conclusions, we give the following recommendations to the policy makers and public agencies in the countries around the Baltic Sea region:

- **Continue collaboration** between the countries in the Baltic Sea Region in order to strengthen industrial symbiosis. This is recommended because the analysis in this report shows strong similarities in enabling and hindering factors across countries.

- **Emphasise resource efficiency at the national level** in order to stimulate regional actors to take actions towards creation and expansion of industrial symbiosis networks.

- **Promote regional networking activities among various stakeholders** of industrial symbiosis including, for example, intermediary organisations and potential investors, in order to strengthen the entire value chain.

- **Promote local networking activities for industrial sites located close to each other** in order to build trust among the companies. It was identified from the literature review that industrial symbiosis networks that have been a result of spontaneous interactions among closely located industries have shown resilience and adaptability over time. This was due to high mutual trust and long-term relations among actors. It is recommended to also promote networking opportunities that might not directly target industrial symbiosis networking, in order to build mutual trust among organisations.

- **Continue supporting development projects that further resource efficiency and environmental sustainability among SMEs** in the Baltic Sea Region. As identified in the

conclusions above, SMEs face a lack of resources to invest into development projects, and identification of possibilities for exchange of streams is a significant factor for enabling participation of SMEs in industrial symbiosis networks.

- **Provide economic support for introduction of new products** on the market, through funding mechanisms for either the supplier or the customer. Market studies to link companies and customers was also suggested during the interviews.

- **Spread knowledge about the benefits of digitalisation** to facilitate the identification of further possibilities, especially the role of digitalisation in connection to identifying new opportunities and developing new business models.

- **Investigate which policies, regulations, grants and subsidies that are most urgent to harmonise across regions, nations and the European Union** in order to minimise the barriers related to differences in regulations between countries and enable fair competition, e.g. subsidies in the production of biogas.

- **Investigate which specific regulations and regulatory procedures are hindering** formation of industrial symbiosis networks. The report has recognised that complicated, or long regulatory procedures are a significant challenge for SMEs, however identification of specific regulations and how to adapt them in order to make it easier for SMEs is beyond the scope of this report. We therefore recommend a further in-depth analysis to identify which regulations are perceived as complicated, and how to ease the procedures.

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Reference numbers 16-42 in the list below have been used in the literature review, the results of which are reported in Section 2.1. The other references have been used in the background chapter on industrial symbiosis.

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Annex 1. Keywords for literature study

The proposed keywords for the literature study were categorised into different themes as per the scope of the study and are summarised below. These keywords were used in different combinations during the search.

THEME	KEYWORDS
Industrial Symbiosis	Industrial symbiosis
	Industrial ecology
	Eco-industrial park
	By-product synergy
	Industrial ecosystem
	Resource synergy
	Cluster
	Circular Economy
	Waste/recycling Network
Barriers, Drivers and Conditions	Conditions
	Drivers
	Benefits
	Enablers
	Motivations
	Opportunities
	Business model
Policy	Policy
	Instruments
	Support
	Incentives
	Enablers
	Political implication
	Directive
	Recommendations
Digitalisation	Digitalisation
	Digitalization
	Smart
	Data-driven
	Tool
	Application
	Platform
	Big-Data
	IOT
	Matching
	Sensors
	Visibility
SMEs	Strategy
	Market
	Inclusion
	Connectedness
	Business Model
	SME
	Small and medium size
	scale

Since the reports were identified using both keywords as well as snowball methodology simultaneously, not all the proposed keywords were used during the search as enough relevant material had been found in the identified reports. The keywords that were used are: industrial symbiosis, small and medium size, SME, digitalization, digitalisation, manufacturing, barrier, driver, business model(s). In addition to the proposed keywords mentioned above, the country names were also used as keywords: Sweden, Norway, Denmark, Finland, Russia and Poland.

Annex 2. Interview guides

Interview guide for companies within an existing collaboration

My name is [..] and I work at […]. On behalf of Swedish Agency for Economic and Regional Growth, we are conducting a project on Industrial symbiosis in the Baltic region […]. The aim of our assignment is to identify the opportunities and challenges for small and medium sized companies to be a part of a symbiosis network.

The purpose of this interview study is to increase knowledge of what is required for increasing the circularity of companies' energy, water and material streams and business models. A total of about 20 companies will be interviewed. The answers from the interviews will be analysed and presented anonymously in a report.

Definition of environmental, economic and social factors used in this study:

- **Environmental and technological** (Includes production processes, feedstock, transports, by-products, waste products and the natural prerequisites of the location of the companies and their surrounding).
- **Economic** (Includes business models, investments, costumers, regulations and costs for alternative resource management of the flows in the collaboration. Factors which provide the conditions for how the companies chose to conduct their business.)
- **Social factors** (Include available competences within the companies and the surrounding, culture and behaviour, experience and capability to collaborate within the companies, within the symbiosis and other stakeholder in the society which the symbiosis are or could be dependent on.)

Date:
Company:
Country and city:
Name of industrial symbiosis:
Name and role of the interviewee:
Interview made by:

Firstly, do you agree to record the interview? We will not quote unless we check that its ok/that the person agree to be mentioned

Background questions

1. What role do you have in the company?
2. When and how did the collaboration start and who initiated it?
3. What were the greatest incentives to establish the symbiosis (environmentally, economically, socially)?
4. What is your company's contribution in the industrial symbiosis (water, energy, materials; other). What do you receive from the others?
   Are there opportunities for further collaboration within or around the cluster? What would be the driving forces (environmentally, economically, socially)

Results

5. What are the greatest advantages being a part of the industrial symbiosis (environmentally, economically, socially)?
6. Are there any disadvantages? (environmentally, economically, socially)?

7. Do you use goals and indicators to measure the results (environmentally, economically, socially)?

Resource distribution and business

8. Do you use digital tools to facilitate collaboration and resource exchange in the symbiosis? If Yes, please tell me more about that tool and the purpose of it (examples a-g)
    a. identifying opportunities (for example matching of input and output)
    b. analysing costs and benefits, environmental impact or
    c. operation and control of resources (i.e. sensors, process control etc.)
    d. business development
    e. organisation of the company
    f. communication between companies
    g. Other?
9. Do you see further possibilities to use digital tools to contribute and benefit from the symbiosis (see examples a-g above)?
10. Does your company make new business and revenues because the circulation of resources? (New products, new services, new processes and new ways to price them)
11. Do you see further possibilities to make new business and revenues in the symbiosis?

Enabling and hindering factors

12. Could you mention factors strongly enabling your contribution to and benefit from the symbiosis
    a. Factors within your own company
    b. Factors in other companies in the symbiosis
13. Could you mention factors strongly hindering your contribution to and benefit from the symbiosis
    a. Factors within your own company
    b. Factors in other companies in the symbiosis
14. According to your experience, are the factors depending on the company's size, and the maturity of the symbiosis?
15. What kind of support or incentives, if any, would be of use to you to facilitate further collaboration and innovation among the companies in the symbiosis? (E.g. capacity building, financial support, policy, regulation etc)
16. How would you prefer to get access to those supports or incentives?
    a. From your own company
    b. From other companies in the symbiosis
    c. From other actors in the society

Summing up

17. Would you like to add something which you consider being important in the context of industrial symbiosis?

Thank you for your time!

Interview guide for companies not yet in a collaboration

My name is [...] and I work at [...]. On behalf of Swedish Agency for Economic and Regional Growth, we are conducting a project on Industrial symbiosis in the Baltic region […]. The aim of our assignment is to identify the opportunities and challenges for small and medium sized companies to be a part of a symbiosis network.

The purpose of this interview study is to increase knowledge of what is required for increasing the circularity of companies' energy, water and material streams and business models. A total of about 20 companies will be interviewed. The answers from the interviews will be analysed and presented anonymously in a report. However, we plan to include a list of the interviewees' respective positions and organisational category in the report.

Definition of environmental, economic and social factors used in this study:

- **Environmental and technological** (Includes production processes, feedstock, transports, by-products, waste products and the natural prerequisites of the location of the companies and their surrounding).
- **Economic** (Includes business models, investments, costumers, regulations and costs for alternative resource management of the flows in the collaboration. Factors which provide the conditions for how the companies chose to conduct their business.)
- **Social factors** (Include available competences within the companies and the surrounding, culture and behaviour, experience and capability to collaborate within the companies, within the symbiosis and other stakeholder in the society which the symbiosis are or could be dependent on.)

Date:
Company:
Country and city:
Name of industrial symbiosis:
Name and role of the interviewee:
Interview made by:

Firstly, do you agree to record the interview? We will not quote unless we check that its ok/that the person agree to be mentioned

Background questions

1. What role do you have in the company?
2. What flows in your company could be of interest to exchange with other industries? (water, energy, materials, other)
3. Have there been discussions about collaborating with other companies about water, energy and/or material?
4. If yes, when and how were the discussions initiated?
5. What would be the greatest incentives to be part of an industrial symbiosis (environmentally, economically, socially)?
6. Could there be any disadvantages? (environmentally, economically, socially)?

Resource distribution and business

7. Do you see possibilities to use digital tools to contribute and benefit from an industrial symbiosis (see examples a-g above)? If Yes, please tell me more about that tool and the purpose of it (examples a-g)
    a. identifying opportunities (for example matching of input and output)
    b. analysing costs and benefits, environmental impact or

c. operation and control of resources (i.e. sensors, process control etc.)
d. business development
e. organisation of the company
f. communication between companies
g. Other?

8. For your company, would a collaboration bring with it new business and money because the circulation of resources? (New products, new services, new processes and new ways to price them)

Enabling and hindering factors

9. Could you mention factors that could strongly enable your contribution to and benefit from an industrial symbiosis
    a. Factors within your own company
    b. Factors in other companies in the symbiosis
10. Could you mention factors that could strongly hinder your contribution to and benefit from the symbiosis
    a. Factors within your own company
    b. Factors in other companies in the symbiosis
11. Could the impact of the factors mentioned differ depending on the company's size?
12. What kind of support or incentives, if any, would be of use to you to facilitate collaboration in an industrial symbiosis? (E.g. capacity building, financial support, policy, regulation etc).
13. How would you prefer to get access to those supports or incentives?
    a. From your own company
    b. From other companies in the potential symbiosis
    c. From other actors in the society

Summing up

14. Would you like to add something which you consider being important in the context of industrial symbiosis?

Thank you for your time!