

Industrial Symbiosis - an end or a means?

State of Art in the Baltic Sea Region

Alberto Giacometti, Maija Kāle & Anna Berlina



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Preface

Commissioned by the Ministry of Agriculture of the Republic of Lithuania, this report contributes to the implementation of the EUSBSR PA Bioeconomy. The aim is to illustrate how 'Industrial Symbiosis' (IS) can be a useful concept and model to accelerate the transition towards the green and circular economy. As point of departure this report poses the question: 'why industrial symbiosis'? To answer it, the concept is unwrapped in connection to related concepts such as circular economy, green economy and valorisation. Furthermore, the report presents a snapshot of development of industrial symbiosis in the Baltic Sea Region (BSR), followed by more in-depth case studies in selected regions. The report, then, provides conclusions reflecting on the key factors that play a role in forging symbiotic connections between relevant stakeholders, and ends with a list of recommendations.

1. Introduction

Why Industrial Symbiosis? What's the point? Industrial Symbiosis (IS) is a collaborative or collective approach to resource management (Mirata 2018). IS serves as a *means* to achieve '*Circular Economy*' and '*Green Economy*' (*ends*) by creating synergistic relations between industries to exchange materials, energy, water and other by-products (Chertow 2000, p. 314). As follows we break down these different concepts to shed some light onto how they differ and in what ways they are interrelated.

The concept Circular Economy was first formalised by Pearce & Turner (1990) drawing on the principle that "everything is an input to everything else". '*Circularity*' implies moving away from a linear model of resource utilisation: extraction – production – consumption – disposal, to a circular model or closed-loop system, which minimises waste and the utilisation of virgin resources and maximises their lifespan via reusing, repairing, refurbishing, and recycling. The bottom line is that resources are limited and that human consumption patterns come with a heavy cost to the natural environment and threaten the survival of society in the long-term. Now, the wicked problem lies in the question of how to reduce resource utilisation without harming the economy or even enabling economic prosperity. From this question stem concepts of *circular economy*, *green growth*, *green economy* and *green transition*, all of which entailing a broader transformation of the social, economic, institutional, and technological systems to meet the principles of circularity.

The quest of transiting onto a green economy demands de-coupling economic growth (value creation) from resource utilisation. A central way to do this is via '*valorisation*' of resources (including waste-streams), which means capturing the highest possible value per every unit of 'X resource'. Waste-to-energy is perhaps the simplest way to give value to waste (or resource); however, it is also the lowest possible value extracted and the quickest path to end resources lifespan. For illustration, the 'bio-pyramid' in Figure 1 shows how the more complex the product extracted from a resource is, biomass in this case, the higher its value and the lower the volume needed. Variations of this commonly used pyramid scheme set a hierarchy of the economic value of different applications of biomass, as well as the chain of applications that can be given to residuals at any step of the ladder.

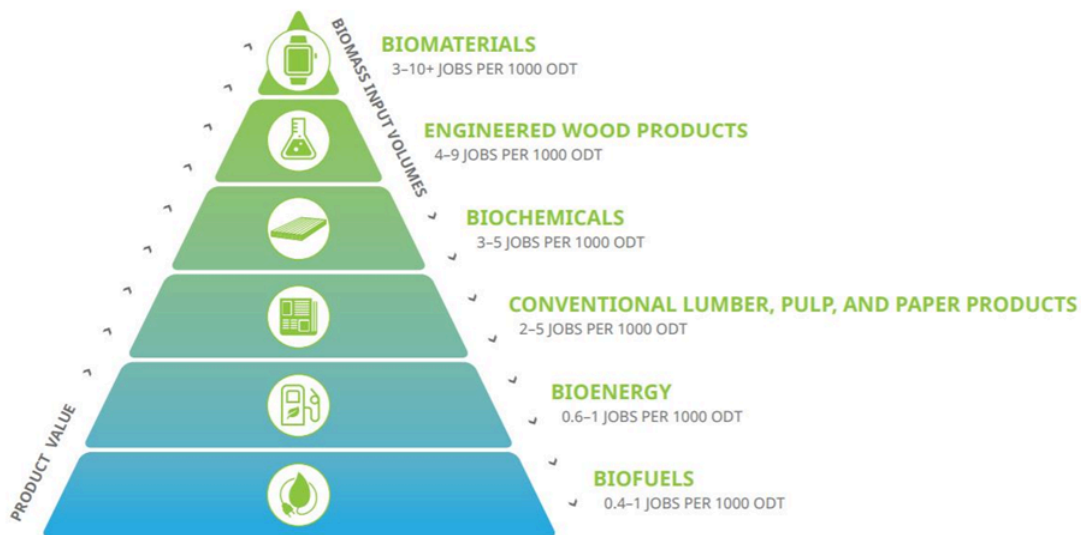


Figure 1: Bioeconomy valorisation pyramid. Source: Government of British Columbia 2024

Besides the additional profits that producing more complex products generates, Figure 1 also shows the spillover effects generated to the broader economy in terms of jobs. In this case, estimations made for the forest bioeconomy in Canada, more advanced product categories generate higher number of jobs. Biofuels create fewer jobs as they require the least value-added processing, whereas biomaterials, engineered wood products used in construction sector, and biochemicals generate the highest number of jobs in relation to volume of biomass needed to produce them (Government of British Columbia, 2024). Furthermore, it can be assumed that the jobs created in more complex processing industries are also better paid than in low complex industries, generating further trickle-down benefits for the host economy.

This shows in practical terms how valorisation can help de-coupling economic growth from resource utilisation. Moreover, valorising biological resources (biomass) is also a way to replace the use of non-renewable fossil and mineral-based resources, such as fuels, plastics, glues, chemicals, etc. A key focus is therefore placed on the potential of the bioeconomy in simultaneously driving the circular economy and replacing fossil fuels.

Resource flows, value chains, and industrial symbiosis

Despite the elegance of resource pyramid schemes, the practical implementation is far from simple. The production of biofuels, for example, requires different skills, knowledge, technologies, industrial processes and capacities than those required to produce biochemicals or biomaterials. In essence, they are different industries. Therefore, business ecosystems and value chains need to be arranged in such a way that the flow of material and human resources is possible (as in practically and economically viable) between different industrial facilities and uses (markets). This calls for innovative business models and institutional arrangements to create new relationships between companies, authorities, consumers and a broad range of intermediaries, such as universities, institutes, incubators, financiers, etc.

Valorisation of resources is not necessarily bound to symbiotic relations between companies. Indeed, it is vastly common that the use of residues and side-streams of resources are reutilised and repurposed within companies themselves, or within a company/corporate group. This, however, requires companies to build up capacity in industrial processes, develop products, and explore markets beyond their core or original business. This may be desired as a strategy for the company to maximise profits with their available resources, reduce their environmental footprint or simply to retain control over the value chain. However, it can also be the result of a missing link in the supply chain. A company may not be able to identify an external partner willing to fulfil the complementary function needed for them to pass on their side-streams or products further, and as result assume that new responsibility internally. One complex example of this is Martinsons, a company based in north Sweden, which started in 1939 as a sawmill and later began producing engineered wood materials. When regulatory reforms in 1995 opened a window of opportunity to build multi-story buildings made of wood, Martinsons faced a hesitant response of construction companies, developers and financiers. As a result, the company bypassed existing business ecosystems by creating its own construction and design company (Giacometti et al., 2024). More recently, Martinsons was acquired by Holm, a forestry company, capturing even more segments of the value chain under a single roof (ibid.).

However, in many other cases valorisation occurs via resource flows between different companies and users. This may occur either via simple business transactions: Company A purchases the residue resources from Company B, or via more formal co-operation between mutually beneficial arrangements. Hence the term 'symbiosis'. The bottom line is that IS is not limited to a transaction but is characterised by a deeper form of co-operation and sometimes co-dependence between firms. Co-operation and co-dependence delivers additional benefits than the sum of their independent activities. In simple terms: '1 + 1 = 3'. Resource flows under symbiotic relations may or may not occur between geographically proximate 'partners', however, the concept of IS is generally used when firms are closely co-located, either within industrial parks or at regional level (Paquin 2009).

Now, IS can exist on mutual accord between two or more companies, or it can be facilitated and coordinated by an umbrella entity. For instance, the IS networks in Kalundborg, Denmark and those in Norrköping, Helsingborg, Stenungsund, and Örnsköldsvik in Sweden emerged spontaneously in a self-organising form in response to identified opportunities for interaction and material exchange (Mirata 2018). In these cases, supporting structures framing the collaboration came afterwards to facilitate further development. In contrast, the Rotterdam harbour complex or the Sotenäs symbiosis network in Sweden emerged by means of external facilitation (ibid.). The coordinating entity can be some kind of 'eco-industrial park', a cluster organisation, or in several cases a local or regional authority. Often, the initiative starts in the form of a project and then evolves into a self-sustaining business-led association. Depending on the specific arrangement, the coordinating entity may be tasked with facilitating dialogue, assisting in the discovery process of synergistic opportunities (e.g., mapping material and energy inputs and outputs), identifying the possible steps ahead, and addressing the practical and legal challenges to establish symbiotic ties.

Besides increasing resource productivity, IS has a political and social significance due to its efficacy in closing the resource loop and cutting the ecological footprint of industry. Therefore, IS initiatives tend to involve a series of other actors besides firms. Authorities at multiple levels and across sectors, incubators, universities, finance entities, among others are often involved. The intensity of involvement is typically boosted with the sponsorship of funds aimed for R&D, competitiveness, regional development, structural change, or supporting sustainability transitions. These may come from national, EU programmes, as well from private and other external funders. Moreover, municipalities are incentivised by their own strategies and goals which have generally incorporated a path towards meeting the Agenda 2030. Thus, municipalities have become increasingly interested in leading the establishment of IS ventures and are often partners themselves via their municipally owned waste management companies, as investors in biogas plants, or as buyers of biofuels in their local public transport services and other procured goods. Therefore, IS tends to evolve around complex co-operation arrangements.

2. Industrial Symbiosis in the Baltic Sea Region

The number of cases of IS and degree of maturity varies significantly across countries and initiatives in the Baltic Sea Region (BSR). Some of the older IS co-operations are Kalundborg Symbiosis in Denmark, Svartsengi Resource Park in Iceland, and Händelö IS in Sweden, established in 1959, 1976, and in the 1990s respectively. Some of the most common resources exchanged are excess gas or heat, wastewater and biomass, and often they also share infrastructure. Yet, depending on the specific industrial composition of the network, the possibilities for exchange are vast. For instance, sulphur fertiliser, ash, metals, CO₂, and so on. These well-known cases have inspired new IS ventures in many regions in varying scale and with different business and institutional arrangements. These have also inspired many projects and policy support mechanisms to foster IS amongst business circles and regional networks.

In some countries, IS has been explicitly promoted nationally, such as the Green Symbiosis programme by the Danish Business Authority and the SITRA National Roadmap for Circular Economy in Finland (Johnsen et al., 2015). The Finnish Industrial Symbiosis model (FISS) is a network created to support coordination efforts, which can be funded by the Ministry of Economic Affairs and Employment of Finland (Järvenpää et al., 2021). On the other hand, in Sweden, Norway and Iceland, the development of IS has taken place in a more bottom-up process and is implicitly supported in a variety of different policy programmes (Johnsen et al., 2015). However, the most decisive efforts have been facilitated by local and regional networks in close co-operation between authorities and universities, cluster associations, green development hubs among others (Moodie et al., 2019). For instance, Sweden is home to a relatively large number of operational IS cases and networks (Mirata 2018) despite lacking a national strategy for IS.

In Baltic countries, different concepts fostering circularity have gained traction in policy and business arenas. Whilst IS has become a popular and commonly used concept in Lithuania, 'bioeconomy' or 'circular economy' are the preferred terms by authorities in Latvia and Estonia. Besides the influence of EU and internationally funded projects, this may denote a clear difference in the economic structure between the three countries. Lithuania is the most industrialised economy among the three countries, with a significant presence of large-scale manufacturing and processing industries. Estonia and Latvia have a smaller industrial sector where manufacturing and processing industries are not as prominent and tend to be smaller in scale. This partly explains why there are no complex cases of IS in the Baltic states, so far. Yet, many examples of valorisation and closed loop system solutions exist but are more commonly found within individual companies without engaging in co-operation with third actors. This means that companies improve resource efficiency internally by giving side-streams new uses and entering new business areas. The governance and institutional arrangements also play a role, as in the Baltic countries,

government functions are significantly more centralised and sub-national government tiers have fewer tools at their disposal to support business and industrial development.

We explore the state of the art in the three Baltic States as follows.

2.1 Estonia

Although IS is not entirely new to Estonia, with some ventures dating back to the Soviet era (see Photo 1) residuals from bioresources is still limited (BioBaltic 2022a), occurring sporadically and with a narrow scope across the country. Existing examples include repurposing residual malt from breweries as animal feed and using wood residues from the wood and furniture industries for pellet production. Moreover, there is currently no co-ordinated national strategy or support schemes to foster IS (Interview 1).



Photo 1: Tallinn Fish Farm in the residual warm water from the Baltic Power Plant in 1979. Source: [Eesti Teadeteagentuur AS \(AIS\)](#)

A *White Paper on the Circular Economy* was published by the Ministry of the Environment and the Environmental Agency in 2022, which sets the vision and developmental goals for

circular economy in Estonia. The White Paper identifies key challenges in promoting circular economy in Estonia, including insufficient co-operation among stakeholders, unclear responsibilities, low environmental awareness, a shortage of experts, and a lack of innovative sustainable solutions. It sets out six priorities to promote circular economy, focusing on responsible resource use, sustainable business models, and minimised waste. The paper envisions Estonia as having strong expertise and cross-sector collaboration in circular economy, bolstered by effective digital solutions and comprehensive data monitoring, along with robust national coordination and supportive legal frameworks (Ministry of the Environment of Estonia 2022).

In 2023, the Ministry of Regional Affairs and Agriculture published a *National Circular Bioeconomy Roadmap*, highlighting IS as a key approach to fostering innovative initiatives and new forms of co-operation (p.9). The roadmap emphasises the need to enhance the valorisation of bio-resources to generate higher added value from biomass. It underscores that "the most efficient valorisation of biomass is achieved not through the perspective of a single company, but through cross-sectoral co-operation among companies and value chains, following the principles of industrial symbiosis and cascading use". Furthermore, it stresses that the broader development of IS requires systematic coordination and oversight by the state, alongside active participation from primary sector entrepreneurs in establishing new value chains (Ministry of Regional Affairs and Agriculture of Estonia 2023:11).

"*Estonia 2035*" is a national long-term development strategy adopted by the Riigikogu (the Parliament of Estonia) in 2021. It outlines strategic goals for the state and the people of Estonia until 2035 and identifies the necessary changes to achieve these goals. The strategy aims to integrate circular economy principles, highlighting the need for enterprises to enhance resource efficiency—such as through IS (p. 24). It also points out that resource productivity in Estonia is relatively low (EUR 0.56 per kg in 2017). To address this, the strategy calls for a stronger focus on eco-friendly technologies, sustainable business models, and improved, greener valorisation of local resources and secondary raw materials (Riigikogu 2021:9).

The *Estonian Research, Development, Innovation, and Entrepreneurship* (RDIE) Strategy identifies the increased valorisation of local resources—including secondary raw materials, waste, and food resources—as one of its five key focus areas (Ministry of Education and Research, 2022). Aligning with this national objective, the Estonian State Forest Management Centre (RMK) has outlined plans in its 2024–2028 development strategy to enhance domestic processing and create higher-value products by promoting the chemical valorisation of local wood (Baltic News 2024).

Recent efforts to enhance knowledge and awareness of circular economy principles and IS include the "*Initiating Industrial Symbiosis in Estonian Counties*" programme running throughout 2024. Launched by the Estonian Business Innovation Agency (Enterprise Estonia) and Kredex, and supported by County Development Centres, this initiative seeks to encourage and assist companies in establishing IS networks and foster a culture of co-operation and trust among businesses. It represents an initial step towards identifying potential challenges, including regulatory and logistical issues, to effectively facilitate IS ventures. Included in the initiative, are informational and awareness-raising activities,

along with two months of mentorship support for companies committed to “testing potential symbiosis in the regions.” The program targets businesses in Viljandi, Järva, Pärnu, and Harju Counties. A project report, to be published in January 2025, will present an analysis of the enablers, barriers, and motivations for IS. It will also offer recommendations to the government to support and enhance the development of IS across Estonia (Enterprise Estonia 2024).

While no functional examples of IS exist in Estonia today, this report describes a concept for the Estonian Industrial Symbiosis Agropark in section 3.4, which presents valuable insights gained during its development process. Additionally, the Paldiski city region is highlighted as a promising area for future IS initiatives. It is home to Estonia’s first long-duration energy storage system, a 500 MW facility located 750 meters below Paldiski Bay, is set to begin operations in 2029 and aims for commissioning by 2031. This project employs pumped hydro-storage technology adapted to zero terrain, providing affordable and reliable renewable energy and bolstering the electricity grid (Zero Terrain, n.d.). This underground renewable energy storage initiative also includes a port, railroads, wind and solar energy sources, and an LNG terminal. Additionally, the area holds potential for underground data centers, warehouses, and other enterprises.

Concluding remarks

With roughly 1.3 million inhabitants, Estonia’s small-scale economy is particularly affected by geopolitical tensions, political, and economic instability. At the same time, the country possesses a strong foundation in primary production across its agriculture, forestry, and marine sectors.

Various stakeholders in Estonia are keen to advance these sectors up the value chain into secondary and tertiary production, aiming to generate higher added value from bio-resources. However, despite these efforts, the valorisation of by-products or residuals from these bio-resources is still underdeveloped (BioBaltic 2022a). This shortfall is partly due to insufficient support for transforming bioresources into higher value-added products. A significant challenge is the fragmented management of biological resources, with responsibilities divided across various ministries, resulting in multiple uncoordinated efforts and strategies (BioBaltic 2022a). Given the limited power and mandate of sub-national authorities, it is crucial for central governments to take on a stronger co-ordinating role and provide financial support to boost know-how and investment in circular business models.

Further challenges to Estonia’s development of innovative bio-based products and IS activities include limited investments in R&D by both private companies and public entities. Additionally, regulatory barriers pose central obstacles to facilitating IS and limit the potential for resource valorisation, as highlighted by interviewees (Interview 1 and Interview 2). For example, high land-use taxes and environmental fees undermine the economic viability of developing large industrial parks. To unlock future opportunities for residue valorisation and enhance IS, Estonia should address challenges related to developing capabilities within the labour market and business community (BioBaltic 2022a). Moreover, there is a need to increase awareness among businesses about the actual possibilities of IS.

Despite these challenges, there are several positive factors that can drive innovation in Estonia. The country boasts a robust startup community and strong consumer support for local products, which are crucial for fostering a vibrant innovation ecosystem. Furthermore, cultivating a shared understanding of IS, its opportunities, challenges, and regulatory obstacles is an important step in fostering effective discussions, encouraging collaborative efforts and promoting the advancement of IS in Estonia (Interview 1).

2.2 Latvia

The term 'industrial symbiosis' is used by a select group of experts in Latvia who are involved in EU-funded projects related to this topic. The term is not widely used in business circles, however. IS is translated to Latvian in two different ways: '*industriālā simbioze*' and '*rūpnieciskā simbioze*' but is rare to find either of them in academic publications in relation to Latvia. However, this does not mean that IS does not exist in the country, but rather that other terminology is used, such as waste utilisation or valorisation of side-streams. The most suitable point of entry for discovering IS in Latvia would be the *LIFE "Waste to Resources IP"* project, which was initiated in 2022 by the Ministry of Environmental Protection and Regional Development of Latvia (now the Ministry of Smart Administration and Regional Development) and overtaken by newly established Ministry of Climate and Energy in 2023 (Interview 4). The project unites 22 partners and has established a platform called '*Sinergia*' with the goal of fostering IS in Latvia.^[1] The platform offers opportunities networking, workshops, support for resource mapping, and technical expertise, helping businesses identify synergies that align with EU policies. It also focuses on reducing waste generation and promoting circular economy principles in line with the *National Waste Management Plan 2021-2028*. The project encourages IS via increasing and innovative technologies to transform waste from one company into valuable raw materials for another. The project supports eco-innovation and provides opportunities for start-ups, SMEs, and larger enterprises to enhance resource sustainability and waste reduction (*Par projektu - Sinergia*, 2023).

The *Circular Economy Roadmap* (CE Roadmap – published in 2024) provides strategies for optimising resource utilisation and reflects the transition from a linear consumption model, characterised by the 'take, make, dispose' approach, to a circular economy, where product and material value is preserved. The approach is phased and provides practical examples for the public, private and non-governmental sectors. These examples are largely based on the results of the LIFE project, '*From Waste to Resources*'. Moreover, the CE Roadmap offers insight into the present state of material consumption and productivity in Latvia. While Latvia's domestic material consumption per capita was 14.8 tons in 2022, which aligns with the EU average, its resource productivity remained low, fluctuating around 0.9 EUR/kg compared to the EU average of 2 EUR/kg (*CE Roadmap*, 2024). This indicated inefficient use of natural resources in the economy and the lack of de-coupling between material consumption and economic growth.

1. <https://sinergia.lv/>, last retrieved on 09.12.2024

The *National Development Plan* (NAP) of Latvia places considerable emphasis on economic transformation through the implementation of the "*EU Green Deal*," which advocates for the advancement of circular economy principles across manufacturing and service sectors. The objectives set out in the NAP are to facilitate the adoption of eco-efficient technologies, eco-design practices and intersectoral IS, with a particular focus on the regional level. While the NAP indicates some funding from the Cohesion Fund earmarked for the implementation of IS at the regional level under the support scheme "*Local Government Development for Business Promotion*", with the aim of developing a regional symbiosis model (*Action Plan to CE*, 2020), field experts mention that there has been no budget funding to advance green deal in IS area (Interview 4).

Despite the lack of explicit IS pilots in Latvia, research shows that while valorisation in Latvia often occur in isolation, some by-product exchanges could be considered examples of 'industrial synergies', especially in the forestry and food sectors. Rosa & Beloborodko (2015) define 'industrial synergy' as industrial by-product exchange between any two companies in contrast to more complex networks of industrial collaboration regarded as "industrial symbiosis". Almost 10 years after that study, similar examples are listed on the 'Sinergia' homepage, focusing on the reuse of brewers' spent grains (BSG) by the regional brewery Valmiermuiža. The brewery produces about 500 kg of BSG for every 2,000 litres of beer brewed. To minimise waste, the brewery donates the spent grains to local farmers, such as the 'Zilūži' farm, as animal feed, which increases milk production due to its high protein content. Some brewer's grains are also used in unique products such as "drabiņu cepumi" (brewer's grains biscuits) made by a local bakery (*Existing Symbiosis*, 2023). Apart from this example, other listed cases by Sinergia are more focused on biogas production. However, most of these activities take place within individual companies, without much involvement of external stakeholders, and thus do not fall under the definition of IS. This confirms previous research showing a quest from companies towards increased valorisation of side-streams, but so far this occurs with little or no co-operation with entities outside their own structures. However, the example of Balticovo (Box 1) shows how initial steps towards valorisation can lead to more advanced initiatives involving other players along the value chain.

Box 1: Biomethane production from chicken manure in Balticovo

JSC Balticovo is a 100% Latvian capital company producing eggs and derivate products since 1972. In 2008 Balticovo invested 5 million euros to build a biogas production plant that produces biogas from chicken manure. Since then, Balticovo has used biogas to generate electricity and heat, with the electricity being sold by its subsidiary to traders on the stock exchange. The heat generated is used in technological processes that facilitated biogas production and the production of high-quality granulated organic fertiliser (Interview 3).

As a next step, Balticovo invested 7 million euros and built a biomethane plant in 2023 to refine and separate the biomethane which is equal to natural gas. The biomethane produced at the new "Bovogas" plant, where biogas is purified to natural gas quality, is transported to adjacent gas pipe in partnership with AS "Conexus Baltic Grid" and "GASO" - the gas infrastructure providers in Latvia. Approximately 17 000 MWh are released into gas grid per year. Producing biomethane from chicken manure required complex scientific research, as a share of poultry feed and manure contains calcium, which is undesirable in biomethane production. After substantial R&D efforts, the company managed to separate calcium from manure. This innovation has been the key to biomethane production from chicken manure. Without any external support nor funding, Balticovo has enhanced locally developed technologies and established Latvia's first connection for introducing biometane into the interconnected gas system (Interview 3).

Biomethane production from chicken manure represents a case of valorisation and IS, as the collaboration can take place due to the proximity of the gas infrastructure to Balticovo and involves stakeholders from several sectors – i.e., the gas infrastructure companies, Balticovo itself and the companies that choose to buy this gas with certificates of green origin. Balticovo is selling gas into the open gas market. Moreover, its sells certificates of green origin, which makes this initiative profitable. At the moment, demand for gas with certificates of green origin is high due to stakeholders' wish to reduce GHG emissions (Interview 3).

The leftover - the digestate from the manure is granulated (by using Balticovo's own energy) and sold in an open market to farmers. The amount depends on the demand for it – 6000 tonnes of granulated fertiliser is produced, but potentially the amount could increase up to 20 000 tonnes. Recently the legislation regarding allowed fertilisers for organic farming has improved – now organic certified farmers are allowed to use such fertiliser for their production. So, this could be a potential market for granulated fertiliser. In 2024 it is planned to take the next step – to capture the separated CO₂ and to use it in a liquified form. It will be good quality CO₂ which can be used for food production (for example – in carbonated beverages) (Interview 3).

In the context of Russia's invasion of Ukraine, the development of 'Bovogas' was seen as an important step towards sustainability and energy independence in Latvia, encouraging other companies to explore renewable energy practices. The development of 'Bovogas' in co-operation with gas infrastructure owners (AS "Conexus Baltic Grid" and "GASO") has never been described as an example of IS, since this is not the term usually used in the business world. Producers talk about reutilisation of waste, side-streams, leftovers, or resources.

Furthermore, a particularly interesting development from a governance perspective at the sub-national level is the Vidzeme bioregion. We delve more as follows.

Vidzeme bioregion

Vidzeme Bioregion is a collaborative governance initiative bringing multiple stakeholders together under the common goal of setting the region towards a development path based on the use and valorisation of bio-based resources. The 'bioregion' was established in October 2023, in Sigulda during the International Bioregion Forum, when attendants were invited to sign the Bioregion's Memorandum of Good Will (see Photo 2).



Photo 2: Public signing of Vidzeme Bioregion Memorandum of Good Will in Sigulda, 25th October, 2023. Source: <https://www.vidzeme.lv/bioregiona-forums-saved-kopa-uznemejus-un-petniecibas-institucijas/>

The establishment of the Vidzeme Bioregion is unique for Latvia, as it illustrates an unprecedented level of co-operation among diverse partners. The Bioregion's Memorandum of Good Will includes six principles and eight priority action areas aimed at promoting organic food production and consumption in the region, ensuring nature conservation and restoration, reducing waste in households and businesses, promoting a circular local economy, encouraging the transition to renewable energy, supporting the sustainable use of natural resources and cultural heritage, and developing tourism that offers an authentic experience. It was signed in 2023 by 13 founding partners from different sectors, including the local governments of the Vidzeme region (Cēsis, Sigulda, Valmiera, and Saulkrasti), environmental protection, education, agriculture, tourism and waste management (*Founding Vidzeme Bioregion*, 2023; Interview 5). While Vidzeme bioregion does not explicitly aim for IS, the push for circularity, valorisation and increased co-operation set the foundation for IS to emerge.

In addition, there are a number of initiatives promoting the circular economy in Vidzeme region. One example is the LIFE research project, which conducted a resource flow analysis of Cēsis Municipality. The study revealed the urgent need to reduce non-sortable and non-recyclable waste, particularly by curbing the flow of banned chemicals and hazardous materials in supply chains (*CE in Cesis Report*, 2023). Furthermore, the results show that businesses are calling for better legislation, particularly on recycling construction waste and supporting organic farming to make it more competitive with

conventional methods. While the region outperforms the national average in agriculture output, particularly organic farming, there are a number of structural challenges that hinder valorisation and circularity initiatives. Namely, declining population, poor quality infrastructure, limited education opportunities, and lacking platforms for communications between farmers (*CE in Cesis Report*, 2023). Despite challenges, the LIFE project identified several companies in Cēsis Municipality that have successfully applied circular economy principles, such as woodworking companies reusing by-products e.g., ash, and organic farming focusing on sustainable practices that are environmentally friendly (*CE in Cesis Report*, 2023).

Overall, the growing awareness of the importance of circular economy, and the cumulative efforts done via research work (e.g., material flow mapping) and policy work (e.g., mobilising stakeholders from different industries working together) represent substantial foundation for the development of IS in Latvia. Particularly, the Vidzeme bioregion, stands out as a collaborative governance model pulling different stakeholders together under the umbrella of a common development vision (Interview 5).

Concluding remarks

The advancement of IS in Latvia is contingent upon the expansion of its social capital and the nurturing of trust within society. To progress beyond isolated business activities, closer inter-regional collaboration and a boost of know-how and investment from the national government would be required. So far, specific support for IS development is mostly coming from EU funding programmes – i.e., Sinergia, funded by LIFE "Waste to Resources IP". However, there is no specific support for companies to develop IS. Latvia's level of industrialisation is relatively low, and thus there are few actors with the capacity to make use of wasted side-streams. Furthermore, there is a lack of a role model for IS in Latvia, which has resulted in a limited understanding of the concept and its practical implications. It is inevitable that IS will grow in line with the maturity and openness of various industries. So far one of the main drivers for change has been the quest for energy independence, rather than a voluntary shift towards a more environment-focused approach. It is therefore probable that lower-level IS cases will develop first, resulting in a resource-to-energy flow development rather than higher added value ventures. Business-science collaborations remain uncommon. Innovative ideas tend to remain locked within the walls of underfunded scientific institutions and applied science universities. However, governance experiments, such as Vidzeme Bioregion, and the increasingly innovative business sector offer a promising outlook for valorisation and IS development in Latvia.

2.3 Lithuania

Although, still small, Lithuania is the largest economy in the Baltics. Lithuania's economy is fast-growing, largely linear and characterised by a strong trade profile and specialisation in industrial processes (*Lithuania's Circularity*, 2021). Growth, however, varies significantly across industries. The life science sector is among the fastest expanding in Europe. Manufacturing industry, including metalworking, woodworking, and textile production have been present for longer time and are particularly important in

south and east regions. Lithuania's richness in bio-based resources also represents a promising area to increase value added by use of technology and boosting co-operation. However, the missing ingredient is precisely that: co-operation. Nevertheless, fully and partly bio-based manufacturing contributes with over 9% of the national GDP, whereas primary production contributes only with around 3% of GDP (See Figure 2). In terms of circular use of resources, Lithuania ranks amongst the lowest in Europe. According to Eurostat the 'circular material use rate' for the period of 2010–2019 in Lithuania is 3,9%, which is well below the 12,4% EU-27 average and the 30% in the Netherlands, the best performer in the bloc (Eurostat in Roadmap for Lithuania's industrial transition to a Circular Economy 2021).

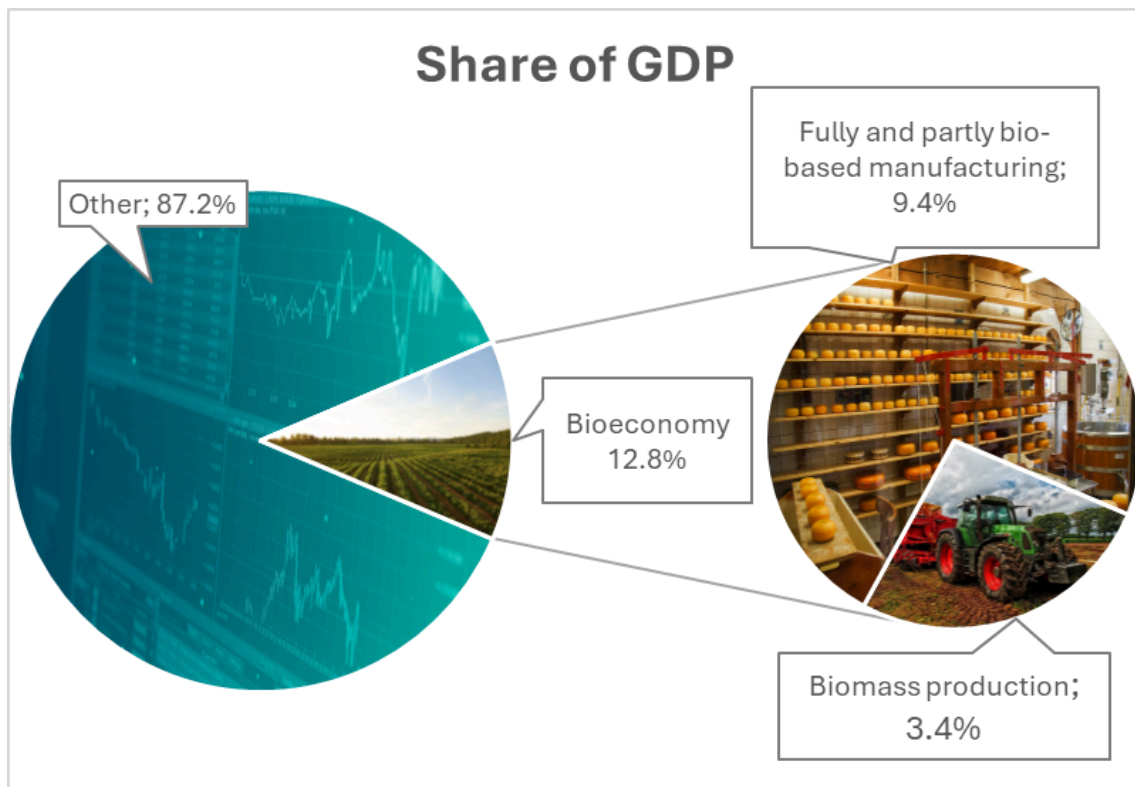


Figure 2: Bioeconomy and its subsectors' share of Lithuanian GDP. Produced by: Henrietta Nyström (Nordregio), based on data by Vitunskienė et al. (2017). BioBaltic project (2022b).

The most relevant policy effort to support IS is *the Roadmap for Lithuania's industrial transition to a Circular Economy*^[2] (2021) developed by the Agency of Science, Innovation and Technology under the Ministry of Agriculture. The roadmap puts substantial emphasis on the need to work along supply chains in a coordinated manner with all relevant stakeholders and the need for application of science and technologies in value creation. The document mentions IS on several occasions and the need to support economic

2. https://mita.lrv.lt/uploads/mita/documents/files/Roadmap_final.pdf

models, monitoring, and funding, however, there is no direct suggestion for how to practically achieve it. The SWOT analysis made in the context of the roadmap pinpoints to the low levels of business participation in R&D, the insufficiently developed platforms for co-operation and coordination and low business participation in associations and alliances (ibid.). All of these are key preconditions for establishing IS initiatives. Yet, the document also points to the opportunities emerging from the increasing demand for 'sustainable and upcycled, remanufactured products', which can serve as incentives for Lithuanian industry to invest in circularity. Importantly, the roadmap highlights the importance of leadership in the public sector in driving transition processes, including the decentralisation of a 'network of circular economy knowledge and competence centres'. Yet, it mostly suggests empowering different players such as education institutes, business associations and other non-governmental organisations, while leaving it unclear what should be the role of local governments. Nevertheless, this highlights the key principles of co-creation that are fundamental for identifying synergies and eventually concrete IS co-operations.

In a more recent effort, the Academy of Agriculture of the Vytautas Magnus University (VDU ŽŪA) together with the Ministry of Agriculture (LR ŽŪM) launched the Lithuanian Bioeconomy HUB. The effort is particularly concerned with enabling co-operation and intersectoral coordination which is needed to boost innovation and value creation in bioeconomy sectors.

Lithuania's National Progress Plan for 2021–2030 has set a strategic goal of raising the circularity index to the EU average of 12.8% by 2025. This will entail improvements in waste recycling and an increase in the use of secondary raw materials for new products. To facilitate recycling, Lithuania plans to reduce regulatory burdens for low-impact recycling activities, waive permit requirements, and provide financial support for innovation in recycling. The *National Waste Prevention and Management Plans* (NWPMP) sets out the objective of expanding separate biowaste collection by 2024, textile waste by 2025, and furniture by 2026. The plans also place an emphasis on the responsibility of producers in the recycling of textiles and furniture, allocating funding to technology development for substituting natural raw materials with secondary alternatives, with a particular focus on durability, reusability, and recyclability to advance circular economy goals. It is noteworthy that since 2022 50 % of all public procurement in Lithuania is green public procurement (GPP). From 2023 all public procurement have been carried out in accordance with GPP requirements (*Lithuania's CE Profile*, 2022).

Lithuania's country profile of circular economy produced by European Environmental Agency's (EEA) lists the following barriers (see Figure 3) for Lithuania to advance in circular economy (*Lithuania's CE Profile*, 2022), and those are somewhat similar to bio-based IS related barriers. However, a notable barrier that should be added is the lack of piloting cases, which would showcase the IS benefits to various industries' players.



Figure 3: Ranking types of barriers to circular economy in Lithuania. Source: (Lithuania's CE Profile, 2022)

Another key strategic document supporting the CE in Lithuania is the *Guidelines for Lithuania's Transition to a Circular Economy by 2035*, adopted by the Government of the Republic of Lithuania in 2023. This document establishes a horizontal approach and outlines six key intervention areas: circular industry, circular construction, circular bioeconomy, circular transport, circular waste management, and circular consumption (Ministry of the Environment of the Republic of Lithuania 2023).

Besides circular economy drivers for bio-based IS in Lithuania, other relevant policy areas boosting it are climate and energy related, as well as bio-economy focused. Thus, the *National Climate and Energy Strategic Plan* for Lithuania places a strong emphasis on the production of high-value goods using biomass as a priority, in line with the country's broader goals in sustainable resource use and renewable energy. The strategic plans, including the *Comprehensive Plan of Lithuania and the National Energy and Climate Action Plan for 2021–2030*, have set the objective of increasing biofuel to 9% and biogas to 2% of electricity production by 2030. This will be achieved by shifting towards biomethane in power plants and local biofuels for heating. In the agricultural sector, the objective is to reduce greenhouse gas (GHG) emissions by 9% by 2030. Land-use strategies are in place to increase GHG absorption through afforestation and perennial crop cultivation. Lithuania's *Smart Specialisation Strategy* provides support for bioeconomy R&D, with a particular focus on sustainable agriculture, renewable energy, and biopharmaceutical innovations. Additional policies, such as the *National Energy Independence Strategy*, the *Regional Policy White Paper*, and the government's strategic programmes, serve to reinforce Lithuania's commitment to advancing its bioeconomy through a prism of energy independence and security where the aspiration for energy independence from third countries (especially Russia and Belarus) is the driving force of bioenergy development in Lithuania (Vitunskienė et al., 2023).

Biogas production for energy independence

The biogas sector in Lithuania has experienced a period of rapid growth, with production increasing by over 25% annually between 2009 and 2018. This growth has been driven primarily by the use of agricultural waste materials such as manure and crop residues. The market is dominated by a number of key players, including UAB Modus Energy, UAB Šilutės Bioenergija, and Ignitis, which are involved in the development of large-scale biogas facilities and biomethane production. Despite this growth, there are still several challenges including limited infrastructure, regulatory barriers and community opposition to new plants. The government has introduced various measures to support investment in biogas, including tax incentives and streamlined permits. Meanwhile, the biofuel sector in

Lithuania is focused on biodiesel and bioethanol from crops such as rapeseed and rye (see Table 1), with companies such as BioBaltis and UAB Mestilla leading the way. However, the sector is facing challenges, including a reliance on imported feedstocks and limited advanced biofuel production from agricultural residues and used oils (Vitunskienė et al., 2023).

Biogas and biofuel production in Lithuania	Value
Annual grain and rapeseed purchase for biofuels production	500,000 tons
Growth in rapeseed processing into biodiesel (2016–2021)	7.5% per year
Growth in grain processing into bioethanol (2016–2021)	4.3% per year
Increase in rapeseed crop area (2016–2021)	Doubled (100% increase)
Average annual yield growth for rapeseed	23% per year

Table 1: Biogas and biofuel production in Lithuania. Source:(Vitunskienė et al., 2023).

These developments could signal that there are untapped opportunities to develop smaller-scale regional biogas production facilities, based on bio-based IS business model instead of using primary biomass for biofuel or biogas production purposes.

Furniture and wood production

The furniture and wood production industry in Lithuania represent 1.5% of material consumption, 1.2% of GHG emissions, and 5.2% of the country's gross value added (GVA). However, the furniture sector, which generates approximately 90,000 tonnes of wood waste annually and is responsible for about 11% of the country's total wood waste, faces distinctive challenges due to its reliance on a single significant buyer (IKEA). This monopsony relationship requires high standards of environmental performance and process digitisation (using Industry 4.0 technologies), but it can also result in cost pressures and the risk of disinvestment, given IKEA's price-setting power (*Lithuania's Circularity*, 2021). So far, IKEA has not made any efforts to initiate IS in Lithuania. Yet, the scale of available side-streams represents an important opportunity to engage the Swedish company to become an important player in increasing circularity in furniture production industry in the Baltics and develop new economic opportunities surrounding the use of side-streams. In addition, there is substantial potential for IS at the micro- and meso-levels, especially within industrial parks (*Lithuania's Circularity*, 2021). This indicates a pathway for Lithuania to deepen its circular economy transition across diverse sectors.

Concluding remarks

Lithuania has a strong potential for developing a bio-based industrial symbiosis. However, a number of structural challenges are hindering its rapid development. The established bio-based energy sector operates with primary bio-based resources and lacks motivation to invest in upcycling waste streams from multiple industries (mainly forestry and food-related). One reason is that the development of a business model for multiple smaller-scale feedstock deliverables requires significant network development and logistics planning. However, Lithuania's growing dependence on imported biomass could provide an incentive for exploring the use of locally sourced bio-based resources. Despite the country's progress towards green public procurement (GPP), a robust framework to support the creation of IS is lacking. This somewhat explains the passive role of strong regional players piloting IS initiatives. However, the policy context and increased awareness have set a fertile ground for new business ventures in the utilisation of bio-based side-streams. The key governance challenge in the near future will be to boost the conversation and facilitate the co-operation between interested parties.

3. Industrial Symbiosis Cases in the Baltic Sea Region

3.1 Sotenäs, Sweden

The case of IS in Sotenäs is one that can give hope to many small regions with moderate industrial scale. Sotenäs showcases a successful example of how small steps can gradually lead to major result by establishing close collaboration between businesses and the local authority and together taking decisive steps forward.

Sotenäs is a small municipality with less than ten thousand inhabitants located in the on Sweden's west coast in Västra Götaland region. As a traditional fishing municipality, its economy remains closely connected with maritime activities and fishing alongside tourism. However, today, some of the main firms are not small fisheries but large fish processing industries of national and international relevance, including Orkla Foods Sweden AB, Lerøy Smögen Seafood AB and Marenor AB.

Large industries usually come with large problems, and so was the case in Sotenäs. The combined impact of the three industries was significant with large amounts of wastewater ending at sea. This environmental threat became also and economic threat for Sotenäs. The increasingly tightened EU environmental regulations generated serious concerns about the future prospects of the companies in Sotenäs. The possibility of relocating activities to Norway was seriously considered by one of these companies. Since then, Sotenäs municipality has taken a giant leap forward towards sustainability and developing a more resilient and dynamic economy all at once (Interview 7).

A journey towards industrial symbiosis

What represented a threat to the environment and the local economy, was turned into an opportunity. The keyword that resonated amongst companies and the local authority was 'symbiosis'. In 2011, representatives of Sotenäs municipality and the industry came together and travelled to Kalundborg, Denmark for a study trip at the to the world-famous case of IS. This initiative paid off, and as an immediate result, a local business owner made the decision to invest in a biogas plant, while the municipality decided to establish the Centre of Symbiosis which serves as a platform for businesses and stakeholders to meet and discuss innovative ideas (Interview 7).

The biogas plant, Renhav AB is now at the core of the symbiotic network in Sotenäs. Now, fish companies: Orkla, Lerøy, and Marenor transfer their waste to the biogas plant and in return receive renewable energy and heat used in their operations. In addition, a side product, the biogas digestate is used as bio-fertiliser, which is sent to the local Klevs Farm to grow organic rapeseed and other crops. Today, several other companies have joined the network, including the Swedish Algae Factory, which extracts "algica" from algae which is then used for solar cells, cosmetics, and other applications. Also, the microbrewery Smögen Ale AB is now connected and delivers its residue malt, or draff, to

the biogas plant, and the land-based salmon farm Smögenlax AB is expected to scale up production soon in symbiosis with the biogas plant and the Swedish Algae Factory. Being located in-land eliminates the pollution otherwise generated at sea by salmon farms. Moreover, algae feeding of the nutrient-rich waste waters provides a win-win solution for water purification. Figure 4 illustrates Sötenäs bio-based industrial symbiosis.

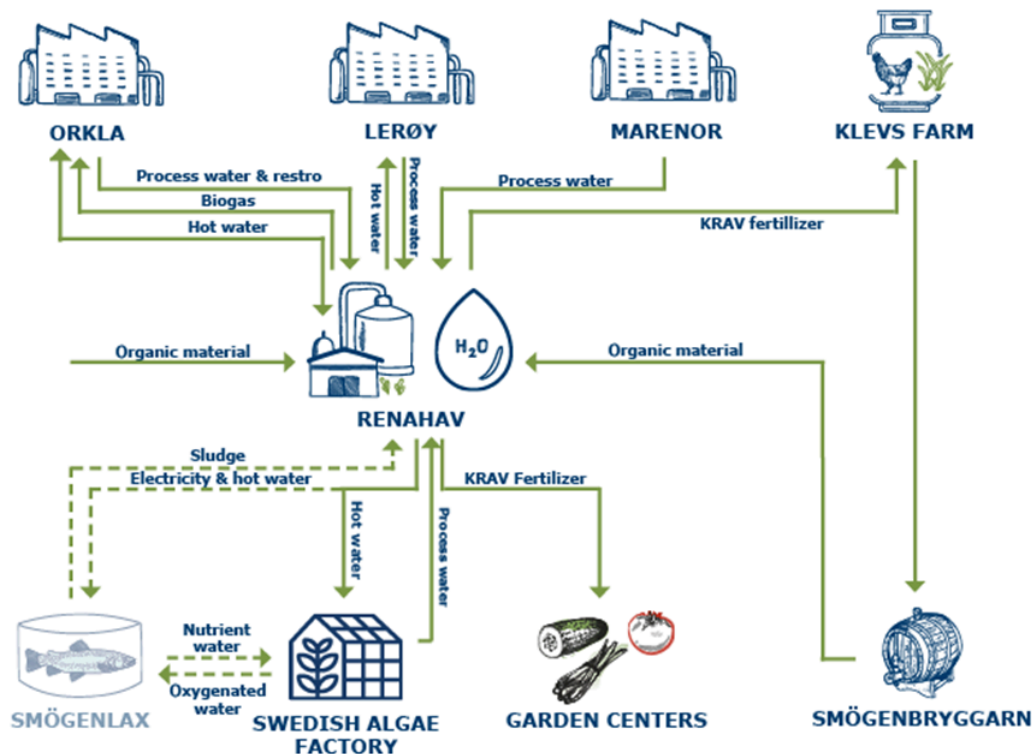


Figure 4: Bio-based industrial symbiosis in Sötenäs. Source: Sötenäs Centre of Symbiosis.

In parallel, Sötenäs has applied the concept of symbiosis also outside of its main biobased industrial symbiosis network. Figure 5 shows a second network of activities connected around Sweden's first Marine Recycling Centre at its core. The centre was established in 2018 by the initiative of the municipality with the aim to keep the seas free of plastics. Seeing its potential the centre received funding from the Swedish Agency for Marine and Water Management in 2020, the centre to establish a national collection system called to collect discarded fishing gear or 'ghost nets' dispersed in Swedish seas. Many of the items collected at the recycling centre are often in good conditions which are regularly picked by Smögens Nät, Sweden's only producer of fishing gears. The recycling centre also counts with a creative space that serves as a testbed for companies or individuals that wish to test and develop innovative products made from recycled materials.

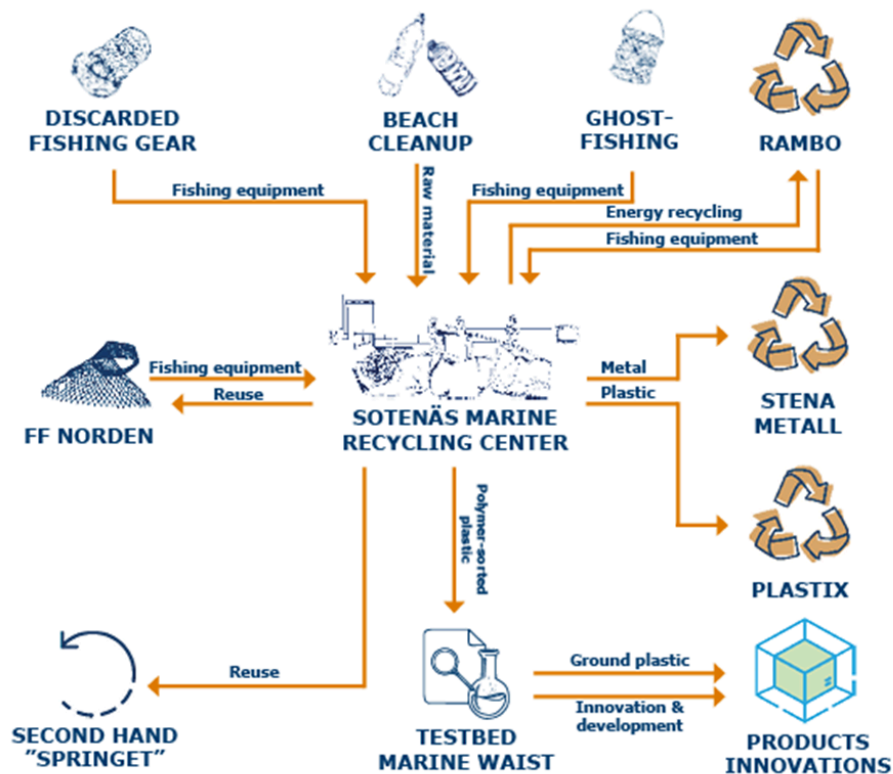


Figure 5: Recycling and circular economy in Sotenäs. Source: Sotenäs Symbiosis Centre.

Success factors

Essential to the successful development of IS in Sotenäs is that it makes sense from an ecological point of view as much as for business and society. Sotenäs stakeholders posed themselves the challenge of applying the logic of ecological systems to their production system, which implies a circular utilisation of resources continuously reusing them and leaving no waste behind. According to a municipal official, the logic is to imitate nature rather than putting humans above it (Interview 8). This represented a major change in understanding of residues from industrial processes as valuable resources. According to one informant, the fish industries were unknowingly dumping billions of Swedish Crowns worth of resources into the sea (Interview 7). What was then wastewater, today generates substantial profits for the industries, while at the same time cutting pollution and strengthening the economic resilience of the municipality in the long run. Moreover, companies are less likely to move away to other regions in the future as the symbiotic ties created with each other depend on geographical closeness, or co-location.

In addition to the financial, ecological, and practical arrangements, perhaps the most important success factor is the social and personal ties built amongst stakeholders and with the broader community. As an informant explains, the basis for symbiosis is networking rather than infrastructure (Interview 7). Regular communication generates awareness of the opportunities and trust amongst people. This then translates into specific initiatives. However, the opportunities are not always obvious or existing at the

beginning but appear over time. The continuous networking among stakeholders has sharpened their eye to identify possibilities for collaboration and spot the opportunities that emerge, either in the form of resource exchange or in other forms (Interview 8). Moreover, the process of seeking innovation can also be enhanced and systematised, and hence the creation of testbeds and resources available for experimentation have been crucial. Indeed, what is interesting from IS in Sotenäs is that it has moved from the more basic steps i.e., biogas to more complex relations and higher added value ventures.

Finally, the strong commitment and dedication of municipal officials laid the grounds for a productive and transparent collaboration with entrepreneurs and the community. Creating a narrative, using storytelling and applying a concept 'symbiosis' that all can relate to, has also been an important part of the success.

3.2 Kemi-Tornio Industrial Symbiosis, Finland

The case of IS in Kemi-Tornio showcases a robust industrial ecosystem that has been developing symbiotic activities for over 20 years. Success has been facilitated by the municipal-owned Digipolis technology park and bolstered by strong commitment and support from public actors. These efforts have earned Kemi-Tornio substantial international recognition as a leader in the circular economy.

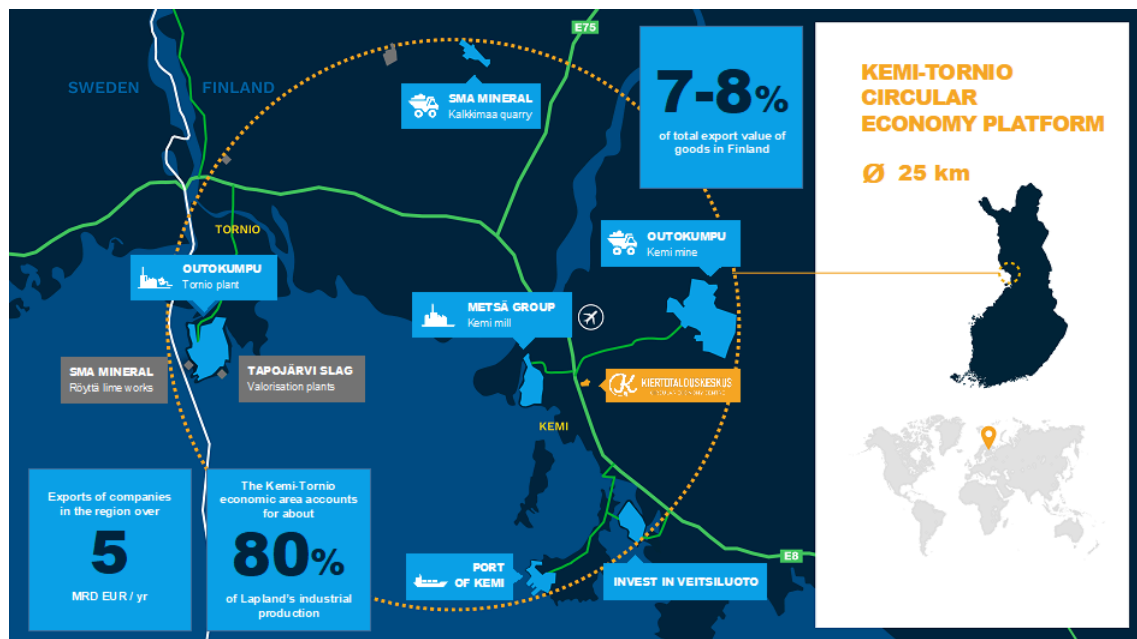


Figure 6: Kemi-Tornio IS, source: Rautio 2024.

The Kemi-Tornio twin cities in northern Finland along with the municipalities of Keminmaa, Simo, and Tervola, home to a small population of around 53,700 residents (2023), is a significant centre for industrial activity (Statistics Finland, 2024). The Kemi-Tornio broader area contributes with 80% of Lapland's region industrial output

A significant milestone in the Kemi-Tornio area was realisation of a detailed mapping of industrial by-product flows, carried out by Digipolis between 2013 and 2014 (See Figure 8). This project led to the creation of a comprehensive databank of industrial by-products, identifying approximately 1.4 million tons of annual residues available for potential reuse in IS—equivalent to about 100 loaded trucks each day. The value of the IS in Kemi-Tornio was estimated at 700 million euros (Lander Svendsen et al., 2021). Additionally, the mapping initiative facilitated the formation of a network of regional stakeholders, enhancing collaboration and communication among them, and helped in matchmaking businesses and uncovering new business opportunities. The databank is still actively maintained and has since been expanded to include data on the region's carbon dioxide emissions, which could potentially be utilised in the future to meet the needs of the hydrogen economy.

TOT. 1.7 MILLION TONNES ANNUALLY		CLASSIFICATION OF SIDE AND WASTE FLOWS	
Side stream	Amount t/a	Process industry fractions classified according to properties suitable for different uses:	
Ferrochrome slag	650 000	Classification	Examples of use
Stainless steel slag	400 000	Load-bearing materials	Civil engineering, concrete aggregate, mining areas
Calcite + filter dust	60 000	Alkalies	pH adjustment, liming and soil improvement
Burnt / slaked lime	30 000	Organic matter	Landscaping, incineration, biogas, fertilizer
Dolomite brick waste	20 000	Ashes	Civil engineering, land improvement, mining
Water purification precipitate	20 000	Sealing materials	Sealing layers for disposal sites
Fibrous clay	19 800	Possibilities of mixing fractions	Several uses
Calcite	15 000		
Biosludge	12 100		
Soda ash	11 400		
Fly ash	9 800		
Riffler waste from the debarking plant	9 100		
Bottom ash	5 500		
Filter dust	5 000		
Calcium carbonate	2 700		
MgO-C brick waste	2 000		
Unfit burnt lime	200–2 000		
Burnt lime waste	200		

Biogenic CO₂ to be added. About 5 milj.t/a available.

Figure 8: The side streams of the industry in the Kemi-Tornio region. Source: Rautio 2024.

As a follow up on a mapping activity, the University of Oulu, in partnership with several organisations, has recently launched a project to map the use of industrial residual streams for water treatment across northern Finland and Sweden. This initiative seeks to discover sustainable practices for repurposing industrial by-products to improve regional water treatment processes. By utilising these by-products as adsorbents, catalysts, or precipitation agents in water purification, the project aims to foster a circular economy.

In 2021, Stora Enso's pulp and paper mill ceased operations, marking the end of nearly a century of activity. Metsä Group, however, has become the leading industrial operator in the region, strengthening its position by building a new bioproduct mill, which was completed in 2023. This significant investment supports sustainable development in the area. Following Stora Enso's closure, Digipolis has been actively seeking new industrial operators for the Kemi-Tornio region. Currently, Infinited Fiber Company is preparing to

establish an innovative textile recycling plant, while Kuusakoski Oy is constructing a new metal recycling facility. In addition, several other green transition projects are under development, contributing to sustainable industrial growth and regional vitality. Hydrogen economy development is also gaining momentum in the region, with significant activities underway. Circular economy principles play a vital role in the hydrogen economy as efforts are focused on carbon dioxide capture and utilisation in Power-to-X (P2X) technologies for producing synthetic fuels and chemicals. Furthermore, the potential for utilising waste heat from hydrogen economy processes is being explored, aiming to improve energy efficiency and reduce emissions in the region (Interview 6).

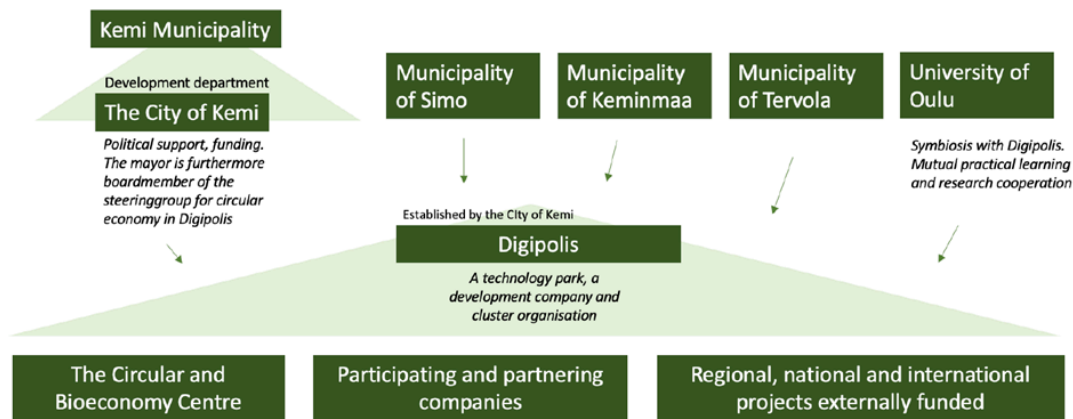


Figure 9: The ownership structure of Digipolis. Source: Lander Svendsen et al. (2021)

Success factors and challenges

Key factors that enable the development of IS in the region include a robust industrial environment characterised by a high output of by-products, primarily due to the prevalence of primary production industries. Additionally, local educational institutions like the Lapland University of Applied Sciences significantly contribute competencies and research facilities, with the majority of R&D activities concentrated within the Kemi-Tornio industrial ecosystem (Lander Svendsen et al., 2021).

Moreover, a proactive mindset and strong support from national and regional authorities have been crucial in fostering green growth and circularity. Strategic programs such as the *European Regional Development Fund* (ERDF) programmes for Lapland (2007-2013 and 2014-2020), *Lapland's Arctic Specialisation Programme* (2014), and the 'Green Kemi' municipal strategy, which focuses on promoting the circular economy, have all played vital roles in promoting the sustainable use of natural resources. Furthermore, Sitra, the Finnish innovation fund, in collaboration with Digipolis, has significantly driven green growth in the region (Lander Svendsen et al., 2021; Nordregio, 2016).

Although many business-to-business IS activities in Kemi-Tornio occur without public funding, such support remains indispensable. Numerous IS initiatives rely on feasibility studies, pilot activities, and similar projects that would not be possible without public co-funding. Digipolis has played a catalytic role in facilitating these efforts.

Additionally, Digipolis has been instrumental in fostering dialogue and trust-building among stakeholders, mapping resource streams, and navigating legislative challenges by identifying legal barriers to IS development. Established in 1993, Digipolis is a publicly owned development company, technology park, and cluster organisation. The endorsement by the Mayor of Kemi underscores top management's commitment and has significantly contributed to building trust with the public sector and industries. Furthermore, Digipolis' diverse membership, encompassing the private sector, public authorities, and academia, reinforces confidence among companies that Digipolis is committed to aligning with their objectives, rather than merely enforcing regulations (Lander Svendsen et al., 2021).

Key challenges for IS in the region include regulatory and legislative barriers, which require significant efforts and resources to overcome.

3.3 Smilowo Eco-Industrial Park (EIP), Notec Valley, Poland

The Smilowo Eco-Industrial Park case of IS located in the Notec Valley region of Poland showcases a pioneering project in Poland in implementing the principles of the circular economy and IS. This case study examines the resource flows, biomass valorisation and the role of multiple companies in creating synergies within an IS network (Kowalski et al., 2023). This is a case where one major private player, Farmutil HS Group, one of Poland's largest agro-food consortia, is the driving force behind the collaboration and IS formation (Farmutil HS, 2024; Kowalski & Makara, 2021a, 2021b).

Background

Farmutil HS Inc. was established in 1982 in Smilowo, Wielkopolska Voivodeship. The company evolved from a small rendering plant into a principal entity within the Farmutil HS group, focusing on to the collection, transportation and processing of animal by-products (Kowalski & Makara, 2021b). In 2007, it underwent a transition into a joint-stock company, which facilitated significant expansion across Poland. Farmutil HS operates a number of rendering plants, including Pilutil and Ekoutil, which enable the company to process categories 1, 2, and 3, as per European Union regulations (Farmutil HS, 2024).

In 2012, the company responded to market demand by launching a biomass production plant, producing hay and straw pellets. This diversification of the product portfolio included also Farmutil HS providing specialised transportation and wastewater management services in the Kaczory borough (Farmutil HS, 2024). A key element of Farmutil HS's operations is its ecological industrial park in Smilowo, which showcases effective collaboration among affiliated companies. This collaboration facilitates efficient exchanges of waste, water, energy, and materials, thereby enhancing both environmental and economic performance (Kowalski et al., 2023).

The company adheres to the principles of a closed-loop economy and is a market leader in Poland's reprocessing industry. It operates modern processing plants, which are among the largest and most advanced in Europe. Today company's primary activities include the

production of meat-bone meal (MBM), animal fats, and biomass in the form of agro pellets sourced from natural agricultural residues. Farmutil employs over 1,000 individuals and collaborates with various partners across the agro-food supply chain, enhancing its position in the industry (Farmutil HS, 2024; Kowalski et al., 2023).

Development of the Smilowo Eco-Industrial Park

The Smilowo Eco-Industrial Park (EIP) is an innovative collaborative network comprising 13 companies operating 36 production and service installations within a 50 km radius (Kowalski et al., 2023). The geographical proximity of the companies facilitates synergistic interactions, whereby the by-products of one enterprise are repurposed as raw materials for another. For example, Farmutil HS processes meat waste into meat-bone meal (MBM), which is then used in the production of pet food and fish feed (Kowalski et al., 2023) – as illustrated in Figure 10. These practices exemplify not only the principles of industrial symbiosis, reducing waste and enhancing resource efficiency, but also the capacity to introduce valorisation within the biomass industrial symbiosis context. Meanwhile, integrating energy and material flows within the eco-park not only improves environmental outcomes but also enhances the economic viability of participating companies.

Annually, the Smilowo EIP processes approximately 300,000 tons of meat waste, converting this material into 110,000 tons of MBM while also generating 20,000 tons of biofuel. This approach mitigates waste and simultaneously generates additional revenue streams for the involved companies. Furthermore, the eco-park operates a modernised central power station, which generates 460,000 GJ of bioenergy each year, thereby substantially reducing reliance on fossil fuels. The integrated operations of the park have resulted in a significant reduction of approximately 92,000 tons of CO₂ emissions annually, contributing positively to air quality and broader climate change mitigation efforts. Furthermore, high-quality drinking water is sourced from wells near the Narew River, ensuring efficient resource utilisation across various processes, including apple juice production and poultry breeding (Kowalski et al., 2023). The Smilowo EIP offers a successful case study, with the implementation of the OXIDOR system for odour control resulting in a significant reduction in local complaints about odour emissions (Kowalski & Makara, 2021a). This highlights the importance of community relations.

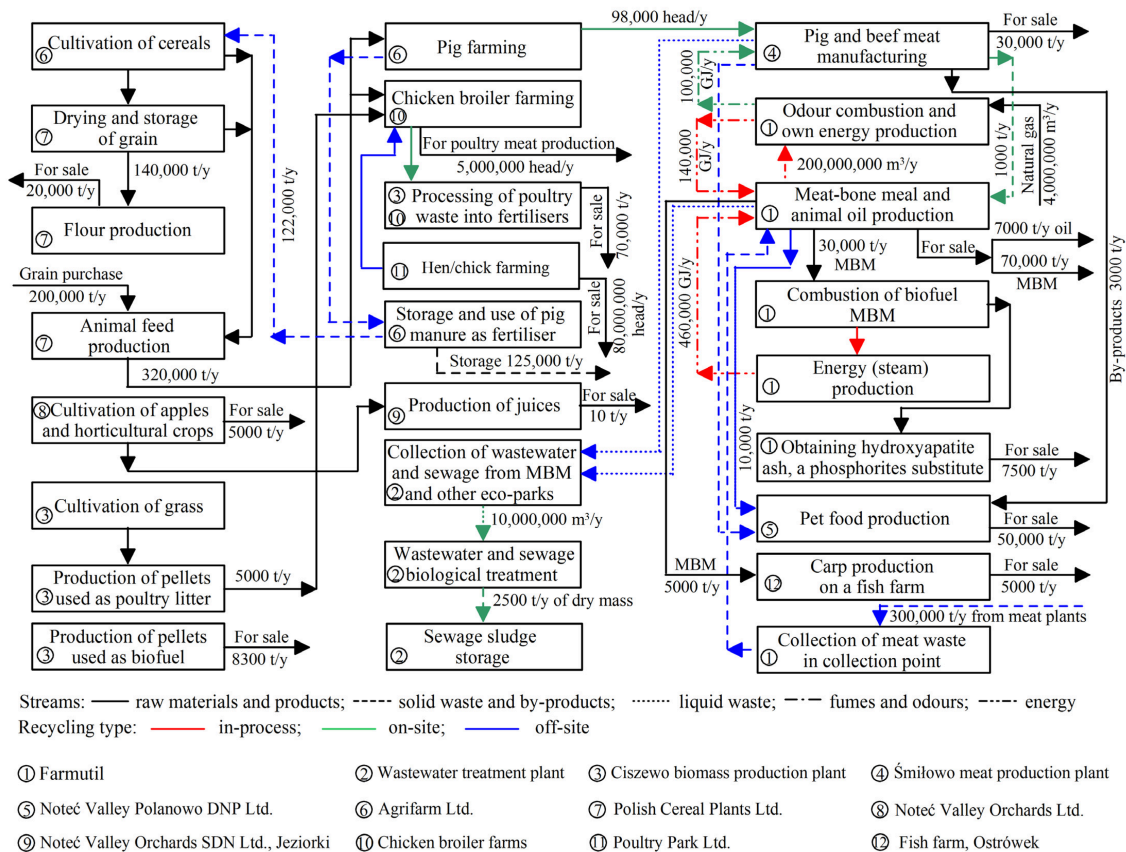


Figure 10: Reserouce flows in Smilowo Eco-Industrial Park, Source: (Kowalski et al., 2023)

3.4 Estonian Industrial Symbiosis Agropark (EISAP)

The Estonian Industrial Symbiosis Agropark (EISAP) illustrates the significant challenges of engineering a symbiotic system from scratch, highlighting how such ventures are especially vulnerable to external influences such as economic shocks and context-specific factors.

In 2019, an idea for an industrial symbiosis agro-park in Ida-Viru County, northeast Estonia (see Figure 11), was born. Spanning 1,500 hectares, the park is strategically located close to Auvere, the Enefit oil-shale extraction site and power plant. The area, primarily a reclaimed oil-shale surface mine now predominantly covered with young pine trees, was chosen for development.

By 2021, a detailed 'master plan' for the Estonian Industrial Symbiosis Agropark (EISAP) was developed by the Dutch consultancy Except Integrated Sustainability, in partnership with Ida-Viru Investment Agency (IVIA). This plan proposes a blend of industrial and agricultural development with innovative features such as CO₂ capture facilities. The vision includes extensive greenhouse operations covering half of the site, alongside nursery and aquaculture. The proximity to a power plant enables to benefit from direct connections to the power grid, leveraging streams of varying heat, pressure levels, and other inputs (See Figure 12) (IVIA 2022).

The European Commission's *Just Transition Fund* has allocated EUR 354 million to Ida-Viru County until 2026 to support climate neutrality and value chain development. As of 2020, the region's shale oil sector employed approximately 5,800 individuals, with around 16,000 residents living in households economically dependent on this sector (CIF 2022). The allocated funds are specifically targeted at bolstering SMEs and large businesses, and research and development (EIS 2024). Estonian companies have shown considerable interest in the fund, and the region has already begun to benefit from the allocation of these grants. Despite significant investments available from the Just Transition Fund in the region, the IVIA has decided to halt the development of the EISAP after nearly five years of efforts due to multiple challenges.



Figure 11: The planned location of EISAP in the north-east of Estonia. Source: IVIA 2021

The park's close proximity to the Russian border, amid increased geopolitical tensions and security risks, has diminished the area's attractiveness to investors. Furthermore, rising energy prices and the loss of the St. Petersburg market—a key export target for the park's

greenhouse produce—have significantly impacted the project's economic viability. Conflicting political goals and land use interests have also jeopardised the project, with Estonia's plan to phase out oil shale by 2040 ([European Commission, 2022](#)) creating further uncertainty in energy use. Investors' growing demands for 100% renewable energy are not met by the proposed 70% biomass and 30% oil shale mix, and national defence needs restrict renewable energy expansion, such as wind and solar, in this area. Recent regulatory and tax changes have further strained finances, with potential land tax increases and stringent land use requirements driving up costs.

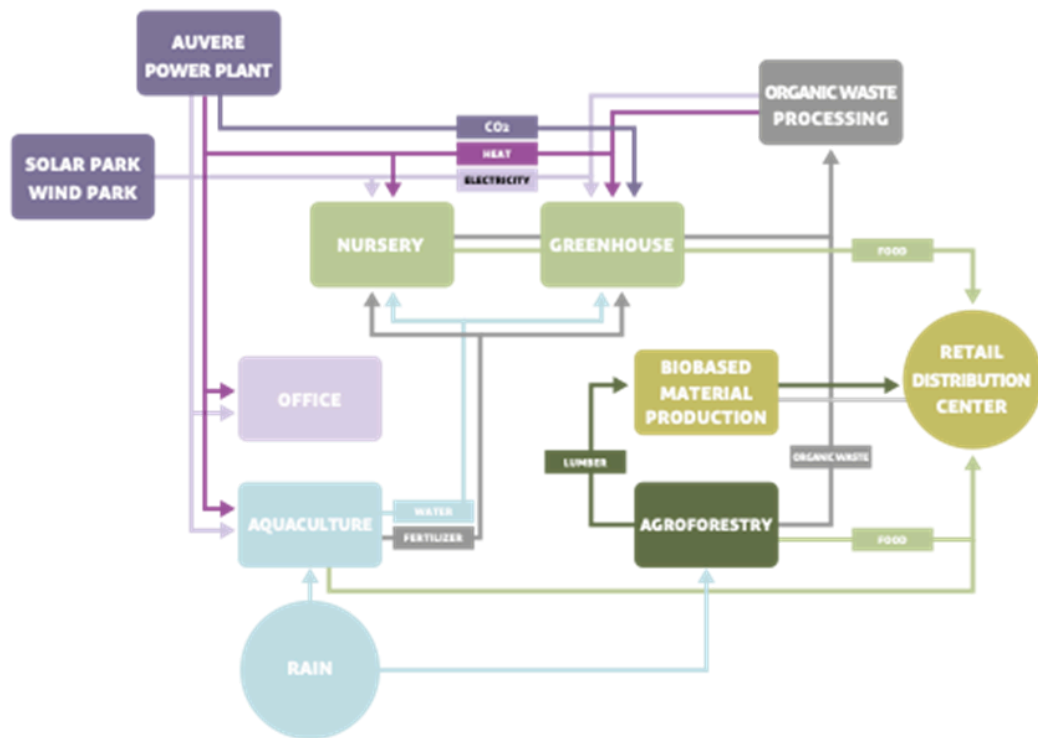


Figure 12: Illustration of EISAP bringing together industries such as agro-food and greenhouses, using CO₂ and waste heat from the adjacent power plant. Source: IVIA 2021.

Despite these setbacks, the Ida-Viru Investment Agency continues to focus on developing value chains and attracting investment to smaller industrial parks in the region, although IS is not a primary focus at this time. The realisation of EISAP was intended to support Estonia's goal of achieving climate neutrality by 2050 (ERR 2019), while also fostering high-tech job creation and economic growth. Given that the Ida-Viru region faces challenges such as outmigration, below-average incomes, above-average unemployment rates, and the largest gender wage gap in Estonia (CIF 2022), the establishment of EISAP could play a crucial role in addressing these issues.

4. Conclusions & Discussion

There are significant differences in the way IS initiatives come to be in different countries and regions, and there are varying degrees of effectiveness and efficiency of the existing approaches of facilitating such arrangements. The comparatively large proliferation of IS networks in Sweden compared to other countries provides valuable lessons. Despite the majority of IS initiatives have first emerged spontaneously in Sweden, they tend to be well functioning, some of which involving highly complex set-ups of exchange involving a diverse range of actors. Mirata (2018) highlights that the limited need for nursing the relevant stakeholders in Swedish cases denotes the existence of favourable conditions for co-operation. These include supportive policy contexts and mechanisms, as well as a solid industrial tradition with extensive presence of industries, material flows and residual streams, and an open culture for collaboration and problem solving. This holds true also in Finland and to some extent in Denmark, although there are some country-specific differences.

In the Baltic States, the development of IS ventures is influenced by two distinct factors compared to Nordic countries. The first is their industrial structure and traditions. The degree of industrialisation in the Baltic countries is limited, with fewer large industries. This means that there are lesser and residual streams compared to Nordic countries and are more dispersed, limiting the possibilities of exchange. Baltic countries have a substantial bio-based economy, but production is predominantly within the primary level. The diffusion of processing industries is comparatively low. This means that the available resources gain little added value along the supply chains within the countries or their regions of origin and hence there is little capacity within the existing industries to valorise residual side-streams. However, valorisation does take place, and increasingly so with many new start-ups and ventures stemming from existing businesses and from universities. However, the most common cases of valorisation exist in the absence of collaboration via efforts concentrated within single companies. Therefore, increased maturity of existing ventures and business ecosystems may well lead to the formation of more complex symbiotic relations in the future. Moreover, initiatives at both national and sub-national policy levels, complemented by EU programmes and R&D projects, are progressively helping to shift mindsets and raise awareness of the business opportunities that stem from the global 'green' transformation of industrial systems.

The second factor influencing the IS ventures in the Baltic states is the governance arrangements. Government functions tend to be more centralised, with sub-national government tiers having limited tools, responsibilities, and resources compared to their counterparts in the Nordic countries. This centralisation restricts local authorities' ability to tailor development initiatives to regional needs and opportunities, potentially slowing the progress of IS ventures. In addition to the formal mandate, it is increasingly recognised that sub-national authorities play a crucial role in mobilising stakeholders and orchestrating regional industrial path creation. So far, isolated initiatives in Baltic countries amount sub-national government authorities to meet this role. The Vidzeme

Bioregion represents one unique example of how collaborative governance can be established sub-nationally, which is setting the region on a promising path towards developing complex forms of collaborations including IS.

Municipalities in the Nordic countries possess essential tools that play a crucial role in facilitating the implementation of IS ventures. For example, they may own or co-own waste management or energy facilities, and control physical infrastructure. Additionally, municipalities are responsible for land-use planning and public services such as schools, daycare, and elderly care. This range of responsibilities grants municipal authorities significant influence over new developments and public procurement processes. It also positions them to potentially engage in new ventures as partners, such as becoming co-owners of a biogas plant. Therefore, the process of strengthening the influence of sub-national authorities in the Baltics will entail a combination between i) formal decentralisation, including reallocation of responsibilities of government functions and resources, and ii) developing informal capacities within building the administrations to orchestrate collaborative processes among different stakeholders.

4.1. Key enablers for Industrial Symbiosis

The discussion that follows centres on the enabling factors for developing IS, drawing on lessons learned from the case studies presented in this report and further enriched by findings from academic and grey literature. The identified enablers are grouped into three key categories: context-specific, governance-related factors, and (inter)organisational factors.

Context-related factors

Examining individual cases reveals that the context in which IS emerges plays a critical role. Place-specific factors, such as geographic proximity and resource availability, are key enablers for IS activities. For example, in the case of Kemi-Tornio, the geographical closeness of the actors, coupled with the availability of substantial by-product outputs, has facilitated direct residual exchanges and streamlined communication among the companies participating in IS.

Additionally, access to affordable, stable, and, more recently, green energy, is often an important precondition for successful IS ventures. An example from a masterplan of Estonian Industrial Symbiosis Agropark in Eastern Estonia demonstrates that the reliance on domestic fossil-based energy sources, and uncertainty about the stable access to energy in the long-term significantly hampered the attractiveness of the eco-industrial park to potential investors, for who access to green energy source was seen as a prerequisite.

Conversely, in the Latvian Balticovo case, the enterprise has invested their own funding in R&D (an area largely underfunded in Latvia) and developed a solution where previously unutilised waste streams can be turned into biogas due to proximity of the gas distribution company's infrastructure. No public funding – neither national, nor EU level have been invested in the project that can be viewed also through the lenses of national agenda for security and independence, highlighting the potential of strategic alignment of 'green' agendas with other governmental objectives, such as energy independence.

Governance system and the role of sub-national authorities

Initiating and promoting IS, as well as coordinating various actors and sectors in subsequent phases, hinges on the ability of different government tiers to mobilise action and promote decentralised leadership. This includes subnational authorities and non-authority actors such as key firms, industrial parks, clusters, research entities, and incubators. Consequently, different 'governance models'—how governments are organised and how the actions of various actors are legitimised—play a crucial role in the opportunities available in different countries. This factor partly explains why Nordic countries have been more successful so far, thanks to their strong institutional structures, decentralisation, and the financial resources and competences inbuilt within the sub-national authorities. Here, decentralisation refers not just to regulatory capacity, but to a concrete mandate and tools that empower these authorities to influence regional development opportunities.

Sub-national authorities can take on a variety of roles in IS initiatives, including acting as initiators or facilitators by providing leadership, developing strategies, offering infrastructure, and fostering partnerships. They may also serve as owners, for instance, of waste management and energy supply services, and also act as regulatory authorities, e.g. addressing complaints, such as those related to noise generated by IS and industrial activities. For example, in Kemi-Tornio, the support from regional and local authorities has been crucial in strategic agenda-setting and in funding feasibility studies and pilot activities.

The study by Lander Svendsen et al. (2021) identifies eight key organisational aspects that can enable municipalities to effectively support the initiation, development, and expansion of industrial symbiosis: vision and leadership, strategy, structure, systems, employees, culture, communication, and partnerships (see Figure 13). The study underscores the role municipalities can play in facilitating IS by supporting business development, waste and supply services, land use planning, and public procurement, as well as by addressing and overcoming potential legal and operational barriers to IS, particularly in areas such as waste treatment and land-use planning (Lander Svendsen et al. 2021).



Figure 13: The role of municipalities in developing industrial symbiosis. Source: Lander Svendsen (2021).

(Inter) organisational factors

In addition to the 'external' factors such as context, policy, and governance, there are crucial 'internal' factors at both the inter-organisational and organisational levels that can facilitate the development of IS. Among these, trust and transparency play pivotal roles. Building a supportive culture of trust, innovation, and collaboration with and between local companies and other stakeholders relies heavily on direct communication and openness—symbiosis is first about the people, and then about practical steps such as funding, infrastructure, or technology.

In this regard, the Baltic countries have a unique advantage due to their relatively small size, close-knit networks, and indirect communication styles, where "everybody knows each other." This familiarity provides a solid foundation for nurturing a collaborative culture among companies, which is a key strength to build upon for fostering IS.

Another key enabler at the organisational level is time and resources to implement new business models such as IS. The study by Johnsen et al. (2014) in the Nordic context highlights that a lack of time and resources is a common constraint at the organisational level, hindering efforts to explore IS opportunities. Additionally, business opportunities—driven by the desire to enhance profitability and competitiveness—serve as major motivators for IS development. Companies are more inclined to engage in IS when they can clearly see the economic benefits, such as cost savings and improved resource efficiency (Johnsen et al 2014).

"It's about smart adaption first, symbiosis second – at the end of the day it has to make sense business-wise, and the circularity and sustainability is a bonus" (Interview 7)

Research and case studies highlight the critical role of a coordinating body in bridging stakeholder gaps, fostering communication, building trust, and managing relationships in IS projects. These intermediaries align interests, provide expertise, and mediate conflicts, ideally operating under public-sector platforms to ensure continuity, legitimacy, and neutrality. Integrating businesses, knowledge institutions, and clusters into these entities enhances engagement and relevance (Mirata, 2018). An example of such effective leadership is seen in Finland's Kemi-Tornio IS initiative, where Digipolis Technology Park, with its diverse membership of companies, public authorities, and academia, has bolstered confidence among participating companies.

5. Recommendations

The following recommendations have been developed based on a combination of academic literature, empirical case study work and informed by the seminar and panel discussion conducted in Vilnius on 3rd December, 2024 organised by the Ministry of Agriculture of Lithuania.

5.1 Recommendations to National Authorities

1. Create an enabling institutional and policy environment to support circular business models (including industrial symbiosis) and valorisation by:

- **Empowering sub-national authorities** — to engage in strategic development of the regions (as opposed to merely performing administrative duties). Being closest to the citizens, resources, and companies, local authorities are in a unique position to build networks and more effectively mobilise action. This requires building capacities within local authorities, particularly in countries with a history of centralised government functions.
- **Designating local and regional intermediaries** — such as regional development companies, cluster organisations or industrial parks to bridge national strategies with local initiatives. Intermediaries acting as coordinating bodies can play a vital role in fostering collaboration, mobilising resources, and facilitating the development of innovative solutions, including resource exchange (Johnsen et al., 2014; Mirata 2018).
- **Aligning industrial symbiosis and circular economy with broader national agendas** — can increase their relevance and urgency. For example, in Latvia, the national push for energy independence has acted as a significant driver for change. Creating additional 'independences' in areas such as biobased medical goods and other critical resources, can serve as a motivation for businesses and authorities to promote IS initiatives.
- **Providing financial incentives** — in the form of funds for structural transformation, or green transition, as well as indirectly via funding testbeds for R&D and piloting or platforms for collaboration. Given that green transitions require innovative and disruptive business ideas, these require specific financial schemes for high-risk investments. Compensation measures could also be implemented to assist companies in utilising secondary raw materials more effectively.
- **Coupling the process of industrialisation with the industrial symbiosis** — given that several BSR economies are growing towards maturity, higher levels of industrialisation can be expected across several sectors. Identifying industrialisation processes at early stages can help to introduce industrial symbiosis arrangements from the start.

2. **Allow for policy experimentation** (institutional flexibility) – increase the tolerance for different management approaches in different regions. Successful examples of industrial symbiosis showcase different approaches and have undergone different trajectories. Hence one-size-fits-all policies may not be most effective for all types of regions.

3. ***Build a shared understanding of industrial symbiosis, including the potential opportunities, challenges, and regulatory barriers. This can be achieved by:***

- **Mapping challenges and turning them onto opportunities** — Close dialogue with companies can generate a two-way understanding of the challenges and identify strategies to overcome them as well as to profit from the opportunities. This process entails highlighting the business opportunities that come with structural change.
- **Promoting knowledge exchange** — Foster multi-stakeholder dialogue between industries, academia, and policymakers to bridge knowledge gaps and align efforts. Showcase successful IS projects to demonstrate tangible economic and environmental benefits, building confidence and inspiring.
- **Creating opportunities for capacity building** — via dissemination of practical experiences from within the country and internationally as well by creating capacity-building programmes focusing on equipping local and regional facilitators with the skills and knowledge to effectively promote IS and business development in general.

4. ***Strengthen research priorities for circular economy and industrial symbiosis development tailored to the specific national, regional and sectoral contexts. Priority should be placed on:***

- **Understanding governance structures, business cultures and local idiosyncrasies** — business and ways stakeholders interact is ultimately rooted in culture, tradition and governance structures. Inducing change requires understanding of these contextual specificities.
- **Industrial symbiosis dynamics and outcomes** — Developing a deeper knowledge of how industrial symbiosis practices evolve, their socio-economic and environmental outcomes, and the factors influencing their success.
- **Promoting interdisciplinary integration** — Enhancing coordination between industrial symbiosis research and other related disciplines, ensuring insights and innovations are shared and leveraged across fields.
- **Evaluating the role of finance** — particularly for high risk, and transformative industries, and collaborative business models.

5.2 Recommendations to Sub-national Authorities

Municipalities and meso-level institutions can significantly enhance the development and expansion of industrial symbiosis via:

5. Strategic integration and capacity building:

- **Integrating industrial symbiosis into broader local strategies** — including local development, business promotion, and sustainability strategies. This will help legitimise supportive actions.
- **Building capacities within local administrations** — on strategic economic and business development issues, including knowledge of business ecosystems, innovation processes, and stakeholder engagement to enhance local authorities' ability to initiate and lead co-operation processes and fora.

6. Support decentralised leadership and partnership:

- **Nourishing decentralised leadership** — encourage different actors lead innovative developments based on their own capacities and initiative. The sum of actions generates collective progress. Coordination is not always the role of the same kind of actor. Open the possibility for different forms of leadership, either industry-led ventures, or a facilitating entity, be it a cluster organisation, a municipality, a science park, or a university.
- **Build strong and transparent social relations** between key players by creating opportunities for networking and learning from best practices e.g., joint study trips. IS cannot be achieved by actors working in isolation, building partnerships between actors with complementary capacities and knowledge is essential.
- **Foster an entrepreneurial and collaborative culture, and closer inter-regional collaboration**— by engaging municipal employees and local businesses, raising awareness of the benefits of IS among the business community. Develop platforms and routines that enhance mutual understanding and trust among diverse local and regional actors.

7. Support data gathering and provide infrastructure:

- **Compiling databases of inputs and outputs** — with emphasis on waste and resource streams within existing industries and match them with a list of possible applications. Identify the practical needs for exchange in terms of location and distance between interested parties, and infrastructure or legal considerations.
- **Providing a hub and facilities for partnership and experimentation** — either physical or virtual spaces that facilitate regular interaction and may include testbeds or laboratories, possibly in cooperation with universities or within industrial facilities. Publicly owned utilities like district heating or energy services

can also serve as practical testbeds for industrial symbiosis, fostering innovation. Strategically plan industrial areas to support IS ventures—ensure available plots are available when potential symbioses are identified and develop supportive infrastructure like renewable energy, transportation networks, and waste systems.

8. *Strategically use 'green public procurement':*

- Use green public procurement as a tool to generate demand, industrial capacity and incentivise market creation. Public entities at different levels are large clients or buyers of goods and services within schools, public transport services, health care, and in infrastructure development. Planning ahead strategically on public purchases can steer private companies towards offering upcycled or more sustainable alternatives. This requires developing procurement criteria that favour circular products and services.

9. Harvest the low hanging fruits — start from the most obvious and easier steps, such as the lowest complexity forms of reutilisation of side-streams e.g., biogas, and then move forwards to more complex ones. This will allow to build trustful relations and get a taste of the mutual benefits of collaboration. Initial success is a strong basis to embark into more challenging endeavours. For example, establishing a joint biogas plant is a basic step to add value to residual biomass. Examples like Kalundborg and Sotenäs show that beginning with easily achievable projects can establish a circular business model, producing not only biogas and heat but also fertilisers, thus generating profits and savings while showcasing the value of industrial symbiosis.

10. Explore creative and viable business models — the potential benefits between companies may rely on co-ownership models and public-private partnerships.

11. Boost communication and create confidence and trust — between different establishments of the network including core companies, suppliers, and authorities.

12. Use storytelling to create a common narrative — using stable terminology and language is key to create common grounds among all stakeholders involved and set clearly identifiable goals. By create storyline of the development journey and collaboration the narrative shifts from individual firms working for their own interests, to a community involved in setting a joint development path. Common ownership of the narrative increases support and trust.

13. Establish collaboration with research institutions — to foster technical and business model innovations. Research institutions and researchers can provide knowledge, technical solutions, but also broader support in adapting to new regulations, creating new business models, and act as neutral facilitators between different actors and interests.

14. Seek external funding to establish pilot projects — Industrial symbiosis can emerge in the form of a pilot project. Funding for structural change and green transitions can provide the fuel needed to establish the basis and build momentum for co-operation.

5.4 Recommendations to Financial Sector

Access to finance is a recurrent bottleneck voiced by stakeholders aiming to work with industrial symbiosis and innovative business models. While rural areas are resource rich, from which promising solutions can emerge, they often are excluded from financial capital. In addition, the 'green economy' calls for highly innovative and disruptive solutions, which are considered high risk investments, and thus are often excluded from financial support. To overcome these challenges finance institutions should:

15. **Develop financial solutions that support 'green economy' initiatives – ranging from circular economy to industrial symbiosis solutions** — including credit for high-risk investments, and loans for collaborative business models.
16. **Promote successful industrial symbiosis and circular economy financing models to the wider financial sector** — by disseminating success stories and financing models to the wider banking sector.
17. **Provide more funding opportunities in rural and economically constrained areas** — where most of the resources available for the 'green economy' are located.

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Alberto Giacometti, Maija Käle & Anna Berlina

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Nordregio

Holmamiralens Väg 10

Skeppsholmen

Stockholm, Sweden

www.nordregio.org