A Roadmap for Increased Uptake of Industrial Symbiosis in Sweden

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Table of contents

Summary

The recent uprising of the circular economy field has reignited the interest in industrial symbiosis and the utilisation of by-product resources between two separate entities. Industrial symbiosis refers to the exchange between companies or other entities, of resource flows typically considered as by-products or waste, where typically there is a mutual benefit in the exchange. Similarly, urban symbiosis looks to exploit opportunities in urban areas or between industry and urban functions. Sweden has a long history of cooperation across industry sectors and urban development.

The practice of utilising by-products and residual energy from industrial and urban processes is therefore not a new practice. However, it appears that many opportunities still exist to be exploited but have not been developed for various reasons. One of the key reasons is due to lack of a facilitation programme that increases awareness and knowledge flows, as well as a lack of specfic policy incentives.

The aim of a Roadmap for IS in Sweden is to highlight key components and actions that will enable the identification, development and realisation of industrial symbiosis exchanges between two or more parties. The Roadmap is focussed around five critical elements and actions:

1. Create a systematic **facilitation programme** - Regional Centres supported by a National Centre.
2. Establish **support mechanisms** – including Task Forces that provide supporting knowledge in key areas, (e.g. recovery technology) and drive forward key issues; as well as research in key areas.
3. Generate **market demand** – e.g. through awareness activities, as well as local and national government procurement.
4. Develop **policy drivers -** for industrial symbiosis whilst improving the overall policy environment by removing barriers.
5. Align **IS across different sectors and approaches –** this refers primarily fostering IS across the key pillars of society urban areas, industrial and agriculture and forestry; as well as aligning sectorial policies to ensure IS can flourish.

The most critical action is argued to be the development of facilitation programme initially consisting of 3-5 Regional Centres, supported by a National Centre. Applied together, this structure will provide one of the most effective and efficient tools to drive IS forward. Subsequently, supporting this structure with support mechanisms and the other critical elements will provide a comprehensive suite of tools to ensure IS is embedded within company actions as a natural solution to resource flows.

The role of industrial symbiosis in stimulating innovative solutions should also be noted, and can it be seen as a key stepping stone and educational aid in the move toward a circular economy. Industrial symbiosis can also help to drive forward innovative technology, which can be required to enable some of the higher hanging fruits. Therefore in the longer term aligning industrial symbiosis with other concepts (i.e. circular economy), policies and strategies is required, not only to avoid duplication of activity but also to maximise the efficiency of its application.

The Roadmap lays out tentative timing for the provision of the five elements.

1 Introduction

In order to improve the uptake of industrial symbiosis in Sweden, collective action and input is needed from a range of actors including industry, academia, government (including cities and municipalities) and consultancies.

The aim of a Roadmap for IS in Sweden is to highlight key components and actions that will significantly contribute to the development, identification and realisation of industrial symbiosis exchanges between two or more parties. The Roadmap lays out a path in terms of actions over time, for IS to be fostered in conjunction with supportive concepts such as the circular economy.

The practice of utilising by-products and residual energy from industrial and urban processes is not new. However, many opportunities have not been realised. Utilising the concept of industrial symbiosis seeks to purposely develop exchanges between companies to utilise otherwise wasted and underutilised resources. Similarly, urban symbiosis looks to exploit opportunities in urban areas or between industry and urban functions. In this document we use the term industrial symbiosis and the abbreviation "IS" to refer to both industrial and urban symbiosis[1].

In Sweden, there are many examples of by-product energy, water and material reuse, which have not been recognised as industrial symbiosis. However, equally there are many opportunities that have not been realised. These represent both economic and environmental inefficiencies but also opportunities.

The purpose of this Roadmap is to propose how these opportunities can be identified, supported and developed.

1.1 Background

The supporting review to this Roadmap "Actions for scaling-up industrial symbiosis in Sweden" (Mirata et al. 2018) provided valuable insights into IS both nationally and internationally. Industrial symbiosis still lacks a uniform definition but we consider it as a dynamic process of multi-party resource management collaborations that are often geographically concentrated and cross-sectoral.

These collaborations contribute to meeting societal and industrial needs more sustainably often by creating improved value from otherwise wasted or underutilised resources, and by developing new products, services and utilities that are more effective and efficient. They also have significant potential to contribute to business competitiveness, reduced resource demand and environmental impact, and to sustainable societal developments. As such, industrial symbiosis offers a pragmatic and effective means for progressing towards more circular- and bio-based economies, for which there is increasing interest and demand from growing number of stakeholders.

Internationally, there are numerous examples of IS that demonstrate the range of benefits. These range from those that have developed by themselves as in Kalundborg, Denmark and Kwinana, Western Australia, to those developed through facilitation such as in the UK's National Industrial Symbiosis Programme (NISP) and in the eco-industrial parks of South Korea and China. The NISP approach was effective in harvesting low-hanging fruits, but had limited impact on building stronger relations, improving innovative capabilities, and building capacity in regions for further support to the concept. Approaches in South Korea, on the other hand put strong emphasis on developing regional capacity

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[1] The abbreviation is used despite possible confusion with unsavoury organisations. However, we feel industrial symbiosis was here first and hopefully will be here last – we therefore continue to use the old abbreviation.

with a common model of application throughout the country. Regional centres were established in selected parks with heavy industrial concentration and received strong financial support from the national government.

In Sweden, there have been a significant number of IS exchanges and networks are identified.

Over twenty networks have been identified and studied to some degree, such as those in Norrköping, Helsingborg, Stenungsund, Örnsköldsvik, These, and many others, have all emerged spontaneously, in pursuit of mutual opportunities identified in bi-lateral interactions. While some networks are confined to industrial parks (e.g. Stenungsund and Industry Park of Sweden) in most other cases symbiotic relationships include strong integration between industrial and urban activities, and in certain cases also extend resource transactions to nearby agricultural and forestry related areas. Most symbiotic activity involves traditional industrial sectors such as chemical and petrochemicals, metal processing, and pulp and paper production and residual energy utilization is often a common element. In more recent times symbiotic activity is increasingly linked to emerging bio-based industries. In recent years, there is also growing interest in supporting IS developments through dedicated action. Facilitation efforts have been on-going in Malmö and Sotenäs for some time, and are slowly emerging in other localities, such as around Köping, and in Värmland. These show similarities but also have their unique characteristics.

Strongly connected to the studies focusing on the international, and to some extent Swedish, cases and programs, there is a rapidly evolving research and scientific knowledge focusing in industrial symbiosis. An important part of that research focuses on determinants, which depending on their characteristics, form barriers and provide drivers within development contexts. These determinants are large in number and are rooted in different domains related to: techno-spatial conditions, informationa and knowledge availability; economic and market conditions; elements of the political system, and organisational and social dynamics.

These determinants are also tightly inter-connected, making the development processes complex and context-dependent. Research also provides insights on different approaches by which these determinants can be influenced to create more fertile conditions and thereby support IS developments. These show large variations, providing a rather large portfolio of dynamics by which IS networks emerge. Different facilitation approaches have been also been investigated and their impact have been analysed both hypothetically and based on empirical findings. These range from the use of ICT tools that help increase transparency in the secondary resource market, to development of resource flow and good practice databases; from organising match-making events with the help of external consultants, to developing institutional capacity with the local and regional actors. While all of these seem to produce results, those approaches that focus on building institutional capacity with the local and regional actors, and that work with creating supportive framework conditions in the local and national context with a long-term view hold the best potential to assist prominent and sustainable development of IS practices. Such approaches require the identification and capacitation of relevant intermediaries, developing stronger professional and personal relationships among diverse actors of the regional economic system, increasing knowledge resources through diverse and systemic interventions, supporting the development of identified opportunities with specific inputs, and maintaining effective communication with regional and external actors for necessary business, market and policy innovations. As a sub-set of such approaches, different kinds of intermediaries and the specific roles they can play receive particular attention. Research also highlights the value of specific tools and approaches that can aid specific elements of IS developments – such as social network analyses, IS maturity grid assessments, or specific analytical techniques.

1.2   From Strengths to Opportunities in Sweden

It is apparent that the situation in Sweden offers fertile ground for the further development of IS. This section utilises a strengths-weakness, opportunities and threats (SWOT) analysis as a framework for further discussion about IS development in Sweden.

Table 1 highlights that Sweden has many key strengths required to support the development of IS including the culture, expertise, industry types and innovative culture. On the other hand, a key weakness is that there is a lack of facilitation, which could overcome some of the other weaknesses such as communication difficulties, mobility of knowledge and lack of incentives and capabilities.

Meanwhile, the opportunities for IS are profound and appear to be increasing due to a growing acceptance of IS amongst businesses and other stakeholders. The major threats include regulatory issues, as well as economic aspects such as the focus of industry on core business. In addition, organisational strategic choices often allocate none or very limited resources to investigate IS and further develop.

Table 1: SWOT analysis for the development of IS in Sweden

Strengths	Weaknesses
• Many existing examples - Urban and industrial symbiosis already happening & fairly common • Existing knowledge and technical skills • Collaborative business culture – with strong public-private cooperation • Progressive and innovative culture • Infrastructure exists in many places – e.g. for district heating • Some supportive policies: landfill tax, CO_2 tax, biomass development support • Major industrial sectors are suitable for IS	• Low hanging fruits may have been picked? • Lack of drivers (e.g. facilitators) increasing take-up of higher fruits • Geographical spread of Sweden with many areas of low density economic activity • Lack of communication of IS concept and benefits to relevant stakeholders • Poor mobility of knowledge • Macro level environment • Lack of incentives and relevant capabilities in municipalities and industry • Limited embeddedness of IS in organisations • Lack o expertise in regions – e.g. technology
Opportunities	**Threats**
• Many opportunities exist for IS exchanges – and there is motivation amongst actors such as municipalities. • A facilitation platform does not yet exist (fertile ground for systematic facilitation) • Growing customer (B2B) demand • Circular economy trend – increases acceptability of IS as a solution • Marketing value of IS • Collaboration is a competitive resource • Resource security and resilience • Technology development to enable IS is needed in some areas	• Legislation is slow to update • Long development time for IS exchanges and permits can take too long • Potential lock-in of current technology or production system • Some IS solutions are not the most optimum sustainability solution • Business is driven by economics – lack of "quality" assessment • Emphasis of core business • Long time for IS network to develop as a recognised network • Complexity of systems

1.3   Recommendations from Analysis

The analysis report accompanying this Roadmap recommends a set of actions to foster further IS developments in Sweden. These were divided into regional and national actions and are summarised below.

Regional:

- Communicate IS – to key private and public stakeholders.
- Build on existing strengths - identify champions and key actors to function as facilitators.
  - Develop IS through, workshops and other activities that bring potential partners together.
  - Form a vision and a plan with key stakeholders.
- Sustainability assessment of opportunities and storage.

National

- Form a National Centre or network
- Build Capacity for IS – for municipalities and other stakeholders, including a database of examples and guides for IS development under different context.
- Develop tools to aid identification and assessment of opportunities.
- Improve communication and collaboration - amongst IS practitioners.
- Collect and communicate barriers to IS development.
- Foster supportive research of IS in Sweden – development dynamics, facilitation techniques.
- Form expert groups – to provide specialised knowledge and input.

2 Key elements for further Industrial Symbiosis in Sweden

In order to capitalise on the strengths and opportunities for IS in Sweden, whilst overcoming weaknesses and threats, this section introduces five key elements.

2.1   Essential building blocks

This Roadmap utilises a framework from earlier research to illustrate the key aspects required for IS development. The framework illustrates that the development of symbiosis exchanges can be viewed as a process that requires three key building blocks (CECP 2007). Hence in order for symbiosis to develop it must have a supportive policy and economic environment, the opportunity needs to be

identified and finally a physical connection is made (e.g. through pipeline or transport). This is then represented by the following framework and illustrated in Figure 1[2]:

- **Platform** – which refers to the conditions and supportive framework needed to encourage and support IS development. In addition, the collaboration and networking context (such as relationship building and history of working together) effects the opportunities to form partnerships.
- **Process** – the process of identifying potential synergies, as well as possible engineering and technology solutions.
- **Project** – refers to the development process where the businesses and other actors involved perform the required organisational procedures (e.g. negotiations and contractual arrangements), physical development (e.g. connecting the output with the input) and potentially develop innovative solutions.
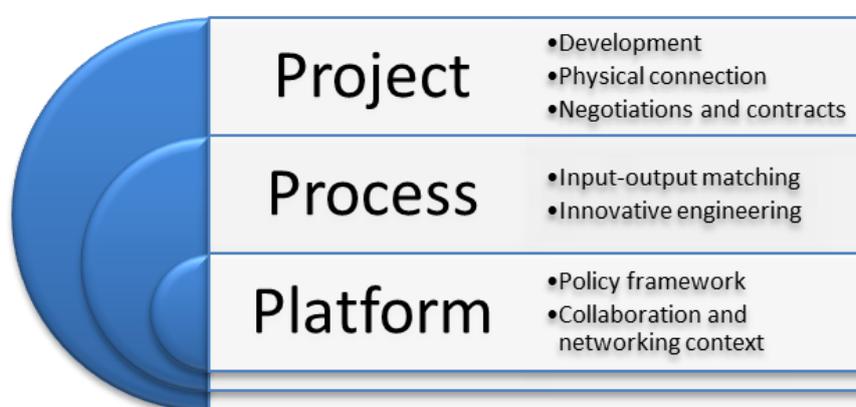

Figure 1: The components necessary for the realisation of IS projects

This simple framework will be used within this Roadmap to illustrate the key actions and functions that need to be implemented and developed in order to support the further growth of IS in Sweden.

2.2   Five critical elements

In order to support each of the building blocks for IS development and its continued growth, this Roadmap identifies five critical elements. These five elements are intended to ensure that the *platform* conditions are optimal, information and awareness of potential input-output exchanges is enhanced (supporting the *process*) and *project* development processes are supported:

1. Create a systematic **facilitation programme** - regional centres supported by a national centre.
2. Establish **support mechanisms** – that provides research and information capability.
3. Generate **market demand** – e.g. through awareness activities, as well as local and national government procurement.
4. Develop **policy drivers -** for industrial symbiosis whilst improving the overall policy environment by removing barriers.
5. Align **IS across different sectors and approaches –** this refers primarily fostering IS across the key pillars of society urban areas, industrial and agriculture and forestry
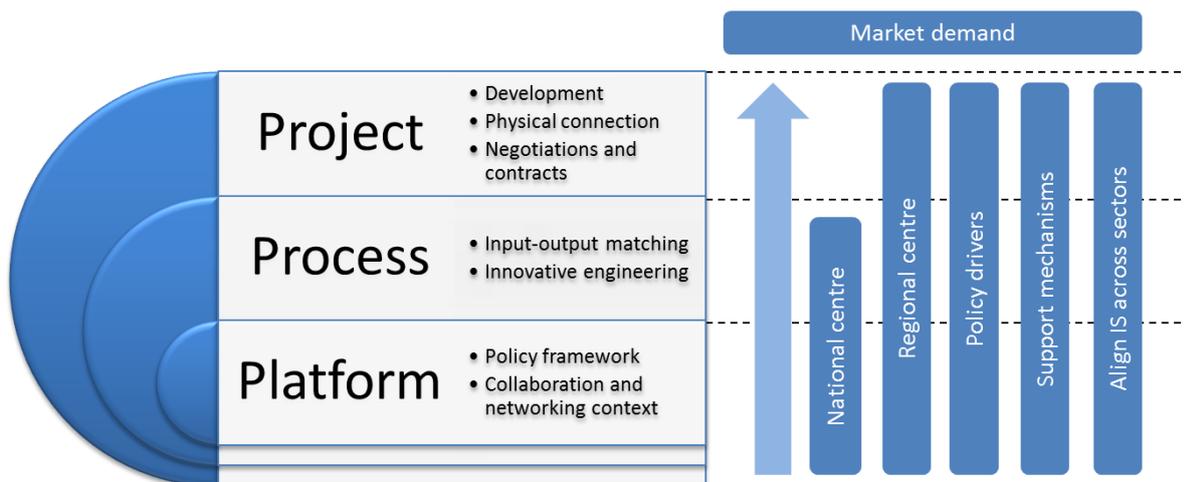
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[2] Adapted from CECP 2007.

Figure 2: How the elements support the IS development process at different levels

The five elements above are elaborated on in the following sections.

2.3   Create a systematic facilitation programme

There is significant evidence to support the notion that facilitation programmes (or even networks and other forms of associations) are key drivers of identifying and supporting the development of IS exchanges and networks. Therefore, a national facilitation programme which supports a series of regional centres/networks can act as a major driver to enable industrial symbiosis. This is a similar model used by NISP in the UK and in principal is an idealised approach.

The national centre (or networks) has a critical initial role within the Roadmap: to establish or aid the development of 3-5 key regional centres (or networks). This involves aspects such as identifying key stakeholders and industrial members, as well as helping to identify or develop the relevant regional actors (with appropriate skills) to develop and run the regional network.

Having established regional nodes the national centre facilitates IS development at a higher level, such as by communicating common policy issues to government, disseminating best practice and overseeing a common web-based platform and database. In addition, the national centre would aid the development of further regional centres in new locations.

Regional centres have the primary function to be hands-on; helping to identify potential IS exchanges and providing functions such as training. It is expected that capacity building exercises such as training on identification and facilitation of IS would be supported by the National Centre.

The functions of the two levels of facilitation mechanisms are discussed below.

2.3.1 A national platform

The role of the national network should include the following:

- **Facilitation of IS** – through promotion and communication of IS benefits, and overseeing the development of regional centres.
  - –This would include identification of relevant regional capacity to facilitate the regional network, as well as training to build the additional skills required.
  - –A steering committee would also be formed consisting of key industry groups, associations, government agencies, academia and other stakeholders.
  - –Facilitating exchange of knowledge and lessons between regions.
  - –Communication and coordination with international research and practice
  - –Development of a common identification tool and web platform - a database to enable input-output matches and an online toolbox to aid businesses and stakeholders in IS development.
  - –Developing a common strategy and vision – including targets, actions and identifying funding sources and business models to enable national and regional centres for long-term operation.
  - –Supporting educational programs and courses, by giving lectures etc.
- **Communicate policy issues** - Represent industry and stakeholders to communicate issues relating to barriers that hinder IS development. E.g. the length of time environmental permits can take in Sweden, or the legislative label of waste.
- **Technical and research expertise**– developing and maintaining a network of technical and research expertise to support individual synergy development. This would also include training of facilitators and companies in identifying and developing IS exchanges.
- **Negotiation and contractual arrangements/business models** – providing support and advice as well as a standard set of options for common types of IS exchanges.

The national centre oversees and supports regional centres which act as the nodes to foster collaboration between relevant regional stakeholders (Figure 3).
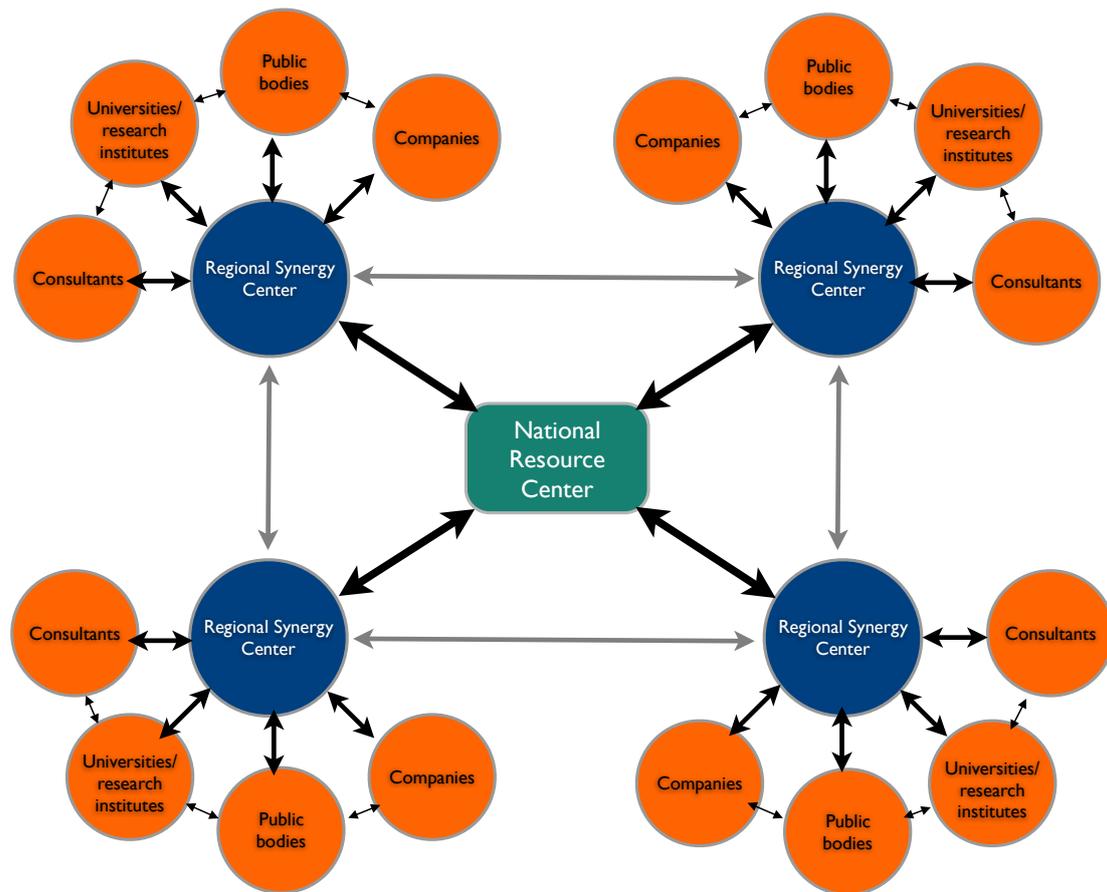
Figure 3: National and regional model for IS development

2.3.1.1   Funding

There are in principal two types of models for the development of a national network:

- A centrally funded approach – a national programme similar to that of the UK's NISP which would require a higher level of direct funding. Depending on the level of funding this could then be distributed to regional networks.
- A network approach - run by several stakeholders such as key industry members, government agencies, municipalities, research organisations and universities. This would have more indirect funding, where network participants give time and facilities on more of an in-kind basis. However, this could be supplemented with other types of funding such as regional bodies, municipalities and research grants.

In order to increase the potential for success the level of funding needs to ideally support the National Centre and 3-5 Regional Centres. The best way to achieve this is by obtaining a sufficient level of funding from a consistent source (e.g. government) that would enable an initial 3-5 years of funding.

Although there are several derivative approaches that could be used. In addition, there is opportunity to supplement the funding with other sources such as EU funding for innovative actions or research. An alternative is to utilise a combination of public-private funding.

2.3.2   Supported regional centres

The main purpose of a regional centre is to foster IS exchanges between relevant stakeholders within the municipality or region. This is achieved through:

- **Forming a regional network** – that brings potential partners together. This could be achieved by establishing a regional centre and steering group consisting of key stakeholders, such as municipalities, relevant authorities, research organisations, consultants and companies. An alternative option is to support existing collaborative associations and networks that already operate in the region. They should already work on common industry and/or urban issues with some relevance to IS (e.g. environment or efficient issues).

- **A series of workshops and activities** – designed to enhance familiarity and trust; and that will help actors come together around areas of common concern.

- **IS exchange identification workshops** – which focus on gathering potential exchanges of material and residual energy between stakeholders regionally (and nationally) and create.....

- **Collecting data from companies –** either directly or encouraging companies to enter relevant data into the national database (which would be used primarily to search locally).

- **Capacity building** – e.g. training company members, other municipalities/regions and other stakeholders, methods for identifying potential IS exchanges and identifying relevant technology that can enable exchanges. This would most likely be supported by the national centre.

- **Communicate policy issues** – to the national centre or relevant regional authorities.

- **Provide access to expert knowledge** – support companies, other municipalities/regions and stakeholders in the development of IS exchanges by helping to identify relevant expertise, knowledge or technology.

- **Identify key research areas** – identify common or key research areas, such as technological or organisational, which could aid IS development. This information could also be passed on to the national centre so research projects could then be developed with key research institutes, and for example by applying for

2.4   Establish support mechanisms

Support mechanisms refer to two main elements that support IS development in key ways:

1. Task Forces; and
2. Targeted research.

These are also elements that could be established and directed by the National Centre, but would largely sit outside the centre itself.

Task Forces are both a source of help for network members in providing knowledge and information in defined areas, but also have the role to drive forward key issues e.g. policy drivers, or technology dissemination. For example, whilst facilitation platforms increase the information flow and awareness of potential exchanges, there is also a need to increase awareness and knowledge of technological solutions (which can open up novel exchanges, e.g. through the ability to recovery components in small concentrations) as well as support in reaching agreements and sharing the benefits of exchanges. A good way to achieve this is in the provision of Task Forces (or advisory groups), which can be derived from network members, consultants, research institutes and the facilitators.

Therefore, the *process* and *project* phases should be supported with key Task Forces in the following areas:

- **Recovery technology** – which can increase efficiency of recovery but can also open up new potential synergies by recovering one or more components in more useable or pure form. In addition therefore, companies can utilise support on identifying potential uses for by-products and their constituents.
- **Legal and regulatory issues** - in particular **drivers** (discussed in the next section), not only to advise members but primarily to collect issues, particularly common ones, and initiate and maintain dialogue with regulators.
- **Assessing potential impacts and benefits** – this includes economic, as well as environmental and social issues (it also includes business issues)
- **Sharing the benefits** – contractual arrangements and negotiation.

It follows that further research is also required in the above areas. In addition, the following should be highlighted as key research areas to support IS development:

1. Symbiosis identification methods – how symbiosis opportunities can be efficiently identified, including those that need to undergo technological processing.
2. Technological development – e.g. through demonstration projects.
3. Organisational and policy aspects – e.g. the process of how organisations become aware of IS and integrate it into organisational processes, and how policies can be adapted to support this.
4. Decision support for:
    a. Business
    b. Local, National Decision Makers

2.5   Develop policy drivers for industrial symbiosis

Policy has a crucial role in providing a *platform* where IS opportunities can flourish and be capitalised upon, as well as providing incentives. There is a need to ensure that regulatory barriers that are obvious impediments to safe and sustainable IS exchanges are effectively and efficiently removed.

Regulatory requirements and the policy context can be a major barrier to the implementation and success of industrial symbiosis (Baumgarten and Nilsson, 2014). Policy related barriers can be a direct hindrance (e.g. preventive legislation), demanding (e.g. permit and administrative requirements), or due to inadequate support (e.g. uncertainties in legislation). But policy can also have a positive effect on the success for industrial symbiosis enabling development through regulations (e.g. legal requirements) and support (e.g. subsidies and identification of possible collaborations) (Baumgarten and Nilsson, 2014). Currently, there are no measures directly targeting industrial symbiosis in Sweden.

However, a key challenge is the implementation of a suite of consistent policy drivers to provide a lasting incentive to utilise IS as a natural solution to resource flows. In order to drive forward the development of the policy suite a Task Force should be established as noted above.

Therefore, in summary the policy approach is recommended as:

- Creation of a **Policy Task Force** – members could be selected through collaborative efforts
- Identify and **develop a suite of policy drivers** – for example (but not limited to):
  –facilitation platforms;

  –fiscal measures that encourage IS whilst discouraging disposal;

  –planning incentives to ensure new developments (urban, industrial or agriculture and forestry) use IS to create value from all resource flows; and

  –creation of standards for specific materials that facilitate legal sale of the material.
- **Drive research** that supports the above point.
- **Open and continuous dialogue** between IS representatives and the regional and national regulators – this is principally achieved through the facilitation centres and the Task Force

2.6 Generate market demand

This is an under-researched area within industrial symbiosis, but it appears that there are three overall approaches to generating market demand at both the regional and national levels:

1. Procurement policies of local (municipalities and cities) and national governments establish procurement policies that promote IS.
2. Through policy drivers and removing barriers.
3. Generate awareness of the benefits of IS from an economic and sustainability perspective

These are elaborated in the sections below.

2.6.1 Procurement policies

Many Swedish Municipalities are already involved in symbiotic activities through aspects such as district heating and biogas generation from food waste. There is also increasing interest on how to foster the circular and sharing economies within municipalities. Similarly the circular economy has been raised as a key strategic issue for national government as discussed above. National government has a significant mandate to create demand through its procurement and infrastructure role (i.e. development and maintenance). Potential avenues should be researched and investigated.

There is also therefore an opportunity to foster further IS by developing procurement policies that demand or encourage recycled content e.g. biogas in transport, in building products, for roads, or composts.

2.6.2 Policy drivers and removing barriers

As discussed above, whilst policy barriers have received attention in the literature (typically the label of "waste" and its consequences), whilst policy drivers have received less attention. Incentives are required to encourage businesses to seek IS solutions for resource flow issues, and for customers to be encouraged (and even rewarded) for opting for IS derived products. Product labels could for instance be developed to illustrate and promote the sustainability of IS derived products.

However, in order to foster the use of by-product resources there is also a need to make it easier and more economic than the alternative (e.g. disposal to landfill or dissipation of waste energy). A key barrier for example with inorganic by-products that has been well noted is the lack of standards and guidance for reuse of many materials (Harris, 2007). The process of obtaining environmental approval for reuse is often too time consuming and arduous. Without legal guidance or standards there is no foreseeable end point that a company can achieve that encourages investment into such as process.

2.6.3   Generate Awareness

There is also a need to increase awareness of the economic and sustainability benefits of IS exchanges amongst businesses, municipalities and other stakeholders. This could be another activity for both the National and Regional Centres – to promote the win-win-win benefits of IS exchanges.

2.7   Align IS across different sectors and approaches

This section discusses the need to align two key aspects:

1. **Recognising and enabling opportunities** for symbiosis across societal functions and sectors; and
2. **Aligning policy and actions of related concepts** to industrial symbiosis such as the circular economy and bio-economy.

These are more long-term, high-level issues which are also related to considerations for future development of products and society. As a first action a fairly high-level Task Force should also be formed from industry, academia and government agencies.

There is a need to remove the current silo approach to societal development and align the three main sectors or aspects of societies:

● Cities and urban development.
● Industry and its products.
● Agriculture, food production and forestry (agro-forestry).

The Task Force should aim to identify key target areas where IS can be implemented across sectors such as between industry and forestry. For instance, biodegradable by-products from forestry being utilised within industrial products, and subsequently leading to more circular solutions, e.g. biodegradable packaging that could be used as compost. In this respect, IS can be seen as both a solution a stepping stone to a more circular economy.

This would require the Task Force to promote research in key areas to support companies in the development of complex IS exchanges and market development.

Finally, to support this the related concepts, such as resource efficiency, circular economy and the bioeconomy, and their related policies and initiatives need to be aligned so that they are mutually supportive and not in conflict. This will lead to increased efficiency of support and application, as well as to reduce confusion of practitioners.

Therefore initiatives such as Sweden's Waste Prevention Programme, Centre for Resource Efficiency in Sweden (CERISE) and the IS programme proposed herein , should be aligned to be complementary and avoid repetition.

3   Next steps and actions

This document has laid out a clear need for concerted action to foster the development of industrial symbiosis. The above sections have highlighted the need for five specific elements to help foster IS and exploit the anticipated opportunities in Sweden.

The deliverable AP1 "International and Swedish State of Play in Industrial Symbiosis" performed under funding from Re:Source showed that IS is widespread in Sweden, but the true extent has not been fully mapped or understood. The wider sustainability benefits of these networks have also not been quantified or established sufficiently. They do however, offer ripe breeding grounds for further IS exchanges. It has also highlighted the benefits. For example, the UK's NISP programme generated over £2 billion in cost savings and additional revenue – many times the £27 million that the programme received in funding (International Synergies, 2018). Clearly such a bold approach needs sufficient long-term funding, both for the facilitators and the supporting research that will help enable the synergies.

In Table 2 we propose the potential actions, milestones and timing to develop the five elements. The most basic and critical requirement is that of a facilitation programme consisting of a Regional Centre supported by a National Centre and programme – which drives forward IS identification and supports the process of development. This can build on the recent work of the Swedish Network for Industrial and Urban Symbiosis, which has already identified several key stakeholders.

The approach must be one of continuous learning and maintaining momentum. This implies continuous activities such as workshops, capacity development, identification processes and integration into regional planning strategies and processes.

Support mechanisms through Task Forces (or expert groups) and supportive research would support the whole process of identification, development and contractual agreements, through to delivery. Market demand includes fostering supportive procurement policies and overlaps with policy drivers and aligning across sectors, both of which can foster market demand. Whilst removing barriers is critical, policy drivers are an under researched area and key to encouraging a higher uptake of IS solutions.

Finally, in the long term there is a need to align societal sectors so that there is integration across the societal functions of agriculture, industry and urban development; as well as related concepts such as resource efficiency, circular economy and the bioeconomy.

Table 2: Action and milestones of the proposed IS Roadmap

Year	Facilitation		Support mechanisms	Policy drivers	Market demand	Align IS across sectors
	National Centre	**Regional Centres**				
2019	Build on existing IS network (SNIUS) and report analysis (AP1)					
	Develop funding model for National and Regional Centres					
	Form a steering committee Develop vision, goals and action plans					
	Identify 3-5 Regional Centres	Form Regional centres 3-5 centres	Form Task force			
	Website		Identify key research support areas			
	Online tools and support	Regional assessments	Support research proposal development in key areas	Form Task Force	Form task force	
	Increase number of stakeholders	Build relations with and among key companies and stakeholders –give ownership	Training of regional facilitators		Promote IS – through awareness raising activities	Form task force: Industry, academia and government agencies
2020		Identify IS opportunities: Regional workshops	Negotiation and contractual support	Identify key barriers		Identify key areas for targeting
	Facilitate cross-regional knowledge and experience exchange (continuous) Liaise with international research and practitioner communities	Feasibility studies & implementation	Develop technical support network Develop financial support network.	Develop suite of key drivers	Identify key procurement areas for local & national government	Implement research into key areas: e.g. integrate with other fields and approaches, policy for integration
2021			Develop contractual and negotiation guide for sharing benefits of IS			Integrate with other initiatives e.g. CERISE, SSEC, Bio-based regions.
2022	**Continuous learning and maintaining momentum**					

4 References

Baumgarten and Nilsson, 2014. https://www.diva-portal.org/smash/get/diva2:729996/FULLTEXT01.pdf

Harris S, 2007. Regulatory and Policy Issues of Regional Resource Synergies in the Kwinana Industrial Area: A Scoping Study. Centre of Excellence in Cleaner Production, Bulletin No. 2. Curtin University of Technology, Perth. Pp. 20.

International Synergies, 2018. National Industrial Symbiosis Programme. http://www.nispnetwork.com/about-nisp/a-proven-track-record

Mirata M, Martin M, Carlsson P, Harris S, Fornell R, Hackl R, Dalväg E and Källqvist T, 2018. International and Swedish State of Play in Industrial Symbiosis. Deliverable report AP1, for Re:Source project No. 6509.