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Feeding Tomorrow – A Workshop Exploration for Sustainable Food Systems Through Industrial Symbiosis in Northern Sweden

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Abstract: Industrial symbiosis is based on the principles of circular economy, and facilitates resource exchange offering economic, environmental, and social benefits. The food industry is a good fit for industrial symbiosis, both for energy recovery and because it produces byproducts for other actors. This paper assesses interest in industrial symbiosis in agri-food workshop. Employing multiple engagement, themes emerged, revealing disparate topic areas and a lack of emphasis on stakeholder communication and collaboration. The study highlights the need for enhanced stakeholder engagement and digital platforms to foster circular food systems.

Keywords: Design for Sustainability, Sustainable Food Production, Resilience

1 Introduction

The increasing demand for food, driven by rapid population growth, is exerting significant pressure on ecosystems, leading to the depletion of vital resources like soil, water, and land. It is widely acknowledged that food production stands as a primary contributor to environmental degradation and climate change (FAO, 2020). A significant challenge is the global interdependence in food supply chains, resulting in many countries being unable to achieve self-sufficiency in food production. This dependence makes them vulnerable to disruptions caused by crises such as pandemics or conflicts. Therefore, it is imperative to redesign the global food system to promote sustainability and self-sufficiency, and this transformation requires rethinking food production methods across various industries, focusing on reducing resource consumption, minimising waste, and adopting Circular Economy (CE) principles (Hamam et al., 2021). The CE envisions a future where waste is minimised, and the value of materials is maximised throughout their life cycles. Industrial symbiosis is a key strategy in advancing the circular economy, involving the collaboration among industrial entities where the waste or by-products of one entity serve as inputs for another (Johnsen et al., 2015).

Despite the growing interest in circular economy principles, the literature on industrial symbiosis within agri-food sector remains notably sparse (Scandurra et al., 2023). Although the inception of industrial symbiosis dates back to the 1970s, exemplified by the Kalundborg industrial ecosystem in Denmark, its widespread adoption remains elusive in industrial practices. Existing research highlights such challenges as information hiding between the companies (Kumar Mangla et al., 2021), lack of empirical data on stakeholders' interest in dialogue before action commences (Bijon et al., 2023), and lack of a network orchestrator (Zucchella & Previtali 2019), which hinder the development of industrial symbiosis initiatives (Kumar Mangla et al., 2021).

In this study we seek to address these gaps by investigating the potential of industrial symbiosis with the focus on food production or use of food waste in Northern Sweden leveraging insights from a diverse array of local stakeholders. The research question we pose in this article is: *What are the opportunities and challenges to develop food industrial symbiosis in Northern Sweden?* Through a qualitative analysis based on the data collected during a workshop involving stakeholders from public sector, business, non-governmental organisations, and academia, we examine the available and required resources in the region essential for advancing food industrial symbiosis. The analysis of these factors will both support the food self-sufficiency the formulate policies that effectively support Achieving food security requires assessing (Horn et.al., 2022). The overarching goal of the workshop was to design circular models for food systems with a particular emphasis on advancing steps for achieving food self-sustainability through the implementation of industrial symbiosis. The primary focus was to design a circular food economy tailored specifically for Northern Sweden with the adoption of a collaborative approach.

The main findings underscore the critical need for a top-down approach to industrial symbiosis in Sweden and the creation of a digital resource platform to mitigate information asymmetry between stakeholders. The results highlight the necessity for a coordinating body, increased information exchange and collaboration among stakeholders.

The paper proceeds by elucidating the concept of industrial symbiosis within the context of food production. Subsequently, the adopted method for the study is explained, followed by the presentation and discussion of findings. The paper ends with brief conclusion.

2 Theoretical Background

2.1 Industrial Symbiosis

Industrial symbiosis aims to establish mutually beneficial relationships among companies, fostering not only environmental but also economic and social advantages. This entails collaboration across industries and sectors within a community framework, enabling competitive advantages through the exchange of materials, energy, and water (Ruiz-Puente and Bayona, 2017). Successful implementations are often rooted in the collaborative and synergistic opportunities facilitated by geographic proximity. Industrial symbiosis represents an environmentally innovative system rooted in circular economy and industrial ecology, facilitating the exchange of materials, energy, and skills among enterprises in green or sustainable industrial parks (Hamam et.al., 2023). This concept elucidates how a network comprising diverse organisations can catalyse eco-innovation and instigate long-term cultural shifts, while also facilitating the creation and exchange of mutually beneficial transactions by enhancing both business and technical processes (Chertow and Park, 2016). The implementation of industrial symbiosis practices is contingent upon contextual factors, including local environmental regulations and political commitment, which serve to incentivise and facilitate the alignment of waste producers with potential waste users.

Industrial symbiosis in the food sector has a significant potential to impact and enhance circularity in food production. Industrial symbiosis introduces an innovative and new opportunities for companies to generate additional income streams (Parker and Svantemark, 2019). By effectively utilising leftovers and secondary products within the network, businesses can tap into new revenue sources. This kind of collaborations not only will provide the financial gain but also contributes to environmental sustainability by redirecting waste away from landfills, resulting in a tangible decrease in carbon emissions (Chen et.al., 2022). Industrial symbiosis can minimise expenses related to raw materials and the disposal of waste, create additional income streams through the utilisation of leftovers and secondary products, redirect waste away from landfills, leading to a decrease in carbon emissions, explore fresh avenues for business growth, enhance environmental standings (Johnsen et al., 2015). Most importantly, companies can reduce expenses related to raw materials and waste disposal, optimising their financial efficiency (Neves et.al., 2020). Nevertheless, various barriers ranging from technical and social obstacles to challenges in intermediary support and geographical considerations may hinder or delay the establishment of such synergistic connections.

There are several examples of successful food industrial symbiosis initiatives from across the globe. Ananas Anam Piñatex in the Philippines showcases a sustainable approach in the fashion industry, demonstrating the production of fashion items, accessories, and upholstery through innovative processes by transforming post-harvest pineapple crops into fabric (Jeong and Chun, 2022). An Italian company Orange Fiber serves as an example of how orange peels can be turned into textile, supporting circular fashion principles (Sugg, 2022). In Poland, an experimental project Appleather demonstrates how apple peel leftovers could be utilised to create sustainable shoes, clothes, and leather accessories redefining traditional leather production. A Polish startup EcoBean demonstrates a multifaceted approach to the coffee industry by upcycling coffee grounds into various products such as compostable flowerpots, straws, and single-use cups, whereas it also investigates the opportunities related to the production of biodiesel additives and other chemicals (Fernández et.al., 2023). These examples clearly show the diverse applications and positive environmental impact achievable through industrial symbiosis.

2.2 Industrial Symbiosis in the Context of Sweden

Most of the developed countries like Sweden that are in climate zones with limited agricultural diversity and low crop yields are becoming more and more dependent on commerce, which is causing the food chain to become more globalised (Kummu et.al., 2020). Sweden overall, including Northern Sweden with its subarctic climate, is highly dependent on imports and is vulnerable to climate change. Following Sweden's accession to the European Union in the 1990s, there has been a persistent decline in domestic food production. Over the subsequent decades, the level of self-sufficiency has decreased by more than 30 per cent, and food production has been increasingly raised as a focal area in the region for resilience and sustainability. The government implemented a food strategy for Sweden in 2016, with the objective to create employment opportunities and mitigate the industry's environmental impact by fostering a transition towards circular food production practices.

In Sweden there are no national support programs directly linked to Circular Economy (CE) or industrial symbiosis. Instead, industrial symbiosis initiatives typically adopt a bottom-up approach, driven by private initiatives and business parks. In Sweden industrial symbiosis development has been ongoing through various channels such as business projects, demonstration areas, and research endeavours. These initiatives encompass activities like energy sharing, enhancing resource efficiency, and collaborative research and development efforts among interconnected industries. Although the term industrial symbiosis is not directly employed at the national level in Sweden, the country has embraced these sustainable approaches and has subsequently amassed expertise in industrial symbiosis, evidenced by several examples across the country, including Sotenäs, Norrköping, Avesta, Enköping, Lidköping, and Helsingborg (Johnsen et al., 2015).

Small-scale instances that would now be categorised as industrial symbiosis have been in existence for decades, encompassing various integrated solutions involving refineries, energy, and waste management. Thus, in Sweden numerous examples of bioeconomy clusters operate in an industrial symbiosis manner for instance initiatives such as biorefineries and bio-based development clusters backed by VINNOVA (Sweden's innovation agency) development grants exemplify this approach. Examples include the Biorefinery of the Future in Örnsköldsvik and Paper Province in Karlstad (Johnsen et al., 2015). Funding for such programs often comes from research councils, regional authorities, universities, and industry. Nevertheless, despite Sweden's numerous industrial symbiosis networks, there remains limited understanding of their operations (Johnsen et al., 2015). One of the studies examining district cooling and greenhouse initiatives in Northern Sweden emphasises the importance of collaboration among diverse stakeholders, effective communication, and the use of visual aids for knowledge exchange to develop industrial symbiosis (Cáceres et al., 2022). The study also points out the relevance of flexibility in urban planning to overcome implementation barriers, while it highlights that ongoing experimentation is crucial for refining symbiosis solutions (Cáceres et al., 2022). The paper on the municipality of Härnösand serves as a significant example of a potential hub for coordinating and facilitating symbiosis development efforts among various stakeholders engaged in the food system (Haller et al., 2022).

The obstacles appear to be primarily economic in nature, relating to investments and markets, rather than technological, social, or policy- and information-related issues. While the latter dimensions are often considered as potential barriers, there is a lack of national investigations into the most significant barriers to nationwide industrial symbiosis development. At the individual level, a deficiency in information and platforms to facilitate company interactions regarding symbiosis may hinder the development of new products or projects (Johnsen et al., 2015). A potential obstacle within the information context in Sweden is the absence of a clear strategy for Circular Economy (CE) or Industrial Symbiosis (IS). In contrast, as outlined in other sections of this report, both Denmark and Finland have clearly defined and promoted CE and/or IS strategies. These strategies are supported by policies, networks, initiatives, information dissemination, and networking platforms. Sweden lacks such a proactive driving force (Johnsen et al., 2015).

3 Method

The study adopts a qualitative approach and is based on the data collected during the food industrial symbiosis workshop organised in the fall of 2023 at Luleå University of Technology and targeted at food system stakeholders in Norrbotten, region in Northern Sweden, which is shown below in Figure 1.

Figure 1. Map of Sweden with Norrbotten. Source: Own elaboration based on Regionfakta https://www.regionfakta.com/norrbottens-lan/.

The food industrial symbiosis workshop was organised by the university researchers as part of the launch of the Northern Food Lab at Luleå University of Technology. Northern Food Lab was born out of the necessity to enhance Northern Sweden's self-sufficiency in food production. Its mission revolves around uniting diverse stakeholders within the food system – including food producers, distributors, suppliers, and consumers – to collaboratively enhance innovative and sustainable solutions for local food production. The primary goal is to deliver high-quality research via the cooperation with industry, NGOs, and the public sector, all with the aim of designing a food system firmly rooted in the principles of the circular economy.

The purpose of the food industrial symbiosis workshop was to gather diverse food system stakeholders, such as municipalities, public sector organisations, non-governmental organisations, business, and academia to discuss the prospects and difficulties of improving food production self-sufficiency and sustainability of the food industry in Norrbotten through industrial symbiosis. The workshop was led by two facilitators who interchangeably run the sessions and led the discussions. The workshop consisted of two main sessions. Session one was centered on introduction and inspiration, during the introduction all the key stakeholders presented themselves and outlined their organisations' roles in the region. The inspiration segment featured discussions on industrial symbiosis through relevant case studies. Session two focused on the activities aimed at identifying opportunities and challenges for enhancing industrial symbiosis in the region with the particular focus on food production or use of food waste. The workshop had four main objectives:

- Introduction of stakeholders and networking – to enhance collaboration and understanding of respective roles and responsibilities.
- Inspiration and knowledge sharing – to explore industrial symbiosis through the discussion of case studies getting inspiration and insights from successful models, and to start the dialogue about the industrial symbiosis with the focus on food.
- Exploration of synergies – to brainstorm about the food industrial symbiosis and collaborative opportunities in the region.
- Strategic planning – to figure out what support is needed to facilitate food industrial symbiosis in order to increase food self-sufficiency in Norrbotten.

The food industrial symbiosis workshop was attended by a group of 29 participants representing in total 16 various organisations based in Norrbotten. The participating organisations included one governmental organisation, three municipalities, five regional development and investment agencies, two academic institutions, three private businesses from food and beverage industry, one agricultural organisation, and one technological company. The stakeholder organisations represented all 14 municipalities of Norrbotten, i.e. Luleå, Piteå, Kiruna, Älvsbyn, Boden, Kalix, Haparanda, Överkalix, Övertorneå, Arvidsjaur, Gällivare, Jokkmokk, Haparanda, and Pajala in descending order of population size. Figure 2 presents the region of Norrbotten with 14 municipalities represented by the workshop participants.

Figure 2. Norrbotten with 14 municipalities represented by the workshop participants. Source: Own elaboration based on Regionfakta https://www.regionfakta.com/norrbottens-lan/.

The food industrial symbiosis workshop hosted a diverse group of participants. Out of 29 participants 17 individuals held direct roles within the food area, *i.e.* food industry, food research, food strategy or agriculture. Workshop participants held various roles in their respective organisations. The types of roles are divided below into six different categories:

1. Administrative and Management Roles:
    - Regional Coordinator
    - Project Manager
    - Sustainability and Innovation Manager
    - Director of Community Development and Business
    - Chairman of the Municipal Board
    - Municipal Manager
2. Business and Economic Development:
    - Business Developer (x4)
    - Business Owners (x3)
3. Innovation and Strategy:
    - Innovation Leader
    - Senior Adviser
4. Project and Team Roles:
    - Project Team Member
    - Project Support
    - Interns/High School Students (x3)
5. Specialised Expertise:
    - Researchers (x7)
    - Regional Expert in Nutrition Policy and Food
    - Food Procurer
    - IT Company Representative
6. Organisational Roles:
    - Chairman and Member of an Organisation

4 Findings: Resources to facilitate food industrial symbiosis

29 participants from 16 diverse organisations based in Northern Sweden actively participated in the food industrial symbiosis workshop fostering a collaborative environment for discussions. The workshop was divided into two separate sessions each with a distinct focus. The first part focused on the identification of the material resources available in the participants' respective municipalities or region, and the material resources required to enhance food industrial symbiosis. The second session aimed at identifying the non-material resources, both available and required.

The analysis of the available material resources uncovered four main categories, i.e. natural resources, by-products and waste, energy resources as well as infrastructure and community. The natural resources include clean water, forest and wood products, berries, land for crop cultivation, land-based fish farming possibilities, free land to grow crops, and future greenhouse spaces. By-products include exceess heat from industries such as for example mining and steel industry or data centres, waste from the mining industry and future resources from hydrogen steel production (water vapor). Waste includes brewery by-products (spent hops, yeast, and grains), animal manure which can be used as a natural fertiliser, other animal by-products like for example bones, food waste from private households, restaurants and public institutions, fish waste, and potato shells. Additionally, available material resources comprise energy resources like excess heat, energy from biogas plants, and CO2 for greenhouse production play a significant role. Finally, the workshop particpants pointed out the available infrastructure and the nearby community as available material resources. Table 1 presents the material resources available in Northern Sweden, pointed out by the workship participants, that could be used to enhance food industrial symbiosis.

Table 1. Available Material Resources

Natural Resources:
Clean Water
Forest and Wood products
Berries
Land for crop cultivation
Land based fish farming possibilities

Free land to grow crops
Future greenhouse spaces
By-products and Waste:
Excess waste heat from industries
Brewery by-products (spent hops, yeast, and grains)
Natural fertiliser (from animal by-products, biogas production)
Food waste from private households, restaurants and public institutions
Fish waste
Potato shells
Waste from the mining industry
Future resources from hydrogen steel production (water vapor)
Energy Resources:
Green energy
Energy from excess heat
Energy from biogas plants
CO2 for greenhouse production
Biogas is a renewable energy source produced through the anaerobic digestion of organic materials, such as plant matter
Infrastructure and Community:
Infrastructure and close community

In the second step of session one workshop participants were asked to indicate the material resources required for the implementation of food industrial symbiosis. Participants highlighted the importance of financial support and investment such as for example EU funding support and fiscal simulation packages. In terms of infrastructure and technology, the discussions led to the conclusion about the need for digital platforms for transaction facilitation. Interestingly, community building in terms of housing and infrastructure for workers was pointed out as necessary to build industrial symbioses in the region. Finally, one of the participants also mentioned the need for wastewater treatment facilities. Table 2 shows the required material resources necessary to enhance industrial symbiosis.

Table 2. Required Material Resources

Financial Resources:
Financial support and investment
EU funding support
Fiscal stimulation packages
Infrastructure and Technology:
Digital platforms for transactions between producers
Access to wastewater treatment facilities
Community building (housing and infrastructure for workers)

The second section concentrated on identifying the non-material resources crucial for industrial symbiosis aiming to strengthen the regional food systems. While material resources are important, non-material resources are just as important for encouraging cooperation, sharing knowledge, and taking action by stakeholders. An extensive range of intangible assets, including knowledge, connections, channels of communication, and institutional frameworks, are included in these non-material resources. Stakeholders can effectively navigate the complexities of industrial symbiosis and forge synergistic relationships that improve the resilience and sustainability of local food systems by acknowledging the significance of these non-material resources. The workshop revealed the presence of extensive knowledge and expertise, particularly in areas such as sustainable food production, water treatment, and industrial production. Networking and collaboration resources include established contacts with greenhouses and energy-intensive companies, clusters facilitating collaboration like Nära Mat in Boden, organisations' networks, and robust research networks and international collaborations. Institutional support, including facilitation for change, regulatory support, and educational programs, further bolsters the available non-material resources.

Requisite non-material resources include the need for enhanced infrastructure and technology capabilities, particularly in industrial connections and digitalisation expertise. Additionally, social and cultural resources like the will to develop, ambitious sustainable goals, and community-building initiatives are deemed essential for effective food industrial symbiosis. Workshop participants brought up tradition and cultural pride as social and cultural resources, which should be preserved in the local society in Northern Sweden, which for example involves offering unique local gastronomic experiences as an alternative to mass production. Table 3 presents available and required non-material resources needed to enhance the food industrial symbiosis in Northern Sweden.

Table 3. Available and Required Non-Material Resources

AVAILABLE NON-MATERIAL RESOURCES	REQUIRED NON-MATERIAL RESOURCES
Knowledge and Expertise:	**Infrastructure and Technology:**
Research network	Industrial connections within the food and restaurant industry
Competence in sustainable food production	Digitalisation expertise
Knowledge about water treatment	Competence in building IT products
Expertise in industrial production	
Creative culinary expertise	
Networking and Collaboration:	**Social and Cultural Resources:**
Contacts with greenhouses and energy-intensive companies	Will to develop and innovate
Cluster of Nära Mat in Boden	Ambitious sustainable goals
Organisations' networks	Community building
Collaborative research experience	Tradition and cultural pride
International networks	Early childhood education on sustainability
Institutional Support:	
Facilitation for change	
Generalist perspective	
Regulatory support (quick regulatory action)	
Coordination	
Educational programs (for green industry)	
Natural Resources:	
Cold temperature	

Muñiz-Martinez and Florek (2023) mark that nostalgic ideologies should blend with modern approaches to regional revitalisation through small-scale, artisanal gastronomy and eco-friendly tourism, fostering authenticity and balance between economic progress and environmental values. However, Veldhuis et al. (2019) highlight that regionalised food production systems may not inherently be more environmentally sustainable than centralised systems. Therefore, caution is advised when promoting local food products for environmental reasons. Policies advocating for transparency regarding the environmental footprints of food products could aid consumers in making informed choices. However, generating substantial evidence to support pro-local policies across environmental, social, and economic dimensions remains a complex undertaking.

5 Discussion

The findings from the workshop on food industrial symbiosis provide valuable insights into the diverse range of material and non-material resources available and requisite for developing food industrial symbiosis practices in Northern Sweden. In the discussion we focus on the two most prominent findings that emerged during the workshop, *i.e.* the need for a top-down approach to industrial symbiosis and the need for a resource digital platform.

5.1 Top-down approach

Findings indicate that workshop participants demonstrated a keen interest and motivation for food industrial symbiosis showcasing a willingness to engage. The utilisation of by-products and surplus energy from industrial and urban processes is not a novel concept. Nonetheless, it seems that numerous opportunities in the region remain untapped due to various reasons. One significant factor is the absence of a facilitation program aimed at raising awareness and fostering knowledge sharing, along with a lack of specific policy incentives. There is a clear need for knowledge and guidance on the specifics of what actions to take and how to implement them effectively to develop industrial symbiosis solution.

The primary incentive for companies to participate in industrial symbiosis endeavours is to enhance profitability and competitiveness. Business prospects serve as the principal catalyst for the advancement of industrial symbiosis. However, significant barriers to industrial symbiosis development have been identified such as companies' limited time and limited resources to adopt new business models like industrial symbiosis, as well as scarcity of expertise and awareness regarding industrial symbiosis opportunities in the region (Johnsen et al., 2015). To address these challenges, the presence of a cluster, network, or coordinating body in Northern Sweden that facilitates collaboration proves essential in organising exchanges among companies. In other words, there is a need for a top-down approach for industrial symbiosis development in Northern Sweden. In Sweden policy orientation favours a bottom-up approach for the advancement of symbiotic industrial practices, unlike the top-down approach prevalent in Finland and Denmark where governments offer grants supporting companies in the implementation of circular business models and run special programs designated to promote industrial symbiosis among them (Johnsen et al., 2015). The dissemination of information about industrial symbiosis solutions has played a pivotal role in the Danish, Finnish, and Norwegian contexts (Johnsen et al., 2015). Also, in line with existing literature findings imply that it is instrumental to develop policy frameworks aimed at fostering recovery initiatives and mitigate the depletion of essential raw materials (Jurgilevich et.al., 2016).

5.2 Resource digital platform

One of the main study findings, which emerged during the workshop, is to design and create a resource digital platform with the overarching aim to facilitate the information and raw material exchanges between the companies in the region supporting them in establishing circular business models to slowly leave behind the linear production. Such a digital platform would provide an online space to share information about the available and requisite resources in the region, which would effectively increase the information flow and potential collaborations between various regional stakeholders. In the context of management, effective information dissemination plays a crucial role in incorporating circular economy principles throughout the food supply chain (Kumar Mangla et al., 2021). The act of concealing information among managers directly hampers innovative capabilities and the commitment of employees to the company. Furthermore, this practice has detrimental effects on the long-term coordination among partners in the food supply chain, resulting in decreased competitiveness over an extended period. Additionally, there is a growing consumer demand for comprehensive information regarding each stage of the food supply chain, underscoring the significance of addressing food safety, security, quality, and trust to mitigate consumer risk. It becomes imperative to prevent information hiding between managers and supply chain partners to not only improve product quality, ensure food safety, and foster consumer trust but also enhance the overall profitability and corporate image of the company (Kumar Mangla et al., 2021).

The goal of a resource digital platform would be to enhance food industrial symbiosis between various regional stakeholders. The goal of such a digital platform, which could inform about the residual waste companies generate in the production process, would be to foster collaborations between multiple stakeholders, companies in particular, for the purpose of resource sharing, waste reduction, development of food industrial symbiosis, flow of resources between urban and rural area as well as encouragement of circular business models with the focus on sustainable food production and/or efficient utilisation of food waste. The idea is to virtually transform the collaboration interface among various industries related to food systems with the goal of forming new resource-efficient value chains. The digital platform would increase cooperation in several ways by digitally facilitating information and knowledge sharing, mapping available nearby resources, serving as a digital marketplace and setting the price for the residual waste, and serving as a hub for collaborative decision-making. It was found that for the food industry, innovation, cooperation, and resource sharing amongst stakeholders are critical to the pursuit of sustainability (Dania et.al., 2018). Stakeholders can promote industrial symbiosis and accelerate the shift to a more sustainable economy by utilising desired resources like cooperative networks, smart value chains, brands that emphasise sustainability, and financial support (Dania et.al., 2018).

The concept of a resource digital platform, in particular residual waste digital platform, can be explained with an example of a beer industry, which generates such leftovers as spent grain, spent hops and yeast during the brewing process. Brewery spent grain, the primary by-product of brewing, is traditionally used in animal feed due to its high protein and fiber content. Spent grains also hold promise for human nutrition and biotechnological applications but are mostly used as animal feed. Industrial symbiosis frameworks offer an avenue for its broader utilisation across various industries promoting sustainability by transforming brewery waste into valuable resources. The digital platform could drive a collaborative approach to facilitate upcycling of brewery waste not only in agriculture and food production, but also in bioenergy, biofuel, textile, paper, pharmaceutical, biotechnological, chemical industry as well as wastewater treatment. Such a collaborative approach would foster a circular economy and reduce the environmental impact of waste products (Mussatto et.al., 2006). Thanks to the design of a residual waste digital platform various not connected industries could receive information about the potential resources existing in the region instead of importing or buying raw materials. The digital platform would support various industries in exploring the potential collaboration avenues to implement industrial symbiosis practices. Figure 3 presents the conceptual visualisation of the residual waste digital platform and illustrates how such a digital platform could serve as a common digital space for increasing collaboration and reducing waste among various industries in the context of the beer industry.

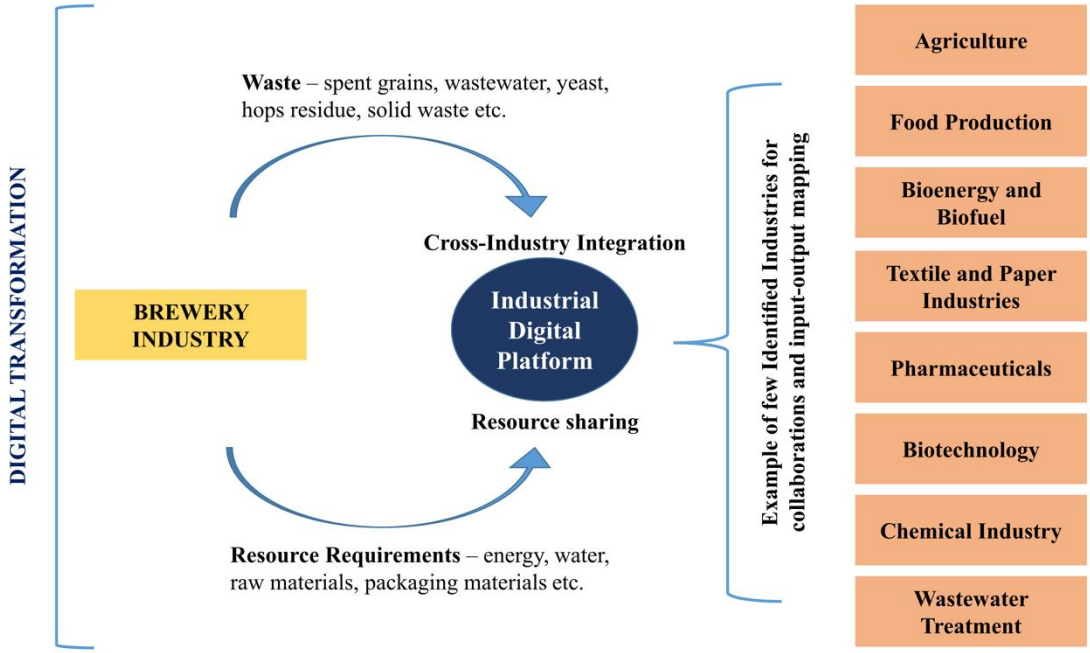

Figure 3. Conceptual visualisation of the residual waste digital platform in the context of the beer industry

6 Conclusion

To recapitulate, the research question we posed in this study was: *What are the opportunities and challenges to develop food industrial symbiosis in Northern Sweden?* Adopting a qualitative approach based on the data collected during a workshop on food industrial symbiosis we provided a list of available and requisite material and non-material resources to facilitate the implementation of food industrial symbiosis in Northern Sweden with the aim to strengthen sustainable food production and increase food self-sufficiency. The two main findings from our analysis relate to the need for a top-down approach and resource digital platform to facilitate industrial symbiosis in Northern Sweden.

The study indicates that there is a keen interest and motivation for food industrial symbiosis among the regional stakeholders who are willing to support the development of food industrial symbiosis approach in Northern Sweden. However, due to a lack of industrial symbiosis know-how, lack of a coordinating body, and no financial support, the regional stakeholders are not able to move forward the circular agenda as they lack knowledge what actions to take and how to implement them effectively. Therefore, the top-down approach for industrial symbiosis in Sweden that would enhance the information and resource exchange between the companies is needed. Chertow and Park claim that industrial symbiosis is not an option, but a necessity in the future, the researchers argue that not taking advantage of interconnected networks of organisations mutually sharing waste streams will be socially unacceptable (Chertow and Park, 2016). Scholars mark that industrial symbiosis has generated compelling imagery and optimistic expectations for a future where nearly all water, energy, and materials are utilised multiple times (Chertow and Park, 2016). The residual waste digital platform in the era of business digitalisation would facilitate the information flow between the companies, and thus it would open up new opportunities for business collaborations based on mutual exchange of raw materials or services paving the way for the implementation of circular business models.

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