Initial Study for Systemic Long-term Support to Industrial and Urban Symbiosis in Halland Region

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Summary

Industrial and Urban Symbiosis (IUS) refers to partnerships among diverse actors and sectors enabling increased value from diverse resources, including energy, water, materials, land, infrastructure, equipment and human resources. IUS can significantly boost business competitiveness and growth, improve socio-economic conditions and civil preparedness, and reduce environmental impact and therefore receives increasing attention from businesses and policy makers to create more sustainable, circular, and bio-based economic systems. With such an understanding, Regional Halland is interested in ways of providing systemic support to IUS developments in its context and commissioned Linköping University to conduct an initial study with the following objectives:

- Motivating and mobilising relevant actors to secure their interest and support to IUS;
- Improving knowledge on existing IUS practices and additional potentials in the region;
- Investigating how systemic support can be provided in terms of activities and structures;
- Increasing stakeholder knowledge and capabilities in the context regarding IUS practices and their facilitation.

To achieve these objectives, key actors representing public bodies, companies, knowledge institutions, and sector- and network-organisations in the Region were identified and informed about different IUS practices, their multiple benefits, IUS facilitation approaches and the objectives of the initial study through individual and collective interactions. Through focused dialogue with these actors, knowledge is gained about existing IUS practices as well as future potentials and their needs. Knowledge is also gain about the roles different regional actors could play in supporting IUS developments.

The findings show the presence of numerous operational IUS practices in the Region, clearly demonstrating the multiple benefits of the concept. Potentials for additional IUS developments were also identified, among others, related to:

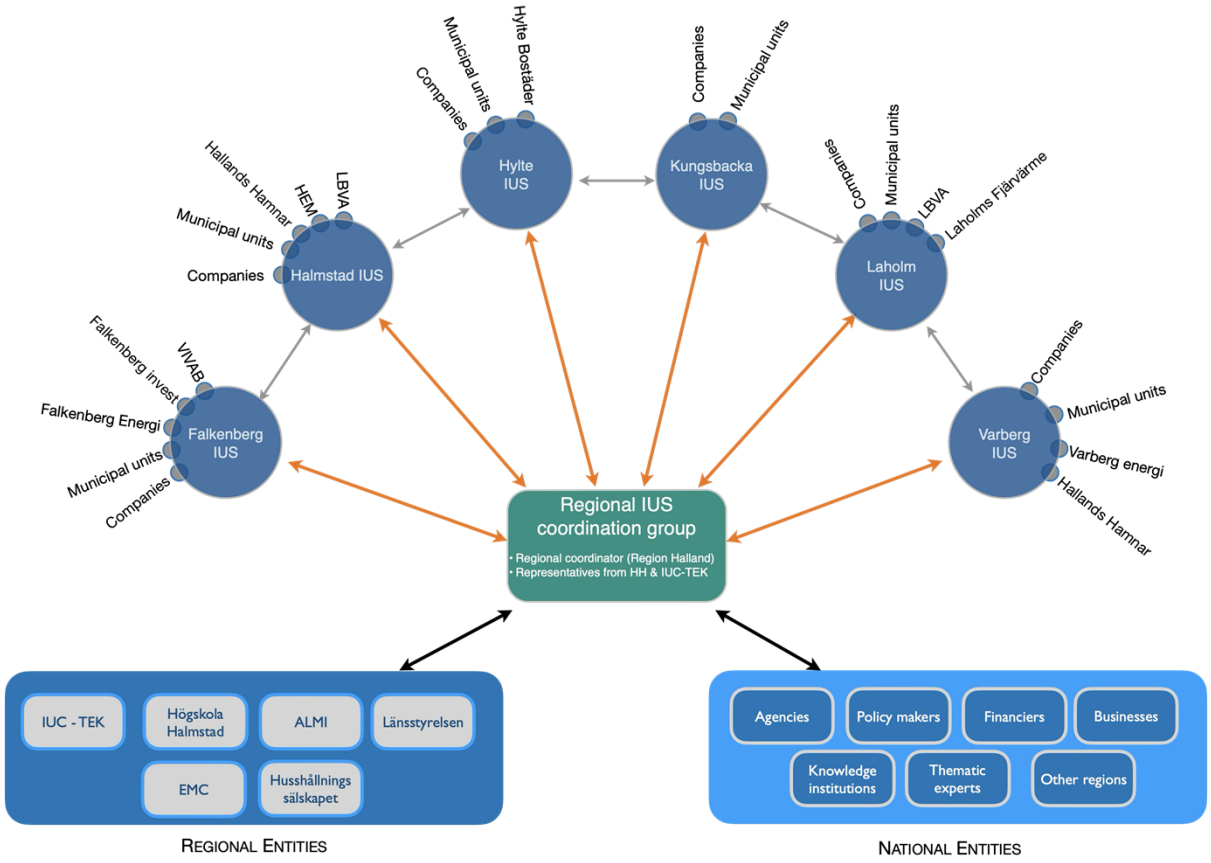
- Improved utilisation of residual heat for space heating, industrial applications and for food production;
- Increased production of biogas and bio-fertilisers from organic residues;
- Utilisation of captured (biogenic) CO_2 from industrial activities in the production of renewable fuels and chemicals;
- Alternative fuels production using from residues from industry, wastewater treatment and biogas production;
- Utility and equipment synergies to support blue economy entrepreneurs;
- Provision of technical water to industry;

Both in municipal and regional levels, there are structures and activities relevant for supporting new IUS practices. Regular business meetings and networking events organised by municipalities and the approaches to assist new business establishments are among examples that can be re-oriented and expanded to provide such support. Exeamples of specific activities to be considered to systemically support new IUS developments include:
Making political commitments at the regional and municipal levels to support IUS;

- Providing education on IUS practices, their multiple benefits, and facilitation approaches;
- Building and improving platforms to facilitate interaction among diverse actors from different sectors;
- Creating knowledge on regional IUS potentials, their potential impacts and development needs;

- Providing dynamic support to meet diverse development needs in different stages;
- Communicating intentions, achievements and potentials loudly and widely;
- Sending relevant feedback to national and EU levels for policy innovations;
- Collaborating with other Swedish and Nordic regions.

IUS development work needs to be mainly anchored in, and driven by, the municipal level organisations and such work should be supported by Region Halland and other regional organisations. Relatedly, a structure similar to the one depicted below can be effective in providing systemic support to IUS developments in Region Halland.



Abbreviations

IS	Industrial Symbiosis
IUS	Industrial and Urban Symbiosis
RH	Region Halland
LiU	Linköping university
BDU	Municipal business development units (Näringslivskontor)
DH	District heating
Carbon Dioxide	CO_2
CCS/CCU	Carbon Capture and Storage/Utilisation
HEM	Halmstad Energi och Miljö AB
VE	Varberg Energi AB
VIVAB	Vatten och Miljö i Väst AB
LBVA	Laholmsbukten vatten och avlop

1 Background and objectives

In Sweden we are also faced with interconnected and growing challenges of maintaining business competitiveness, securing the stable supply of resources for social well-being and resilience, and preserving environmental quality – all linked to excessive and growing fossil- and primary-resource use and emissions. Addressing these challenges requires rethinking what kinds of resources are used and how in our industrial societies.

Industrial symbiosis[1] (IS) refers to partnerships among diverse actors across sectors that enable increased value creation from diverse resources such as energy, materials, water, equipment, infrastructure, land and knowledge. In practice, the concept includes productive utilisation of one actor's unwanted or under-utilised resources by others as well as development of joint solutions for common needs – such as provision of utilities for energy, water, effluent treatment, compressed air, logistics, or services. It allows doing more, by using and emitting less.

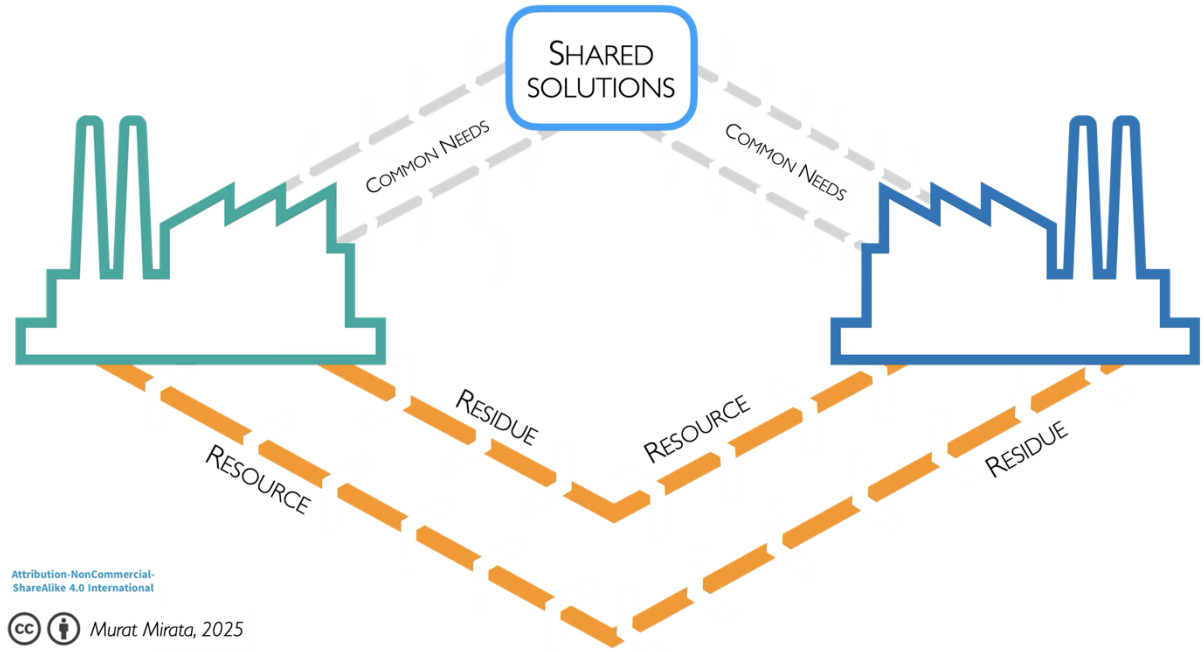


Figure 1: Simplified depiction of the industrial symbiosis concept.

To give resolute attention to the importance of including resource flows associated with communities, the term Industrial and Urban Symbiosis (IUS) entered in common use. As shown by operational examples, IUS practices have a significant potential to foster business competitiveness and growth, provide socio-economic benefits, and reduce the environmental impact. As such, IUS is recognised as an important strategy for more sustainable-, circular-, and bio-based economic systems, and more recently to enhance regional resilience and civil preparedness[2]. However, despite their potential, IUS practices remain under-developed and associated benefits remain unharvested.

[1] In our understanding, the word "industrial" refers to "man-made activities", rather than being limited to manufacturing industry. To highlight the relevance and inclusion of resource flows associated with the communities, for the remainder of the report the term Industrial and Urban Symbiosis (IUS) is used.

[2] Slätmo et al., 2025.

While majority of the operational IUS cases have developed organically, there are several examples where IS practices are facilitated through concerted efforts driven by public bodies, network organisations, knowledge institutions, or any combination thereof.

Region Halland is interested in exploring ways of providing systemic support to IUS developments in its jurisdiction and more specifically in improving relevant stakeholders' awareness of the concept, gaining an improved understanding of existing and potential IUS practices in their context, and exploring what activities and structures can be used to support new IS developments in a systemic way. Accordingly, an initial study has been commissioned together with Linköping university, the objectives of which include:

- Motivating and mobilising relevant actors to secure their interest and support to IUS;
- Improving knowledge on existing IUS practices and additional potentials in the region;
- Investigating how systemic support can be provided in terms of activities and structures;
- Increasing stakeholder knowledge and capabilities in the context regarding IUS practices and their facilitation.

Before summarising the key findings and recommendations in Sections 4 and 5, the next section provides a brief background on IUS and Section 3 gives an overview of the approach used in the study.

2 Background to Industrial and Urban Symbiosis

Industrial and urban symbiosis represents a strategic approach to improve resource productivity through collaboration. It involves long-term partnerships among different actors and sectors which enable higher value from diverse under-utilised resources – including energy, water, materials, equipment, infrastructure, and human resources.

These partnerships can be categorised into the following groups:

- **Residual resource synergies:** These involve one actors under-utilised resource being used by another as a productive input. Materials, energy and water are commonly recognised resources that are involved in these kinds of partnerships, but others such as equipment, facilities, land and human resources can be equally important resources;
- **Utility or service synergies:** These kinds of synergies involve creating shared solution for common needs. Centralised energy, water, wastewater, and compressed air systems serving multiple actors is a good example. Joint transportation, purchasing, and service contracting are also among these.
- **Knowledge and capability synergies:** These kinds of synergies involve different actors combining their knowledge and capabilities in creative ways in developing new products and services, which may or may not include tangible resource exchanges or sharing[3].

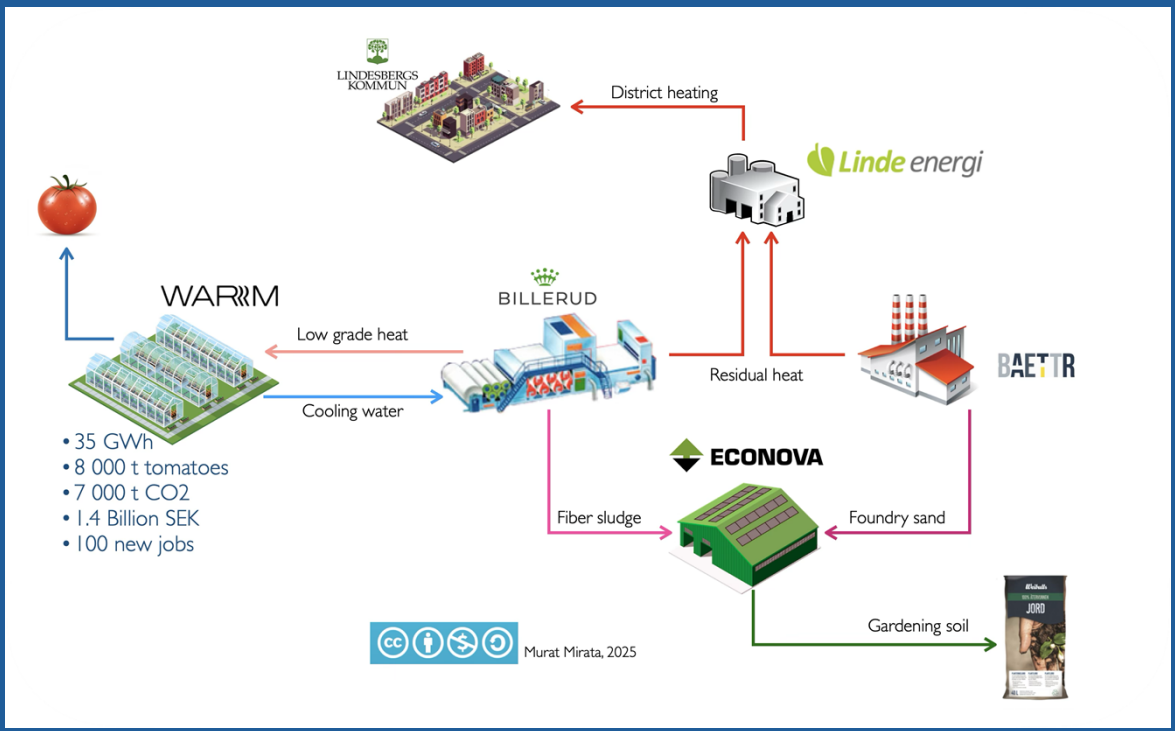
There are numerous organically grown examples of IS practices that demonstrate multiple and sizeable benefits of the concept (see Box 1 and refer to https://www.industrialsymbiosis.se/cases for more Swedish examples), that commonly include the following:

- **Improved business competitiveness:** Creating more value from under-utilised resources in partnerships helps reduce costs and risks associated with input sourcing and residue management; eliminates, reduces and/or delays costly investments; increases sales and boosts innovation capabilities, which collectively safeguard and improve business competitiveness;
- **New business development:** Entrepreneurial initiatives focusing on creating value from residuals create new businesses and employment in sectors aligned with sustainability objectives;
- **Safeguarding and increasing employment:** The above-mentioned dynamics increases and improves employment prospects which then contributes to the tax base of the regional economy;
- **Better services to the communities at lower costs:** The benefits mentioned for businesses also apply to organisations providing services to communities – such as energy, water and wastewater, mobility, waste management. This results in better, more secure and competitive service for the inhabitants.
- **Improved environmental conditions**: reduced waste generation and emissions imrpove the environmental conditions attracting more people.

[3] Mirata et al., 2017.

- **Place promotion:** municipalities and regions who host and promote IS practices attract more investments (Kalundburg and Skive in Denmark, Sotanäs in Sweden are all but few of the examples)
- **Improved regional resilience and civil preparedness**: Diversifying the sources for critical resources and increasing the share regionally available resources in meeting regional needs improves supply security for critical resources and shaves price peaks, which is increasingly important in with the geopolitical dynamics Europe is experiencing since 2019.
- **Progress towards political commitments** – as the above-stated outcomes are often aligned with existing political objectives enabling IS also enables progress with

Lindesberg is one of the Swedish municipalities where organically developed symbiotic relationships provide numerous benefits. Instead of being cooled off at a cost, high-temperature residual heat from a cardboard manufacturer and a foundry is sold to the local energy company to provide low-cost and low-impact heating to the local community. The fiber-sludge from the cardboard mill and the process sand of the foundry are taken by a gardening soil company, instead of being managed at an extra cost as waste. Since summer 2024, a newly established greenhouse purchases the low-temperature residual heat from the cardboard mill and uses this heat to grow tomatoes in a 10-hectar greenhouse. This new business produces around 10% of the tomatoes consumed in Sweden in a sustainable manner, created around 100 new full-time jobs and turned more than 70 long-term unemployed people into tax-paying citizens. The development of the greenhouse has been catalysed by the local municipality and Region Örebro in different ways.

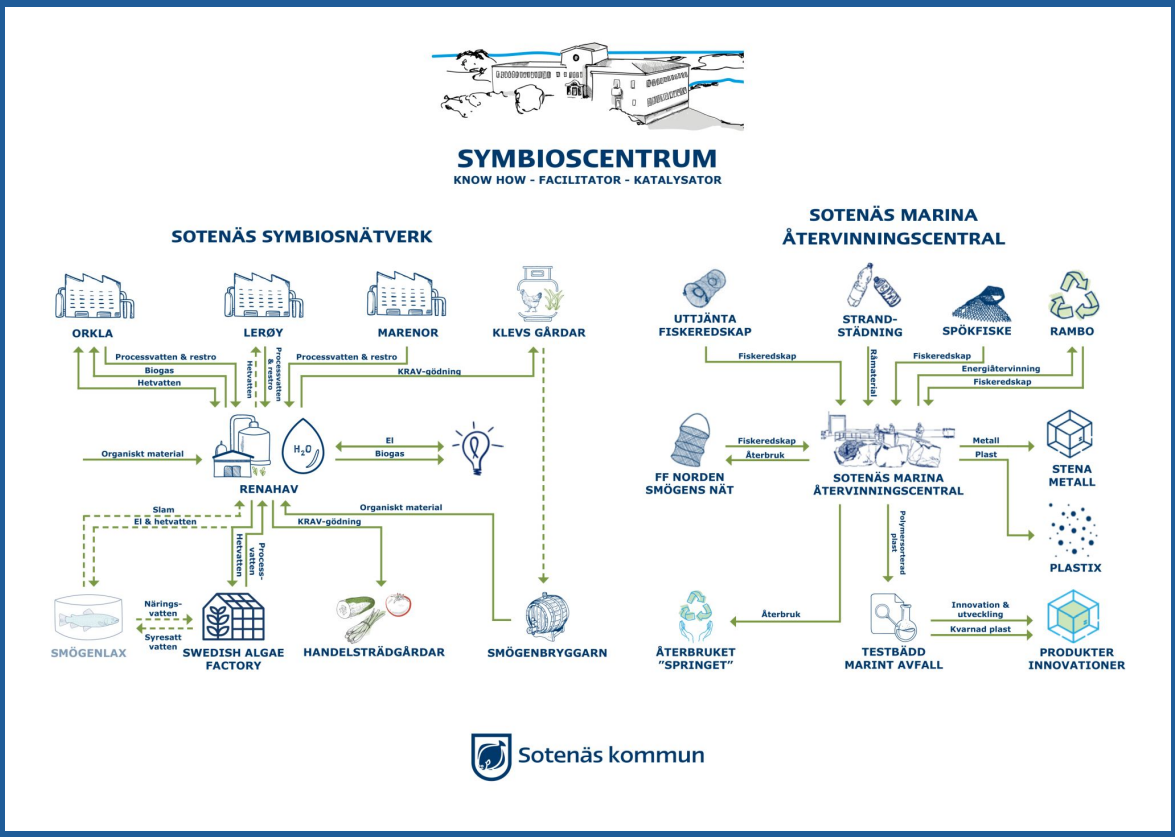


Box 1: Industrial and urban symbiosis in Lindesberg municipality.

Despite all these benefits, the IUS practice remains under-developed and significant benefits remain unharvested. Therefore, there is increasing interest around the globe, and in Sweden, to facilitate IUS developments through structured approaches to harvest associated benefits (see Box 2). Such work is informed by an understanding of the development determinants of IUS practices and different actor roles – derived from studying both organic and facilitated developments.

Stakeholders of Sotenäs first recognised the vital importance of IS when three fish processing industries providing main employment in this small municipality faced an existential crisis linked to their growing effluent volumes. A utility synergy in the form of a shared biogas plant both enabled the companies to continue their operations and started to provide them with renewable energy. Recognising the positive impacts of the concept, the municipality decided to establish the Symbioscentrum and give systemic support to new IS practices. The Symbioscentrum provides a platform for diverse actors to identify their joint opportunities and supports realisation of these by securing the support of additional actors with needed resources and capabilities.

Efforts of the Symbioscentrum and engagement of the local actors, helped create numerous new businesses and symbiotic connections in the area. These safeguard existing employment create more new ones, improve business performance, reduce the environmental impact by making productive use of locally available resources otherwise discarded. Persistently communicating its achievements, ambitions and challenges, Sotenäs has made itself an attractive destination for circular entrepreneurs, helped improve the policy context in Sweden and in the EU, and attracted significant funds for development and research.



Box 2: *Facilitated industrial symbiosis developments in Sotenäs municipality.*

2.1 Development determinants

Successful emergence and development of IUS practices depends on diverse and inter-dependent factors rooted in different domains. Table 1 provides an overview of the key determinants.

Table 1: Key determinants of IUS developments[4].

Determinant categories	Examples of factors
Techno-physical determinants refer to technical and material and technical conditions influencing the practical foundation for resource exchanges between firms.	• Local resource availability • Type and diversity of activities • Physical and chemical characteristics of resources • Geographic distribution and distances among actors • Scale and timing of actors' resource flows • Performance of existing technologies and processes • Land and infrastructure availability and accessibility
Knowledge and information determinants relate to access to, sharing of, and capacity to use information needed to identify, evaluate and implement partnerships	• Awareness of the concept and its benefits • Knowledge of needs and capacities of different actors • Knowledge of symbiotic possibilities, their impacts, and challenges • Systems supporting information needs • Confidentiality concerns
Managerial determinants refer to aspects influencing firms' willingness and ability to initiate and maintain partnerships	• Recognition and support from leadership • Relevant former experiences • Allocation of organisational resources • Business value and risk perceptions • Effective risk management/relationship governance; • Organisational trust
Economy and market-related determinants refer to the broader economic conditions and market dynamics shaping the feasibility and attractiveness of resource exchanges from financial and market-based considerations	• Cost, revenue and investment implications • Market demand and stability • Price volatility • Economic incentives • Finance and insurance availability and terms
Policy related determinants refer to the influence of regulations, government policies, and institutional dynamics supporting or hindering resource partnerships.	• Legal and regulatory frameworks • EU-, national-, regional-, and local-level policy support or hinderances; • Permit processes
Social determinants refer to human and relational aspects influencing engagement and support from key stakeholders	• Relationships and trust • Communication and familiarity • Community acceptance • Networks and their characteristics • Champions and intermediaries • Institutional capacity for collaboration

Relatedly, facilitation of IUS developments requires influencing such determinants to create more fertile development conditions. Regional Institutional Capacity for IUS (RIC-IUS) is a particularly important dynamic for achieving this. RIC-IUS is defined as "collective capacity of diverse regional actors – including businesses, public bodies, knowledge institutions, network organisations, civil society– to take collective action towards IUS". RIC-IUS is regarded a dynamic force developed in the context of its use, through the interactions and activities of the actors who are also the beneficiaries. RIC-IUS develops through advancements along the following inter-connected dimensions:

[4] Adapted from Mirata, 2018. International and Swedish State of Play in Industrial Symbiosis. A review with proposals for scaling up industrial symbiosis in Sweden. Re:Source Strategic Innovation Program.

- **Relational capacity:** Improved formal and informal relationships among diverse actors increase mutual understanding and trust, help people identify areas of common concern (and opportunity), and increase willingness to work together in the face of uncertainty;
- **Knowledge capacity:** By collectively accessing, generating and using information and data actors improve their knowledge on symbiotic possibilities, their expected impacts and development challenges and needs. Increased knowledge capacity enables identifying promising opportunities to be prioritised and avoids wastage on unfeasible alternatives;
- **Mobilisation capacity:** this refers to the ability to mobilise actors who can bring the diverse resources needed for developments in different stages[5].

IUS developments can be facilitated through advancement of relational-, knowledge-, and mobilisation-capacities by coordinated efforts. This is visually depicted in **Figure 3**.

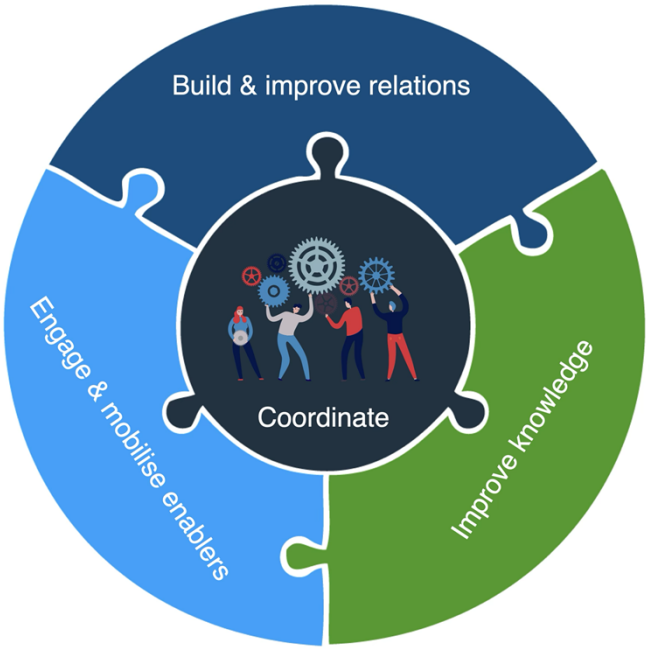


Figure 3: *Facilitating IUS developments by improving regional institutional capacity.*

Actual facilitation activities needed in given contexts to improve institutional capacity for IUS will depend on the contextual conditions. However, following activities may typically be needed:

- Raising the awareness of stakeholders about IS and its benefits;
- Creating platforms to intensify communication and relationship building among regional actors;
- Creating knowledge about symbiotic possibilities, their impacts, and challenges;
- Securing large-enough and stable supply and demand conditions;
- Performing technical assessments, research and development;
- Assisting the development of suitable business models and agreements;
- Assisting the acquisition of legal- and social-license to operate;
- Assisting access to land and infrastructure;
- Assisting access to finance;
- Influencing the policy context;
- Legitimising and communicating achievements, potentials and needs.

[5] Boons et al., 2012.

IUS literature and practice also highlights several actor roles in relation to the facilitation activities , which are summarised in Table 2.

Table 2: *Key actor roles relevant for IUS developments*[6].

Actors	Description
Local/regional champions	Key individuals within the regional industrial system with the ability and energy to engage others, push for and broaden IS participation among firms.
Organisational champions	Key individuals within an organization that can get others interested in the concept and that can secure support for the identified opportunities.
Physical anchors	Actors that control large and stable resource flows around which new synergies can develop.
Institutional anchors	Actors with the possibility to bring actors together to facilitate interaction, to provide education, to give development, financial and policy support, and to legitimize and disseminate learned lessons.
Coordinators	Actors that can oversee and drive diverse range of activities needed to realise symbiotic practices.
Brokers	Facilitate transactions between other actors who lack access to, or trust in, on another. Brokers can be sub-divided into relationship-, information-, and knowledge-brokers
Relationship brokers	Actors helping others who are interested in collaboration but who lack experience, knowledge or contact with other interested firms by making introductions.
Information brokers	Actors collecting information on what different actors need and can offer, in order to identify compatibilities and inform relevant parties about potential options.
Knowledge providers/brokers	Actors who can fill knowledge gaps by providing knowledge directly or through connections to other holders of knowledge.
Technical system operators	Actors who own and operate systems for transferring and processing energy, water and material resources.
Regenerators	Actors specialised in creating value from residuals and wastes.

[6] Adapted from Baumgarten and Nilsson (2014) and Mirata (2018).

3 Approach

In early stages of the study, relevant stakeholders from municipal organisations, businesses, and network- and knowledge-organisations of the region were identified in dialogue with representatives from Region Halland (RH). Meetings were then requested with these, first by project's owner from RH, and afterwards by a consultant engaged in the project to assist contacts.

An awareness-raising seminar was organised for the Business Development Unit in RH focusing on principles, operational examples, multiple benefits, and facilitation techniques of IUS as well as the objectives of the study. In subsequent meetings, business development unit representatives of different municipalities were given similar information. Then, through a dialogue, knowledge about relevant conditions, actors and activities in their context is gained. These actors were requested to enable contacts with companies in their contexts, to which only some responded. An offer was also made to all municipalities to organise IS-related awareness-raising and knowledge-enhancing activities targeting companies and other relevant stakeholder in their context. Consequently, such activities were performed for stakeholders of Falkenberg, Halmstad, Hylte and Laholm municipalities.

A "synergy identification workshop" was planned and announced for regional companies, which intended to both identify new symbiotic opportunities for the region and to give experiences to regional stakeholders on how to organise such activities. This workshop had to be cancelled due to lack of company participation.

To provide knowledge and inspiration to regional stakeholders on IS facilitation approaches, a study trip was organised to Skive, Denmark, where participants also had the opportunity to interact with stakeholders working with IS facilitation in Norway. Only one person from the region has joined this study visit.

Meetings were also held with representatives from regional organisations and initiatives whose work is considered relevant for IS developments, such as IUC-TEK, Högskola Halmstad, EMC Network, Hallands Hamnar, Hushållningssälskapet and others that are considered relevant to support IUS in the context. In these meetings similar introductions to IIS and the project were provided and different roles these actors could play were discussed.

To gain an improved understanding of existing IUS practices and experiences and to identify new potentials numerous companies, including utility- and port-operators, were contacted and 18 semi-structured interviews were conducted [7]. During these interviews, companies' needs and resources that can be made available to others were discussed, along with the views regarding perceived needs to support new IS developments[8]. Identified new opportunities are summarised in Section 4 of this report along with the expressed development needs.

The insights gained through these interactions were synthesised through the lenses of academic knowledge and experiences from practice to identify regional strengths, improvement areas and actions, and appropriate structures, which formed the basis for formulating suggestions.

[7] For Hylte and Falkenberg contexts independent, yet related, studies were conducted by students taking the "Industrial Symbiosis" Master's course in LiU, within which interviews were conducted by diverse stakeholders. Relevant findings from these studies are integrated into this report.

[8] List of actors interacted with during the study is given in Annex 1.

4 Key Findings

This section summarises the key findings of the study.

4.1 Industrial symbiosis practices in Region Halland

In Halland, numerous industrial symbiosis practices are already in place and provide multiple benefits. Examples of such practices are provided in **Figure 4** and **Table 3**.

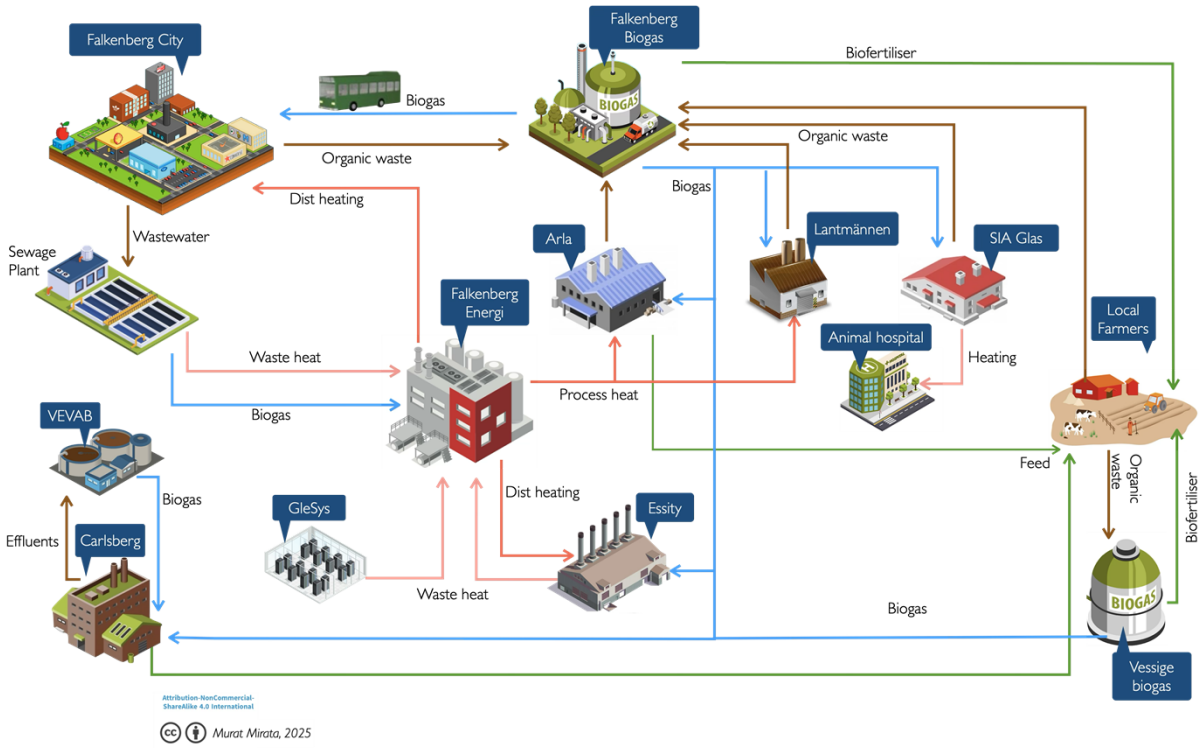


Figure 4: *Examples of IUS practices identified in and around Falkenberg.*

Table 3: *Examples of other operational synergies in Halland.*

Location	Actors involved	Nature of the synergy
Halmstad	Höganäs AB – HEM AB	Residual heat synergy
	Stena, RagnSells – HEM AB	Combustible waste as fuel
	HEM AB – Viking malt	Utility synergy for process heat
Laholm	Laholms Fjärvärme – Local companies and real estate owners	District heating with forest residues
	Södra Hallands Kraft – local farmers and food production companies	Upcycling of organic wastes
Hylte	Hylte Paper – Hylte bostäder	Residual heat for DH
	Derome – Hylte paper	Wood residues for paper production
	Derome – Uddevalla energi (outside Halland)	Sawdust for pellets production
	Smurfitwestboard – recycling operations in Piteå	Production residuals for new material prod.
Varberg	Södra – Varberg Energi	Residual heat for DH
	Södra – Varberg Energi	Residual bark as fuel

	Varberg Energi – various companies	Utility and knowledge synergy for flexible electricity utilisation

Benefits provided by these synergies include, but not limited to:

- Reduced production costs for businesses;
- Additional revenues for businesses;
- Avoided or reduced investments for businesses;
- Reduced energy, water and waste utility costs for the communities;
- Improved supply and price stability;

4.2 Relevant characteristics and conditions in the region

Several structures and activities relevant for IUS developments have been identified during the study and summarised in this section, first at the regional level and then specific to the municipalities.

Regional level characteristics

With its extensive coastlines and agriculture and forestry land, industrial activities in diverse sectors, and several urban centers the region has a good diversity of resource base and economic activity. Moreover, being placed between Skåne and Västra Götland offers an advantage to access resources and attend to needs in these regions[9] with large economic activity. Presence of a natural gas pipeline, DH networks in multiple towns, significant off-shore wind production capacity, and three ports provide significant techno-physical leverages for new developments.

The regional businesses are characterised as having strong entrepreneurial spirit and collaborative attitude, with relatively large share of privately owned businesses with headquarters in the region. These are important strengths for IUS, creating stronger relationships and communication as well as local decision power. Clustering within region's diverse industrial segments is also limited. While this can be seen as a weakness for business development within individual sectors, it represents a strength for IUS, which focuses on resources and cross-sectoral collaboration, and in times suffers from strong silo structures. While the interviewees report having good communication and relationships with others, they also recognise a need to broaden and intensify focused communication on resource needs and haves among wider group of regional actors from diverse sectors and express an interest in platforms that would enable these.

All municipalities of the region have processes aimed to ease business development processes (företagslots) that are regarded effective. Although these workflows have a good potential to also highlight symbiotic possibilities and support their realisation, this is not commonly used (Falkenberg is a rare exception).

Regional actors

There are also several organisations operating at the regional level with important capacities and relevant work, including the following.

[9] Chemicals and metal processing industries in these regions have ambitious sustainability commitments and Halland region can orient itself to towards providing the renewable inputs they will require.

Region Halland

Region Halland is committed to support more sustainable business development in the context and they recognise the importance of IUS in reaching such an objective – as manifested in commissioning this study. Some companies positively recognise RH's stronger interest in this area. Moreover, the region develops and supports relevant strategies (e.g. energy, planning[10]) and has access to communication experts. RH also distributes EU, national, and own funds for projects that are aligned with objectives set at these levels. All of these can be very important for IUS developments. RH holds a good potential to be an institutional anchor for IUS.

Larger manufacturing companies

Several large companies (e.g. Södra, Höganäs, Hylte Paper, Derome, Viking malt, Carlsberg, Vattenfall) have large-scale operations associated with large scale and relatively stable resource flows. Most of these also have industrial symbiosis experiences and look positively on additional resource synergies. These represent important "physical actors" around which additional synergies can be developed.

Utility companies

Regional utility companies working with energy and power, water and wastewater, and solid waste have experience with, and interest in, IUS practices. Their strong technical knowledge and capabilities, ownership and control over important infrastructure, and their administrative strengths – such as existing permits and ledningsrätt – qualify them to serve as effective "technical system operators" for the development of new synergies.

Högskolan i Halmstad (HH)

As region's main higher-education and research institutions, HH has strong competencies, among others, in district heating technologies, biogas systems, business entrepreneurship, circular economy and sustainable city development. Furthermore, HH has strong experiences with and capabilities for conducting joint applied research and development projects in collaboration with smaller and larger businesses and public actors of the region. HH is also an organisation where High Five, regional node supporting innovation and entrepreneurship, is anchored. Last, but certainly not the least, students enrolled in relevant education programs of HH, such as innovation studies, can be a valuable resource for IUS developments. As such, HH is a qualified actor to serve as a knowledge provider/broker and to contribute to coordination efforts.

IUC – TEK

IUC – TEK is a central organisation with good connections and communication with regional businesses, and in particular SMEs, and is perceived as having solid track record of delivering value[11]. IUC TEK works with resource efficiency in businesses, which is both an important step to precede industrial symbiosis practices[12] and supports the knowledge foundation for supporting symbiotic possibilities. Being part of the network of 21 other IUC's in other Swedish regions, some of which

[10] Regional Halland is one of the four Swedish regions involved in a pilot to work with land-use planning at the regional level.

[11] For example, many interviewees referred to TEK competence project that is regarded to bridge important needs in businesses with different support system actors accessible.

[12] The priority in resource transition needs be on using less resources and reducing under-utilisation as much as possible in individual actors/plants before finding alternatives for residuals that cannot be avoided through IS.

are already working with IS programs/projects offers another strength to draw in knowledge and experiences. The organiation is involved in the "Industry in West" initiative, which aims to increase knowledge about circular economy and business models among SMEs, which aligns well with IUS developments. As such, IUC-TEK is well-qualified to serve as a relationship-, information- and knowledge-broker.

Invest I Halland

As the regional organization responsible to promote inward investments in Halland, Invest in Halland supports international companies looking to establish or expand operations in Halland by providing strategic advice, local insights, and connections to regional stakeholders. Representatives of this organisation are already familiar with the IUS concept and promote symbiotic possibilities in their work. The organisation can also work with actively targeting businesses that can be a good match for the region's industrial and resource base. As such, the organisation can serve as an important relationship- and knowledge-broker for new IUS developments.

ALMI

As one of the important building blocks of the Swedish innovation and business support ecosystem, ALMI offers financing, business development, and advisory services to small and medium-sized enterprises (SMEs). For IUS developments, ALMI can play important roles in supporting circular practices in existing SMEs and regenerative[13] entrepreneurs with business model formulation and investment assessment and support.

EMC

As the regional membership organisation for sustainable business development, EMC network is an important structure for providing education and inspiration and for coordinating initiatives that serves the collective benefits of their members. Within this initial study, the EMC network has already served as an effective platform to diffuse knowledge on IUS to different businesses. The organisation is well-qualified to serve as a relationship- and knowledge-broker and to contribute to coordination efforts.

Hushållningssällskapet

As a membership-based research, advisory and development organisation for agricultural and rural sectors, Husshållningssällskapet is an important organisation with good link and communication to actors working with land-based bio-resources and has experience and on-going projects to create more value from the resources they control. It is also connected to its sister organisations in other parts of the country. As such, Husshållningssällskapet is a qualified actor to serve as a relationship- and knowledge-broker.

[13] In this context "regenerative entrepreneurs" refer to those that adopt value creation from residual resources as their core business activity, which differs from "regenerative agriculture" where the term is commonly used.

Falkenberg

Of the six municipalities in Halland, Falkenberg seems to be most advanced when it comes to structures and activities relevant for IUS developments. Businesses in this context already have a diverse range of synergies[14] (see **Figure 4**) and are interested in creating additional ones. For example, local energy utility company bringing more residual heat from other industries in Falkenberg, and from Gecko's in Ullared, and exploring alternative biomass sources that can be used as fuel.

The municipal Business Development Unit (BDU) provides several platforms enabling relevant actors to form strong social networks, and to discuss and act upon common interests, which are also supported by the municipality. Klimatinitiativ[15], the breakfast meetings of Företagsträff, and the energy management team are examples of these where actors interact, find collaboration opportunities and mobilise. These are important structures for more systemically introducing and diffusing IUS into relevant actors' agenda.

Although not formalised, the BDU also works with facilitating new IUS practices in connection to new establishments (Företagslots). More specifically, the unit tries to build a diverse business activity base in the municipality (against a common trend of establishing more logistics centers) and considers multiple implications of new businesses – including environmental performance and compatibility with local economic activity). As part of its dialogue with new developers, BDU also pays specific attention to resource needs and expected residuals of prospective developments. Using such knowledge it explores integration possibilities and facilitates communication between developers and existing actors to further discuss symbiotic potentials. They also work with land allocation to ease synergy development (e.g. by placing actors with residual heat close to DH grids) contacts.

Another strength in Falkenberg is the presence of a local investment network, FBG Invest, and its close cooperation with the city's business development unit. Formed by local investors and companies, this network has the mandate to invest locally and is interested in leveraging local impact. The network has been instrumental in the establishment of new actors whose solutions intend to more value from locally produced side streams. The upcoming energy strategy of the municipality includes IS as an important concept, and municipal employees recognise the need to integrate IS consideration in their waste management strategy and detailed planning processes.

There are plans to upgrade wastewater treatment facility in Falkenberg, which is an important phase to explore and implement new synergies.

Halmstad

In Halmstad, local energy utility company Halmastad Energi och Miljö (HEM) and several local industries have long experiences with different IUS practices and are also interested in establishing new symbiotic partnerships. HEM has on-going discussions and plans to increase the share of residual heat in the DH systems in connection to new residential areas and expansion of HH's campus. Local water and wastewater utility company (Laholmbuktens Vatten och Avlop AB) has intentions to provide technical water from treated wastewater and in the past had project applications to explore alternative uses of wastewater treatment sludge after solar-drying.

[14] Thanks to these synergies, residual heat makes up 25% of the heat provided by the DH system in Falkenberg.

[15] More information on Kliamatinitiativ is available at: https://kommun.falkenberg.se/bygga-bo-och-miljo/hallbar-omstallning/falkenbergs-klimatinitiativ/om-falkenbergs-klimatinitiativ

In Halmstad, the Business Development Unit (BDU) of the municipality organises regular meetings with local companies, called Guldmorgon, to profile different areas of development interest. The same unit also develops forums (Näringslivsforum) for more elaborate interaction and knowledge exchange in areas demanded by the businesses. There is also a newly formed network of companies involved in the value chain of producing fitness and strength training equipment and who want to cooperate on sustainability issues. IUS has not been a topic in any of these forums/networks but actors recognise the utility of these structures to create awareness around and work towards IUS.

The BDU also recognises the growing potential of sustainability considerations in relation to new business establishments. In recent years, the unit brings questions around secondary building material utilisation and technical water use in discussions with new establishments. The unit also recognises the importance of working with IUS developments more systemically but lacks the expertise to do so.

Hylte

Companies in Hylte have good communication and a collaborative spirit, which has manifested itself also in material partnerships such as equipment sharing. Indstriträff brings several key businesses regularly together to discuss competence needs. This platform can be a good starting point to discuss IS opportunities and doing so will require participation of technically oriented personnel from companies, in addition to those that are mostly working with human resources.

Geographic distribution of businesses in this context makes synergy development among existing companies difficult. New IUS developments need to take place by attracting new actors to the municipality or finding suitable partners outside the municipality with whom longer-distance resource exchanges will be feasible[16]. This, however, requires a good understanding of local needs and how these can be complemented with capacities elsewhere in the region or in the country. Currently, the actors in the context lack such capacity.

In Hylte, Hylte Paper deserves special mention as a major employer with large physical resource flows and operating under tough business conditions. Currently, organisational resources of this company is concentrated on finding innovative alternatives for its traditional products facing declining demand. Once on the other side of this journey, Hylte paper is likely to serve as an anchor around which multiple new synergies can be created.

There is industrial land available in the context and work is under way to create more land. The municipality recognises the importance of creating new synergies when new businesses are established in their context and is interested in supporting such developments. However, currently, the municipality lacks human and knowledge resources to effectively facilitate a more symbiotic development.

Laholm

The industrial landscape in Laholm is dominated by smaller-sized mechanical workshops specialised in metal products and few food producers, and farming. In this context “Made in Laholm” is one of

[16] Derome and SmurfitWestrock already send their by-products to further away Swedish regions for valorisation demonstrating the feasibility of such practice.

several business networks in the municipality that arranges various forms of meetings to strengthen members and collaborate with the municipality. Regular breakfast meetings of this network, which are combined with site visits, are highly valuable activities for improving mutual understanding among local actors and for identifying new symbiotic development possibilities[17].

The municipality has designated 200 ha new land with very good transportation prospects[18] and is working to plan more of the municipality's land reserve to be able to offer opportunities for business establishments in the future. The industrial land is planned near good infrastructure with the idea of optimizing opportunities for future establishments, such as joint resource utilization. So far, these issues have not been prioritized to the same extent as, for example, in Falkenberg. Further preparation of this land (in terms of key utility infrastructure) and development of new activities in this area offers an important opportunity. Laholm has its own workflow (Näringslivslots) to help and support new business establishments. Currently this workflow is rather very conventional and lacks elements to foster sustainability or synergies among actors. This function can be developed to, for example, improve the work with IUS. The municipal representatives feel that they lack human and knowledge resources to foster such dimensions.

Laholms Fjärvärme is a recently established private operator who delivers competitive and low-carbon district heating to local industries as well as private real estate owners using forestry residues. The company has ambitions to scale up district heating usage in the municipality but has had limited success in securing interest from important actors, including municipal real estate management company. Recently, a municipal employee has been tasked to explore ways of expanding district heating in the area. The same individual has closely participated in various activities involved in this study, and understands the IUS concept, its multiple benefits and development needs well. That individual can serve as an effective champion and coordinator for IUS developments in this municipality.

Varberg

Being home to the Södra mill, Ringhals nuclear power plant and one of the ports operated by Hallands Hamnar offers significant techno-physical potentials for Varberg thanks to the scale and diversity of resource flows connected to these actors.

There are operational synergies in this context, most of which are connected to Södra plant’s residual heat and forestry residues in Värö. Varberg Energi (VE) is experienced and progressive with energy use, residual energy utilisation, and with utility and knowledge synergies for flexible energy systems. The company engages in dialogue with existing and new establishments to explore optimal solutions for the individual actors as well as the entire local energy system. However, the company recognises the importance of having a dialogue with new developers at an earlier stage and would like to have more support from the municipality for this.

The integrated operations of the Södra group in Värö generates very large amounts of residual heat, of which only about 10% is productively utilised by VE. When the upgrading of the Ringshalls nuclear power plant is finalised, significant amounts of additional residual heat could be made available for productive use. Considering the expanding residential, commercial and industrial building stock in the context, VE is interested in increasing the share of industrial residual heat in the district heating

[17] Within this study, two new symbiotic potentials were identified in one of these breakfast meetings combined with site visits.

[18] The land is literally by the side of E6 highway, and has good access to railroads.

system. However, bringing in lower temperature waste heat to the system requires significant investments. Available residual heat can also be used in a range of other industries, however this is today not possible due to lack of industrial land for third parties in the vicinity of the Södra site. Some new industrial land was designated for industrial use in the municipality, but its location does not allow utilisation of available residual heat. However, the business developments unit is attentive to integration possibilities among new establishments on this new land and gets significant help from VE. Municipality also has plans to create an additional 50 ha of industrial land. The municipality is also home to Sweden's largest and most efficient port for forestry products, which is recently relocated out of the city center leaving its former site for new residential developments. With all these large-scale changes, the municipality has significant potential to create new symbiotic possibilities at the design stage.

The BDU in this municipality interacts with businesses regularly and brings their needs and concerns to other municipal departments. Its support system for new businesses also provides a "one stop shop" approach by coordinating interactions with all relevant municipal units and other regulatory bodies. However, it is not clear whether the diverse businesses interact among themselves

Kungsbacka

With the exception of few, the business landscape in this municipality is dominated by many very small companies (> 10 employees). The municipal BDU maintains bi-lateral communications with existing businesses and supports them with their needs by establishing contacts with relevant municipal units, universities and actors of the regional innovation and support system. Physical resource needs and haves are not typically a part in these interactions, which are dominated by competence and market needs. Some companies in this context are working with creating circular flows in the wider society (e.g. with construction materials and copying machines) and seek the support from BDU to explore developing local testing and accreditation support services[19].

There is around 5 ha of development land available for industrial usage, and the municipality has plans to designate an additional 30 ha. Resource use issues are discussed with the new developers only to determine whether the infrastructure available in the municipality could provide basic resources needed (electricity, natural gas and water). Some large-scale development ideas had to be turned down due to constraints to provide required resources. Dialogue with new business developers do not include discussions on symbiotic connections with other activities in the municipality.

The municipality is in the process of building a new wastewater treatment plant for the inhabitants, which is expected to apply more advanced treatment and sludge management options. This offers a unique window of opportunity to explore possibilities for productive applications for both treated water and wastewater sludge, initiate relevant partnerships, and integrate necessary design changes. This is particularly relevant given the new industrial land that will be available for new establishments, concentrated presence of blue-innovation entrepreneurs in Glommen, and the increasing demand for alternative fuels from regional energy operators.

The municipal BDU also appears to have limited human resources and seemed unable to prioritise IUS related discussions during our study.

[19] Currently, different materials are sent to Germany for different tests, creating excessive costs and time lags.

4.3 Identified potentials for new symbiotic developments (and their needs)

Identified potentials, and some of their key needs, are summarised in this section.

Residual heat utilisation

Residual heat from different industries is already utilised to varying extents for space heating in four of the Halland's municipalities. However, significant amounts of additional residual heat is available from different actors and is currently wasted (as stated above, around 800 to 1 000 GWh of residual heat is reportedly cooled off to the sea by the Södra operations in Varberg alone). Substantial amounts of additional residual heat availability is expected after retrofitting Ringhals nuclear power plant and if any hydrolysers are installed in the region. There is a growing interest to bring more residual heat to the district heating systems, motivated by: a) production assets of region's energy companies getting older; b) the need for residential, commercial, industrial and public buildings is increasing, and; c) the energy companies have gained positive experiences with residual heat utilisation. The energy utility companies already have ideas, on-going discussions and even plans for increased utilisation of residual heat in Halmstad[20], Falkenberg, Varberg and Hylte[21]. The exact quantities have not been possible to identify, however, investments of more than 1 billion SEK are considered possible to avoid with increased residual heat utilisation.

Going beyond space heating, residual heat can be used in industrial processes directly – e.g. for drying biomass – or after upgrading its temperature with heat pumps. This potential is further elaborated in relation to synergies concerning blue economy entrepreneurs and alternative fuel needs of energy companies.

Last, but certainly not the least, residual energy, and particularly the low-temperature fractions with limited alternative applications, can be used for food production in greenhouses. In fact, if half of the energy currently wasted by the Södra mill were to be used for growing tomatoes in nearby greenhouses, produced volumes will cover entire Swedish demand and several hundred new jobs can be created[22].

Using more residual energy can provide sustainable and competitive energy to users, can reduce costs and generate new income streams for generators, and can increase overall energy resilience in the regional economy. Furthermore, producing other products, like greenery, can significantly enhance region's preparedness and resilience potential crises situations affecting food imports

Needs

Interviewed energy companies highlight the need to map residual heat availability from diverse activities – such as manufacturers, data centers, cold storage facilities and others – to get a better understanding of what is available, where and when. They mention that they have some knowledge from their existing contacts but consider this inadequate. Moreover, interviewees highlight land planning and industrial placement as a critical techno-economic determinant for such synergies. This is a particularly big, wasted opportunity in Varberg where lack of nearby industrial land is one of the

[20] Halmstad Energi och Miljö is in discussions with Höganäs AB to bring around 20 GWh/y of additional residual heat into the district heating system to serve new development areas in the city.

[21] Hylte Bostäder has a Klimatklivet application to capture 1.6 MW of residual heat from AGES to provide residential heating in Unnaryd.

[22] Calculated based on the fact that using 50 GWh residua heat in a newly established tomato greenhouse in Lindesberg produces 8 000 t/y of tomatoes covering 10% of Swedish demand and generates around 100 new employment.

main factors limiting productive utilisation of large amounts of residual heat. Therefore, making industrial land available close to residual heat generators, concentrating new actors with heat demand in the same area, and placing new residual heat producing actors in areas with easy access to DH systems, or other energy demands, will create more fertile conditions for the valorisation of an important resource. Residual heat synergies may also require substantial new infrastructure and equipment investments, making public grants critical.

To improve valorisation of residual heat, work is also needed on demand side. Investigating the energy needs of new developers, identifying and targeting activities that can utilise available residual heat, involving energy utility companies earlier in discussions, and encouraging eligible actors to consider residual heat usage can help increase productive utilisation of this resource. Seasonality of heat demand and cooling needs is also an important aspect here, as the industry is particularly interested in providing residual heat in the summer months when the space heating demand in DH is is low. Relatedly, finding alternative users with heat demand in spring and summer (such as biomass drying covered in coming sections) would provide strength.

Integration of Region's district heating networks

In the region, there are numerous facilities and activities that can provide heat energy for space heating as well as for industrial operations. Currently, the district heating networks connecting producers and users of heat operate in individual municipalities and in isolation from one another. Integrating these networks with each other can enable wider utilisation of both low-cost and low-carbon heat sources and diversify access to different production assets during times of extra energy need – collectively providing sizeable economic and environmental gains[23].

Needs

Integrating separate district heating grids will require thorough analyses of heat generation profiles (in terms of quantities, qualities and costs) from different industries. It also requires substantial investments into pipelines between different municipalities. Equally important, it requires the development of business models and agreements among energy utility operators and different heat providers, for which open communication on production profiles and cost structures will be central.

Farm scale biogas systems

According to a 2022 study, approximately 650 GWh of additional biogas can be produced in Halland using organic residuals available in the region (and 480 GWh by using agricultural residues and manure alone)[24]. This highlights the importance of additional farm-scale biogas systems, for which successful examples, like Vessige biogas, already exist in the region. Biogas faces increasing demand from industry and is an important part of making industry and transport more climate friendly. It also provides fertilisers, a critical input, and additional income streams to farmers, and improves regional resilience. Hushållningssälskapet also drives innovation projects aimed at creating higher-value products from biogas digestate– such as pellets, consumer fertilisers. There is also strong interest from the farming community to make investments into new farm-scale biogas systems.

[23] In Skåne the district heating systems of Helingborg, Landskrona, Eslöv and Lund is already integrated and provides sizeable economic and environmental gains. Further integration with Lomma is under way.

[24] Broberg, K., Lindahl, L., Tamm, D. 2022. Potentialstudie för biogassubstrat i Västra Götaland, Halland, och Skåne. RISE Report 2022:58.

Needs

While organic material available from agricultural and animal farming provides sufficient substrate, the techno-economic feasibility of the farm-scale biogas systems would be increased if bio-residuals from communities and industry can also be used in farm scale biogas units. This requires dialogue with generators of suitable residuals, which can be supported by municipalities. The business case for the interested farmers is strongly linked to accessing first an upgrading[25] plant to remove impurities and then having a grid connection to distribute the high-purity bio-methane to the customers. A low-pressure plastic piping grid will technically enable such connections, but their investment requirements are considered too high for the farmers to bear alone. There is, therefore, a need for securing investment support or for the third parties to make the initial investments to enable such connections (farmers are positive about gradually paying off the investments and acquiring the ownership). Relevant stakeholders believe that Halland's tillväxtutskott should be contacted to discuss their potentials to support. Experiences from other Swedish regions also indicate that energy utility companies may support such investments. Nordion energi, which manages gas grids nationally and has ambitions to expand pipelines to enable increased renewables, can be another actor that can help. The costs and time associated with lengthy administrative procedures for getting permits for biogas plants and to connect to the natural gas grid is also considered too high. For this, Länsstyrelsen and other involved agencies could investigate more efficient and streamlined permit processes. For biogas developments, financing and insurance, specially if the establishment has an innovative dimension, are also important bottlenecks. Here, regional actors can explore possibilities to access to National and EU grants and help secure better financing conditions. Lastly, for biogas having a stable and certain market demand is important. This can be assisted by the local companies and public bodies showing preference to biogas.

Alternative fuels for energy production

Two of the interviewed energy companies highlighted their interest to explore alternative fuel sources to replace wood chips[26], the price of which has increased significantly in recent years. The fibre sludge produced by the two pulp and paper mills, the sludge from regional wastewater treatment plants, and even the digestate produced by regional biogas operators can be turned into such alternative fuels for the energy plants.

Needs

Fiber sludge, wastewater treatment sludge, and biogas digestate all need to be dewatered and dried before it can be used as fuel in boilers. Existing dewatering equipment in wastewater treatment plants, and the utilisation of region's extensive industrial residual heat for drying can be explored for such fuel production. Moreover, the regulatory feasibility and emission implications of using such alternative fuels needs to be checked as the plants using wood chip (and bark) neither have the permit to combust waste, nor the gas cleaning infrastructure to remove harmful substances.

(Biogenic) Carbon Dioxide (CO_2) Capture and Utilisation

Significant amounts of CO_2 is currently wasted into the atmosphere by industrial activities in Halland, as well as in neighbouring regions, and contribute to climate disruptions. There is, however, a

[25] Depending on the used substrate, raw biogas can contain more than 55% of CO2 and smaller amounts of other impurities, all which need to be removed to obtain bio-methane with high purity that can be used as a transportation fuel or can be injected to the natural gas grids.

[26] One of these companies have replaced a considerable share of wood-chips with bark but still in the lookout for cheaper alternatives.

growing recognition that CO_2 will be a critical ingredient for creating more sustainable fuels (e.g. e-methane, e-methanol) and feedstocks (e-plastics) of the future.[27] This creates important opportunities for industries emitting CO_2, particularly with a biogenic origin. A combination of primary and secondary data show that that Södra plant in Värö, HEM, Hylte Paper, Essity, Falkenberg Energi, and Statkraft are among the largest direct emitters of CO_2 in the region, collectively emitting more than 2 million tonnes of CO_2 annually[28].

Some of these companies, like HEM and Falkenberg Energi, have been involved in CCU related feasibility studies and others like Södra express an interest to explore this are more closely. Hallands Hamnar (HH) also recognises the growing importance of reaching scale and has taken part in HEM's feasibility study on Carbon Capture. Capturing (biogenic) CO_2 generated by different industries and using it in clusters involving additional renewable electricity, hydrogen, fuels and chemicals producers can enable significant amounts of sustainable fuels/feedstock production[29]. HH aspires to becoming a logistics hub for CO_2 to serve such clusters, by even consolidating CO_2 that can be captured even in the neighbouring regions of Halland.[30] However, currently there is higher probability of shipping captured CO_2 to Grenaa in Denmark, where cluster development is more advanced. While potentially allowing for faster mobilisation on CCU, this can be a missed opportunity for developing a sustainable industry cluster the Halland.

Needs

Capture and utilisation of CO_2 in sustainable fuel and chemicals value chains needs the presence of various techno-physical, market and economy related and political conditions. Techno-physically, infrastructure to capture, transmit and store of the CO_2, for sufficient renewable electricity and hydrogen provision, and for the processes to synthesise the fuels/chemicals and many of these lack mature technologies. Depending on the technology routes, sufficient water and biomass may also need to be secured. Given the significant investments and high production costs, produced greener products need off-takers willing to pay a price premium as well as electricity, fuel and chemicals markets that can offer supply/demand and price stability. There is also a need for more clear and robust policy incentives both from the EU and from Swedish government. These developments also need legal and public license to operate, which may be challenging due to resistance to off-shore wind projects and significant rises in electricity prices for public in recent years.

New and under-utilised industrial land

Land designated for industrial activities is an increasingly scarce resource, and such land is particularly important if close to important infrastructure – such as pipelines, electricity grids, and port facilities. Hallands Hamnar has such land plots available and the company recognises establishing businesses working with Hydrogen and CO_2 value chains in an integrated fashion can enable the emergence of an important cluster, while also creating additional synergies with the

[27] Wenzel, H.

[28] Data compiled from Näringslivets klimatpåvarken statistiksammanställning (available at: https://app.powerbi.com/view?r=eyJrIjoiZmE0NDUwOTktMzFmZi00ZDAzLThhMzUtOWY1MTMzYjVmMjdiIiwidCI6IjIyZjA4NWJlLWI1MjMtNGVhYS05YTI3LTQyZjZjYjExZTBlNiIsImMiOjh9) and from Falkenberg Energi (avaiable at: https://www.falkenberg-energi.se/om-oss/miljo/klimatbokslut/) indicate fossil-based CO2 emissions in the range of 300 000 tonnes/year. However, there are significant biogenic CO2 emissions in the region, with only one of the important actors working with forestry products emitting 1.8 M tonnes of CO2 annually.

[29] Assuming sufficient availability of Hydrogen and full conversion, only the bio-genic CO2 that can be captured from a singular emitter working with forestry products can enable around 1.5 million tonnes of e-methanol.

surrounding activities[31]. Hallands Hamnar also has land slots that are only used intermittently for port operations and sits idle for majority of the time. Exploring the utilisation of such land by mobile production units could enable significant shared wins, as it would allow the port to better utilise their land and it would enable entrepreneurs to gain access to land with needed utilities.

Needs

Mobilisation on this idea will require finding entrepreneurs that can run their operations intermittently and from mobile production units. Given the existing economic activity and future plans in the region, some of the following can be of interest: Food dehydration and freeze drying, micro-greens and mushrooms production, insect farming, modular housing components production, plastic and textile recycling/upcycling, bio-plastics and bio-polymer production, bio-char and activated carbon production, desalinisation, and material drying. Actors working with blue-economy (see next section) already express an interest in drying and freezing related possibilities. Progress with such an idea requires detailed assessments of the possibilities and needs of different alternatives.

Synergies supporting blue economy entrepreneurs

The region recognises blue economy as an important development area for securing alternative protein sources, for improving food-supply security for the Swedish population and creating employment. There are already two players farming seaweed (macro-algae) along Halland's coasts and there have been interest in developing industrial scale land-based aquaculture systems in the region. Seaweed industry faces technical and economic challenges related to accessing the rigs, harvesting and processing the farmed seaweed. The industry is further challenged by permit processes, by local acceptance, and market demand. The following symbiotic opportunities, both within and outside the sector, have been identified can help address their challenges:

- Co-development of farming infrastructure and shared transport and maintenance services with off-shore windfarms for seaweed and mussels farming[32];
- Shared development/acquisition and utilisation of machinery and infrastructure (e.g. for harvesting and processing);
- Utilisation of residuals heat from industries for biomass drying and heating batches for on-land fish and shrimp farming;
- Utilisation of nutrient-rich effluents from food and drinks industry for land-based algae farming[33];
- Provision of under-utilised buildings and land close to port facilities to be used for hatcheries and seeding preparation;
- Integration with actors that can utilise side-streams from primary producers – e.g. biogas plants, pet-food producers.

Needs

In Halland, an emerging cluster is in its early stages of brining actors from the blue-economy sector together. However, it needs to improve communication with, and engagement from, additional

[31] For example, Hydrogen production of e-fuel synthesis generates significant amounts of residual heat, which can be used for space heating or for other industrial applications after upgrading.

[32] OX2 approaches these synergies seriously and invests its own resources as part of their planned developments in Galatea-Galena (off the coasts of Falkenberg and Varberg). The company already has framework agreements with two seaweed producers to explore and realise synergies as part of these developments.

[33] Stedt et al.,(2022) show that significant increases in sea weed growth rate and protein content when using effluents from fish processing industry.

actors – such as industries that can provide residual/excess heat or whose effluents can enable advanced product growth. Therefore, seaweed actors can benefit from platforms that will catalyse interaction with other industrial activities in the context. For seaweed farming, ability to share sea areas, sea-based structures and transport vehicles with off-shore windfarms if highly valuable. While several of the windfarm developers show interest in such developments, so far only one actor supports such partnerships with its own resources. Here, placing demands on windfarm developers for co-utilisation of the designated sea areas can increase their commitment and support for such synergies.

Processing of the seaweed takes place during a period when the demand for residual heat usage and capacity for drying and blenching other food products (e.g. grains and peas) is low and therefore the synergy can be beneficial for all involved actors. However, such partnerships will require investments, which can be supported through regional funds available for entrepreneurs or from EU funds (such as Life+ projects). Exploring ways to ease the permit processes and information campaigns to increase support from local population would be beneficial.

Actors in the sector are also in need of securing markets for their products. Here, public procurement initiatives of the municipalities and region can play an important role – for example, by securing can also benefit from collaboration with each other in product development, standardisation and regulatory acceptance matters and with municipal and regional authorities for permit processes and for market creation.

Organic residues from food and beverage industry

The region is rich in food and beverage actors, whose organic residuals are mainly used as feed and substrate for biogas production today, but can be used for producing higher value products. An initiative being launched in the Falkenberg area for this purpose but later being bankrupt due to financial difficulties speaks both for the potentials and challenges of such developments in the region.

Needs

The establishment of the above-mentioned initiative has been enabled by the significant institutional support provided by the BDU of Falkenberg municipality – in terms of access to residual organic matter, land, and financing. Despite limited success of this first mover, similar support should be provided for similar entrepreneurs who may lack relevant local knowledge and relationships. In future cases, additional integration potentials – such as residual heat utilisation – that can improve the techno-economic feasibility of such initiatives should also be considered and supported. Like blue-economy products, public procurement can be used to improve market conditions for alternative protein sources derived from organic residuals.

Flexible and interactive energy solutions

Some of the energy utility companies in the region, and most notably Varberg Energi, highlight the importance of developing flexible energy system solutions in collaboration with new and existing energy users (industrial, commercial and residential) and keen to work with such developments. They argue that by having a closer, and early, dialogue with energy generators and users and by installing needed hardware and software systems, multiple production, storage and demand regulation systems can be integrated to enable different energy users to consume the right type of energy (e.g. district heating and electricity) at the right time. Such arrangements, which can be seen as a combination of “utility” and “knowledge and competence” synergies, can create significant

business-, environmental- and socio-economic gains. This will also offer important steps towards "power collaboration" (Kraftsamverken) interests in the region and help support sufficient power availability for existing and new actor of the region.

Needs

Interviewees mention that for such solutions early and open dialogue with new energy generators and users is of critical importance. They further state that advancement of such solutions require additional considerations when responding to investment proposals, where predominant employment implications need to be complemented with private and public economic gains integrated actors can generate.

Joint procurement and waste management services

The workshop and site-visit organised in Laholm revealed potentials and ideas for SME's working in same/similar sectors (in this case metals processing workshops) have potentials to collaborate both on input purchasing, storage and inventory management and in waste management issues. In this case, several mechanical workshops purchase similar metal products that are delivered and stored individually in a sub-optimal fashion. The companies realise joining forces for purchasing, storage and inventory management can provide economic and environmental gains. Similarly, these companies generate similar waste streams (such as pallets and other wooden packaging material, which is today sent individually to a further away waste handling site. Companies recognise that these streams can be used as fuel in the nearby heating plant.

Needs:

Progress with the joint purchasing idea requires finding a practical business model including the division of costs and responsibilities. Companies of the context stated that this may require external help from the business development unit of the municipality, from consultants, or perhaps even from university. Similarly, joint collection and delivery of wood waste to the local heating plant requires exploring both logistical and regulatory requirements, for which external support need to be provided.

Textile waste

Elis Textil Service AB located in Hytle municipality offers textile products (like bed sheets or table clothes) as a service to different commercial and service organisations and has sizeable amounts of textile material which is no longer fit for their original purpose and therefore considered waste. Such material can be productively used in different applications. One possibility, identified during this study, is pulp production and there is already an interest in Södra plant in Värö to use non-wood cellulose sources for this purpose.

Needs

Besides pulp production, other potential use areas that can make better use of the functional properties of the textile materials – such as clothing, furniture or other products production – should be explored. This can be done by communicating the availability of this material with parts of HH working with innovation, with the Swedish School of textiles in Borås university, and with the S-P-O-K initiative which tries to bring creative communities with industrial partners to increase local production of different crafts. Alongside, quantitative and qualitative requirements of the Södra mill to use this material for pulp production can be explored. Once different alternatives and relevant parties are identified, the business models can be investigated, along with regulatory demand that may need to be fulfilled.

Technical water and other resources from wastewater

There are ideas to provide technical water to industry within the jurisdiction of Laholmsbukten Vatten och Avlop AB (LBVA AB), which will be sourced from effluents treated by LBVA. Information provided by one of the important industries in Halmstad indicate that around 30 – 40 000 m3 of primary water can be substituted by secondary technical water in their operations alone. Technical water provision and usage will be even more important if any of the Hydrogen production projects considered in the region move forward.

Falkenbeg and Kungsbacka are also looking into making large investments into their wastewater treatment infrastructure. These offer unique possibilities to extract useful resources and put them into productive use. Nitrogen, phosphorus, biogas[34], heat[31], charcoal, and alternative fuels are some of the example resources that can be extracted from wastewater - in addition to the technical water – if investments in needed measures are made.

Needs

Despite repeated efforts, we have not been able to talk to LBVA representatives regarding this initiative and therefore are unable elaborate at this stage. However, given the increasing challenges of water availability in the future, this should be seen as a critical area to be followed. Regarding investments in Falkenberg and Kungsbacka, it would be important to include a wider stakeholder group in the dialogue regarding the design of new wastewater treatment installations to create a wider spectrum of ideas that can be implemented. Actors outside the context, such as EasyMining which has innovative solutions

Rock crushing fines

Several rock crushing actors are producing aggregates for the construction industry in the region. These produce a side stream containing smaller than 4 mm particles – called “fines” –that cannot be used as aggregate. While a small part of the material is used by concrete producers, a significant fraction is landfilled. Such fines can be productively used in various applications, such as paving and landscaping, cement-based products, agriculture and soil improvement, waste- and storm-water treatment, ceramics and glass production[35]. Only one of the rock crushing companies interviewed in this study reported producing more than 40 000 tonnes/y of fines in two of their sites collectively.

Needs

Additional information needs to be gathered about the characteristics of the fines from different producers, as certain applications require certain rock types (e.g. such as soil enhancement and ph control). Moreover, it would be helpful to bring producers of similar flows in the region and map the availability of the fines. This may allow actors to join forces in developing alternative applications and reaching scale.

[34] These resources are already recovered within existing set ups in Falkenberg.

[35] Some of the applications are rock-type dependent.

5 Recommendations for structural support to IUS in Halland Region

In this section, recommendations for providing structural support to IUS development in Halland region are provided.

5.1 Why public support to IUS?

As noted in earlier parts of this report, IUS practices can enable significant benefits for business competitiveness and development, for the society and for the environment – all of which are among the main objectives of public authorities, including the "sustainable development" strategy of Region Halland. There may still be questions regarding "why the businesses need to be supported?" to develop new synergistic partnerships, to which several arguments can be provided:

1. IUS practices require businesses to work in new ways, with new and diverse partners, and sometime further away from their core. Furthermore, the processes to identify and pursue opportunities can be complex and uncertain. Many of today's increasingly lean and core-focused businesses lack, or find it difficult to allocate, resources that are needed to initiate and pursue IS processes
2. Even for the companies who want to work with the topic, initial interactions with unfamiliar and different actors may be challenging;
3. Businesses will always be focused on areas that are in or close to their core and a wider perspective to guide developments with system level benefits require the guidance from wider oversight the public actors have, and;
4. Certain enabling conditions – such as land allocation, conductive permit processes, and supportive policy formation is beyond the reach of businesses;
5. For IUS practices affected by regulatory and market uncertainties, having strong institutional support from public bodies help reduce risk perceptions.

Relatedly, public sector acting as a catalyst can increase businesses interest in the concept and help reduce the barriers to action.

5.2 Activities for structured support to IUS developments

In Halland Region there are numerous structures and activities that can support IUS developments. To become effective they need better orientation, support and coordination. There are also several additional activities that should be considered for providing structured support to IUS developments. All these are elaborated on below.

Create and communicate strong political will

Many of the interacted stakeholders recognise the importance of IUS and appear interested to work with it. At the same time, they recognise that the process may involve significant challenges and risks and therefore are hesitant to initiate action. These actors will be more confident to engage with IUS developments if Region Halland takes a strong and credible stand to support IUS developments and declares to provide lasting support in specific areas – such as permits, land availability, finance, and other aspects.

Integrate of IUS into strategic documents

Although there is interest to support IUS across the board, such work is conducted informally in best cases (e.g. Falkenberg) and handled sub-optimally in most municipalities. Experiences from elsewhere show that more effective support and tangible outcomes are enabled when IUS becomes part of strategic documents (e.g. energy-, land-use, or business development plans or strategies). Besides communicating political commitment, such formalisation give both the mandate and the resources to relevant people – such as BDU personnel – to work with IUS developments in dedicated capacity. This is particularly important in contexts where human resources are stretched even to meet existing responsibilities, which is the case in several municipalities of the region. Learnings can be obtained, among others, from Malmö, Lidköping and Sotenäs municipalities.

Provide education

Most actors interviewed in this study mentioned their familiarity with the main principles of the industrial symbiosis concept but showed limited understanding regarding different practical applications, the multiple benefits these can provide, and the approaches that can be used to give systemic support to the developments. Therefore, educational activities targeting key stakeholders should be considered, focusing on multiple forms, examples and benefits of the concept, as well as proven facilitation approaches[36].

Profile and diffuse good practices

Related to the previous point, there are good examples of operational IUS practices and approaches to facilitate new ones in the region –examples include, but certainly not limited to, residual energy and utility synergies from Falkenberg, Halmstad, Hylte and Varberg; several biogas initiatives in Laholm, Falkenberg, and Vessige; business development approaches and stakeholder platforms, and sustainability awards of Falkenberg municipality (See Section 4 for details). Structured communication about these has the potential to provide both inspiration and guidance, particularly given that seeing regional good practices can motivate actors more strongly.

Strengthen diversified relationships

As covered earlier, the region has potentials to develop new synergies around diverse resources requiring the involvement of different actors, and bridging different sectors. Numerous actors also mentioned the need to meet with a wider group regularly to discuss issues of common concern. Forming local and regional hubs to bring diverse actors together and to strengthen interactions among those working with specific fields (eg. energy, vs farming, vs blue innovations) could enhance relationships and understanding of areas of mutual interest. This clearly makes a case for creating platforms that will enable focused interaction (ie. ideas to create more value from diverse resources collectively) and enhanced communication among diverse actors.

Individual municipalities, IUC-TEK, EMC, Husshållningssälskapet Bruka Halland already host platforms. One effective approach would be to first integrate IUS thinking in these and then enable communication and interaction among these.

[36] LiU has existing programs and significant experience in delivering training for practitioners and can contribute to educational efforts in the context.

Improve context-specific knowledge

In Halland, there is a need to build on the process initiated in this initial study and further increase the contextual knowledge regarding:

- New symbiotic opportunities;
- Multiple benefits of these opportunities;
- Development needs of opportunities and means of meeting these needs.

Firstly, as acknowledged by most actors interviewed, there is a need to create higher awareness around what resources are available from different actors and which needs they can fulfil. Several approaches can effectively assist such knowledge enhancement. One of these would be to continue in the footsteps started in this study and continue holding bi-lateral meetings with individual actors to discuss their input needs and residuals they can make available to others, as well as their plans[37]. Such input will then need to be processed by a coordinator to identify potential connections. Another approach, that requires limited resources and usually very effective, includes organisation of so-called "synergy identification workshops"[38]. As also tested in this initial study, another highly effective and low-cost activity would be to organise site-visits to individual plants[39], to which interested actors in the region can join[40]. Both scientific knowledge and practical experiences show that such site-visits assist deep mutual understanding among actors that are is hard to match with other practices.

> "*When you see things in factory visits, you understand how they do things, their needs and challenges in a much better way. This can also be very useful to identify symbiotic possibilities"*
> *Business development and Engineering Director, Carlsberg Sverige AB*

Then, business-, environmental- and socio-economic implications of the identified possibilities needs to be assessed to identify potential gains in multiple domains. Here, it is important that the business[41] and socio-economic implications are assessed in a comprehensive manner by considering all relevant dimensions and that environmental implications are assessed with a systems perspective.

Last, but certainly not the least, development needs of different opportunities should be identified along with the activities and actors that can help meet such needs. This forms the very basis of providing systemic and dynamic support – as elaborated below.

Systemically support with development needs

There are already numerous ideas in the region, however, structures and processes to respond to their development needs systemically is lacking. When additional opportunities are identified, the importance of providing systemic support will increase. It is critical to create workflows to identify support needs in different development stages and seek to secure needed support by reaching out to, and engaging, relevant regional or national actors. Such work can be assisted with the use of "dynamic action plans", which monitors needs in different determinant areas as they emerge, and

[37] It would be helpful if the persons holding the interviews have basic technical understanding as well as some knowledge of synergies applicable to different industries.

[38] Such a workshop was planned within the current study but was cancelled due to lack of participation.

[39] Velenturf, 2016.

[40] Such practices are already in place in Falkenberg and Laholm, although without a focus on symbioses.

[41] A recent publication by Mirata et al. (2025) can provide guidance on comprehensive business value assessments.

sets actions and responsibilities needed for progress[42]. While also assisting timely support during different development stages, such approaches will also enable identification of structural difficulties delaying or stopping symbiotic developments and will enable focused feedback to politicians at higher levels to take necessary corrective actions.

Support demo cases to show wins

Multiple municipal actors hold the opinion that companies located in their jurisdiction can be important nodes to create synergies around but acknowledge lacking needed resources and capabilities to coordinate such work. It would be particularly helpful if dedicated work focusing on these companies could be carried out to demonstrate tangible outcomes and show the impact of facilitation efforts. This can increase the interest from both companies and politicians to support facilitation efforts.

Integrate symbiotic considerations into establishment/investment processes

The periods when new establishments, and new investments in existing plants, are planned are unique periods to also identify and plan for new synergistic connections. Relatedly the workflows linked to these should also focus on identifying possibilities and assisting their realisation to the extent possible. Discussing resource demands and expected residuals with developers, involving energy-, water- and waste-utility companies in development dialogues, brokering connections with existing actors with compatible resources and needs, and making resource exchange potentials a consideration in land allocation can be among the steps that can be considered for such objectives. Similar interactions should also be considered when existing actors renew or expand their operations.

Target and attract “good-match” businesses

When sufficient knowledge on under-utilised resources, needs and plans of different regional activities is gained, this can be used to target and attract new actors to create new synergies from the outset. Such task can be driven by Invest i Halland and be assisted by other national entities like Business Sweden to target and attract relevant Swedish and international businesses.

Interact and join with other regions

In different Swedish and Nordic regions, there are IS facilitation practices with different levels of maturity and success. Organising study trips[43] with key stakeholders to these locations and exploring other ways of interaction and idea exchange can provide useful knowledge and inspiration on how different approaches are adopted in different contexts and to which effect[44]. A good way of achieving this would be to join the Swedish Network of Industrial and Urban Symbiosis, which brings diverse stakeholders interested in advancing practical application in Sweden by working together[45].

[42] The “needs” connected to “farm based biogas systems” have been developed with a proper application of the dynamic action plan approach promoted by Linköping university.

[43] Study trips are found to be particularly useful as this also gives the local stakeholders to spend considerable time together in an informal setting, strengthening relationships and mutual understanding among actors.

[44] A study trip to Skive in Denmark was organised as part of this study, and the only person who attended this from the region found the insights gained during the trip very useful.

[45] More information can be obtained from https://www.industrialsymbiosis.se

Become the messenger to the national EU level politics

Related to all of the above, it would be highly valuable to systemically keep track of challenges encountered and needs identified in relation to different IUS development efforts and bring them to the attention of Swedish and EU level policy makers to catalyse policy innovations in favor of IUS developments.

5.3 Structure for systemic support

There is consensus that IUS development work needs to be mainly anchored in, and driven by, the municipal level organisations and such work should be supported by the RH and other regional organisations. There are already numerous structures and workflows in the region that can contribute to systemic support to IS developments. Rather than creating a new structure, improved coordination among these could offer a better approach. More specifically, the following should be considered:

Municipal IS platforms and functions

Municipalities should consider developing IS platforms and functions that can continuously work with relationship building, knowledge enhancement and development support within their own jurisdictions. Most municipal organisations should start integrating relevant activities mentioned in previous section in their regular individual and collective meetings with the businesses in their contexts. A symbiosis function, like the one promoted by Malmö municipality, should also be set up, to work both with new investments and existing actors. Such function will be responsible for creating innovation and support groups with representatives from different municipal units, utility operators, knowledge institutions, as well as relevant existing companies to engage in dialogue with new investors, or existing companies, to identify and assess symbiotic possibilities that can be applicable. This group should then have the main responsibility to explore ways of supporting these opportunities and seek the support from regional level when necessary. It should also communicate and coordinate its efforts with similar functions in other municipalities.

Regional IS coordinator and coordination group

Someone at the Business Development Unit of Region Halland should be assigned the task to coordinate the support to individual municipalities to facilitate IS developments and provide strategic advice. This regional coordinator should preferably have a good understanding of both business development and of IUS facilitation needs and approaches as well as having good relationships with key businesses and other relevant organisations. This coordinator should be responsible for engaging input from other RH units and regional and national actors as needed.

Headed by the regional IS coordinator, a regional IS coordination group should be formed, to oversee that the needs of key stakeholder groups are effectively and equitably attended to. It is suggested Högskola i Halmstad and IUC-TEK are permanently represented in this group, where representatives from each of the following groups have annually rotating representatives to assure the work remains properly attentive to diverse regional interest.

- Companies – e.g. Höganäs AB, Viking Malt AB, Carlsberg AB, Arla AB, Hylte Paper AB, Södra AB, Derome AB, Berte Gruppen, Stena Recycling.
- Municipalities – Falkenberg, Halmstad, Hylte, Kungsbacka, Laholm, Varberg
- Utility companies – HEM, Falkenberg Energi, Varberg Energi, LBVA, VEVAB

The proposed structure is depicted in Figure 5.

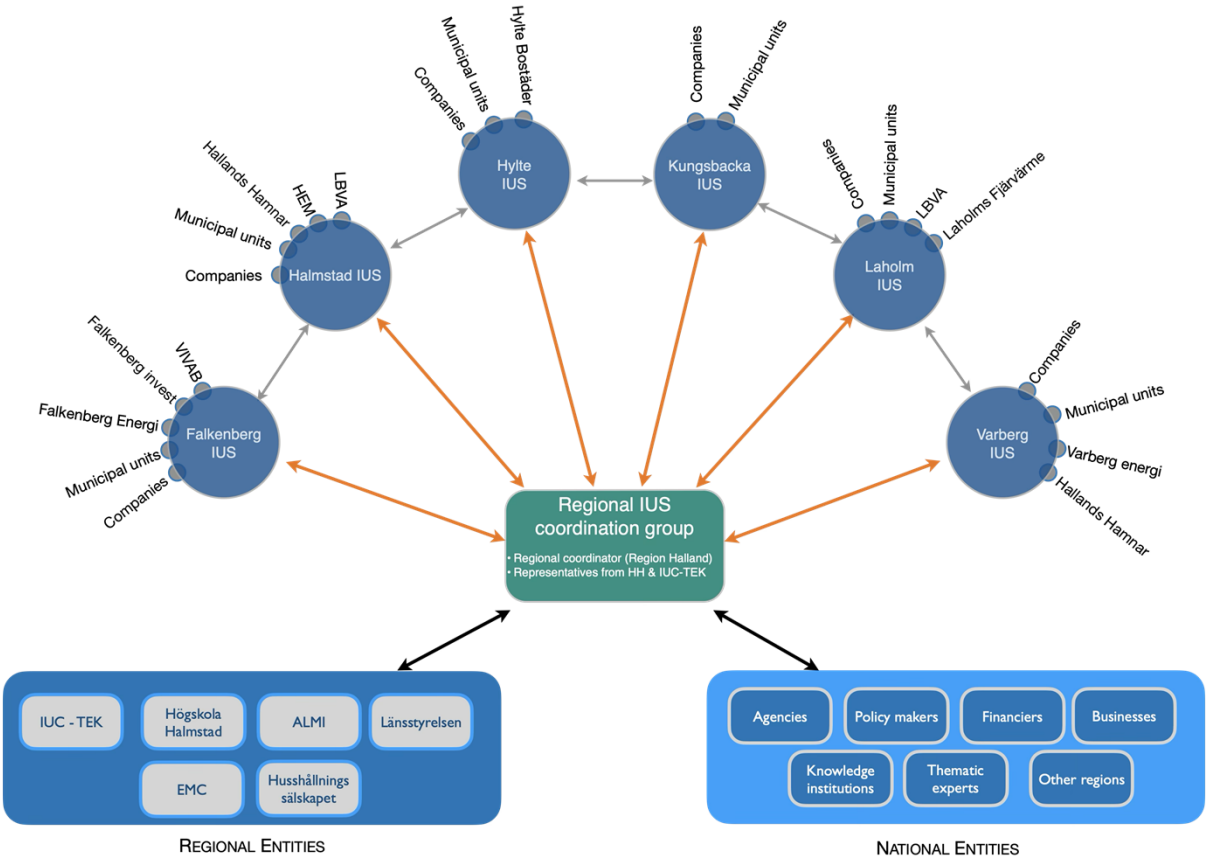


Figure 5: Proposed structure for systemic support to IUS in Halland.

The main responsibilities of this coordination group can include:

- Identification of symbiotic opportunities among municipalities as well as across regional boundaries;
- Securing the support needed in individual IUS functions in municipalities;
- Communicating IUS practices and opportunities from the entire region;
- Coordination and communication with IUS initiatives in other regions;
- Providing necessary feedback to national and EU agencies.

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7 Annex 1 – Stakeholders Interacted

Organisation(s)	Nature of interaction	Additional remarks
Ages AB	On-line meeting	
Arla AB	On-line meeting	
Berte Gruppen		Interview by the students
Bendex AB	Collective discussion in real life	
Carlsberg Sverige AB	On-line meeting	
Derome AB	Telephone and e-mail communication	
Diab AB	Interaction in real life	
Eleiko AB	On-line meeting	
Hallands Hamnar	On-line meeting	
Halmstad Energi och Miljö AB	On-line meeting	
Husshållningssälskapet	Two on-line meetings	
Höganäs AB	On-line meeting	
Högskolan Halmstad	Two on-line meetings	Additional interview by students
NCC AB	Two on-line meetings	
Södra	Three on-line meetings	
Varberg Energi AB	On-line meeting	
Vessige Biogas AB	On-line meeting	
Region Halland	Several on-line and real life meetings; One seminar	
IUC-TEK	Meeting in real-life	
Invest i Halland	Meeting in real life and e-mail communications	
Falkenberg Energi AB	On-line meeting	Additional interview by students
Gekab Verkstad AB	Meeting in real life	
Hylte Paper AB	Collective discussion in real life	
Mellanders AB	Meeting in real life	
Näringslivskontoret Falkenberg Kommun	Several meetings in real life and on-line	Additional interviews by students
Näringslivskontoret Halmstad Kommun	On-line meeting	
Näringslivskontoret Hylte Kommun	Several meetings in real-life and online	Additional interviews by students
Näringslivskontoret Laholm Kommun	Several meetings in real-life and on-line	
Näringslivskontoret Kungsbacka Kommun	On-line meeting	
Näringslivskontoret Varberg Kommun	On-line meeting	
Nordic Seafarm AB	On-line meeting	
OX2 AB	On-line meeting	
Smurfit Westrock AB	E-mail	Communication by the students
Ulleryd Model AB	Collective discussion in real life	
Uppcyclr	On-line meeting	
Varberg Energi AB	On-line meeting	
Vivab AB	On-line meeting	