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## Development of the urban and industrial symbiosis in western Mälardalen

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### Abstract

From a product service systems business model development perspective, this paper presents a case study of Västra Mälardalens industrial symbiosis, its maturity level and potentials for further development. The status and potentials of the symbiosis network, based on a survey, interviews and workshops, together with background statistics, is used to evaluate the potential improvement areas and suggest future research. The study contributes with application of evaluation models and confirms earlier research and in addition suggests future research in the field. The Symbiosis network has potential to be acting as innovation catalyst supporting companies to go beyond core business development.

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*Keywords:* Industrial symbiosis; Product service systems; Sustainable industrial development; Regional innovation networks;

### 1. Introduction

Urban and industrial sustainability in relation to resource efficiency is increasingly demanded and pursued combined with cost efficiency. Since loss of energy and materials contribute to high environmental impacts and high costs, reducing these losses and/or making secondary use of these losses is of great sustainability importance [1,2]. Maximizing transport efficiency, using more effective transport modes and using less fossil fuel is recommended. Fossil free solutions e.g. promoting solar energy and efficient heating/cooling exchange is thus regarded important for sustainability.

One strategy to address resource efficiency is to try to share physical resources locally, and let unneeded outlets from one enterprise feed another enterprise or share resources needed seldom in common pooling systems. Urban and industrial symbiosis (UIS) encompass industrial symbiosis and urban-industrial interaction [3] including urban production (e.g. society/knowhow/human resources, energy and materials) [4] and industrial symbiosis. UIS can be seen as the network of community and industrial actors collaborating to bridge local needs by improved resource utilization [5]. The collaboration

may include intangible values and require business models between actors that can handle both products and services. The individual business relations between actors within an UIS may be enabled by product service system (PSS) business models to utilize the resources [6]. Personal and organizational aspects will affect the symbiosis development. According to Mirata [5] regional industrial history and the nature of the companies involved in an UIS influence the progress of the program. The importance of municipality involvement and to have some large manufacturing companies in the UIS-network as fore runners is pointed out [5,1] and seen as a requisite.

The West Mälardalen region is a sub-region of Västmanlands län, an administrative body in Sweden. The UIS-network in the region started already in the 1980-ies with a district heating collaboration in Köping municipality where local industries could tap in their excess heat for public use. In addition, manufacturing competence centres like Kuggcentrum has been acting in the region as network for industrial competence exchange, focusing on manufacturing companies. Recently, the energy network has extended to three municipalities in the region and a broader exchange of materials, transportations and common competences is

developed. The focus areas for the UIS in West Mälardalen are to expand the collective efforts of resource efficiency in energy and material consumption, logistics as well as in further utilizing competence in the region.

### 1.1. Aim

The aim of this research is to propose a method for assessment of collaboration between companies and community, focusing on factors important for continued development of the UIS in all the focus areas. The research questions formulated to reach this aim is:

RQ1. How could an UIS development state be evaluated?

RQ2.a What factors are critical for UIS development and what are the shared challenges with PSS development?

RQ2.b How can the UIS catalyse concrete solutions for participating actors?

The scientific contribution lies in the empirical experience on how to map and evaluate an UIS and its development.

## 2. Method

This analysis has collected open statistical data for the industrial specialization, historical development and innovation in the county, compared to other counties in Sweden (Regional history and background in Fig. 1). The current nature of the companies/actors involved, and UIS network maturity (fig. 1) was assessed by a survey and workshops, supported by interviews leading to a maturity analysis. The empirical study included action research, by participating in the pre-study ‘Industriell symbios i västra Mälardalen’ with aim to support development of the UIS resource efficiency in the focus areas energy, materials, transportation, and competence in terms of personnel networks and for instance academic actors.

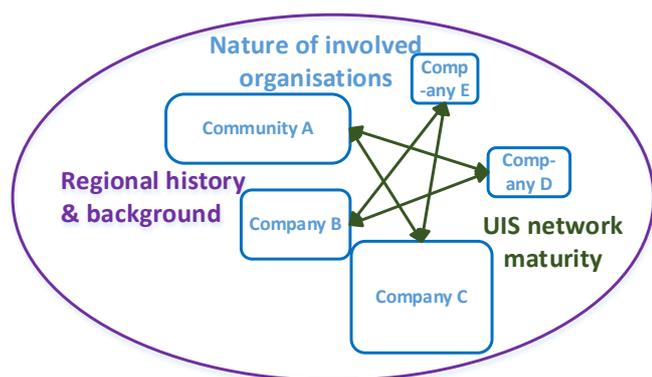


Fig. 1. Elements in the analysis of the current state of the UIS.

The workshops and interviews discussed opportunities in the focus areas and aimed at identifying new solutions that can be offered by two or more actors together in common initiatives.

The history, background and nature of the involved actors were analysed with respect to the requisite factors of a UIS. The nature and status of companies' collaboration was investigated in the survey examining the status of collaboration and collaboration interest. The survey was inspired by waste flow mapping [7], transportation and energy mapping, presented questions about current use, current circularity and sharing, and

potentials of sharing. The municipality industry and trade department sent out the survey to companies in the region. Out of 180 contacted, 20 companies answered the survey, among them the two largest industrial employers in the region with over 500 local employees each. Further, more than 50 physical open-ended interviews have been performed with different actors. Workshops were held at two occasions with approximately 15 participants each, including actors not participating in the survey. Around 75% of these were industrial related and the rest represented community services (e.g. energy network, harbour, municipality, research centres and authorities). The companies included, manufacturing, farming, services, IT sector and process industries.

The collaboration around physical resources and competence/innovation shared were then analysed separately in a maturity model based on Golev et al. [8], and by identifying possible hinders for UIS. The model evaluates a symbiosis as 1. *Not recognized*, 2. *Initialised*, 3. *Active*, 4. *Proactive* or 5. *Forming the future*. The evaluation was conducted for energy, material and transportation sharing and to some respect on innovation and knowledge sharing. The sub question/issue level identified was investigated via surveys and interviews, with the 20 companies. To identify challenges that are hindering UIS-development categories of barriers/enablers were used; Commitment and community awareness, cooperation and information sharing, regulatory requirements, economic and technical feasibility [8]. The evaluation was used as input for further development of the UIS. The two workshops were used to get input about ideas and potentials for the future, reflecting the state of art as well as the level of ambition for collective efforts and sharing around resources. In addition to the two workshops in the study, one workshop with project leaders and researchers from several UIS in Sotenäs took place, seen as a benchmark with other regional UIS's.

The data collection and evaluation is summarised in four steps:

- Regional industrial history, status and specialization
- Regional innovation collaboration
- Maturity evaluation /resource-area
- Innovation development factors

## 3. Theoretical background

Biologic symbiosis means different species “living together” [9]. Among the various definitions of industrial symbiosis and UIS, most authors agree that there should be mutual benefit, synergies for the parties and collective efforts [5, 8, 10]. Also, a UIS must, according to several definitions, be beneficial for sustainable development by being more resource efficient and/or promote renewable resources. Lombardi and Laybourne [11] mean that industrial symbiosis “engages diverse organizations in a network to foster eco-innovation and long-term culture change”.

The potential synergies of UIS are limited by several nontechnical barriers [8]. These barriers can be; lack of community awareness, cooperation, information over the shared resources or commitment to the common sustainability development goals. They may also include technical, regulatory

or economic obstacles. These can be overcome by network innovation activities and knowledge sharing [8, 12].

Innovation centres should be aiming for win-win or “developed collaboration” between academia and industry to enhance innovation and manage knowledge in a regional network setting. To achieve efficient research and development, knowledge needs to go both ways, beneficial for both parties [13]. Some critical collaboration attributes for innovation networks are dependence on: personal relationships, trust over information sharing, aligning the goals and motives for participating [13]. Large industrial companies, have usually structured ways of collaborating with academia. Small and medium sized companies (SME’s) on the other hand are often challenged by lower educational level, dispersed needs and low contact with universities and may have particular needs of regional support connecting them to universities [13, 14]. Developed innovation centres should address these and support access to funding [15]. Developed centres support translational processes in sustainable development activities for long-term benefit of the actors’ knowledge sharing and collaboration.

Collaboration between the actors in the UIS is manifested in their common business. The business models between the actors need to fit the UIS definition (see ch. 1) and should include products, services and an aim for sustainable development [1]. Such business models can be classified as product service systems (PSS) [16, 17]. In a collaboration around sharing physical resources, the providers and users collaborating over a resource need to define the physical resource, the service or function adding value to the user, the responsibilities and risks associated before a business model can be agreed [18, 19]. Since PSS is a complex business relation the parties need to have trust and communication, common goals and targets that are followed up on, and knowledge for the development of the product/service [6, 18].

It is important to acknowledge the values of the PSS. The provider gains further values than just the payment for the product/service. These provider values may be; enhanced customer relations, strengthened infrastructure, increased quality and improved environmental performance etc. [20]. These added values need however to be designed into and recognised by the business models. To improve business model innovation for the actors, the UIS network can therefore be useful, forming a context for sustainable business innovation activities [12, 11].

## 4. Results and analysis

### 4.1. Regional conditions

The UIS network in the west Mälardalen region started already in the eighties with an open district heating system in Köping municipality where process and manufacturing industries could tap in their excess heat. In this system, mainly large users and suppliers of heat has been collaborating providing heat to the community. In addition, manufacturing innovation centres like Kuggcentrum and Mälardalen industrial technology centre (MITC) has been acting in the region as network for industrial competence exchange and technical development. Recently, thanks to the project, the energy

network has extended to the three municipalities of Västra Mälardalen and initiated exchange of materials as well as sharing transportations and connecting competences (Fig 2).

For the Västmanland county of which west Mälardalen is one part (approximately one third), according to Oxford Research [21] the largest industries (# employees) are; construction, steel, metalworking/manufacturing, vehicle and other machines, computer and electronics together with industry services. The construction industry is the largest industry, but only as big as in the rest of Sweden, while computer and electronics and vehicle and other machines have a significantly larger share than in other parts of Sweden. The most important specialisation (the industries with larger ratios than Swedish average ratio) is in the steel-metalworking-vehicle industry supply chain [21]. The county has a long history of development in the specialised areas metalworking/vehicle industry and electronics/computer industry. Although the rate of higher education in the three municipalities (<16,5%) is lower than the Swedish average (26,6%) [22a], the potential for development of innovation and entrepreneurship is believed to be high. Västmanland have several innovation initiatives supporting these industries (e.g. MITC, Robotdalen and Automation region are active in the county) with competence development, business development and industry collaboration research with university and research institutes. On the list of top 25 employers [23] (>500 employees) in Västmanland, the three municipalities and Köpings two biggest companies are all part of the UIS network. In addition, the port, hospital and companies from process, automotive industry farming, agriculture, education, logistics and block chain IT have participated in the network.

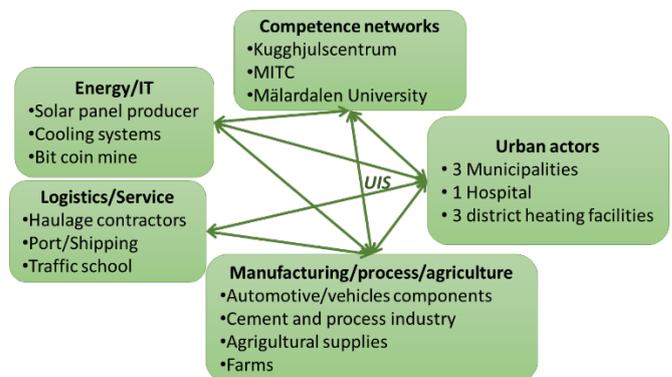


Fig. 2. The current UIS network.

### 4.2. Survey and workshops on collaboration over resources

Based on the 20 surveys, 50 interviews and the outcome of the workshops, the UIS was evaluated. The IUS collaboration overall was rated as active (3), mainly thanks to the existing collaboration around energy (heating and cooling). Material and transportation collaboration mainly take place through regular logistic and waste management providers although other initiatives rated as initialised (2) does take place. In Table1 below is presented results of the grading inspired by Golev’s et al. [8] maturity model, according to survey answers, interviews and workshop discussions. Table 1 also include circa 15 proposed symbiosis solutions generated during the project. For each solution a collaboration business model is needed.

Table 1. Maturity evaluation

<b>Area</b>	<b>Level of maturity (1-5)</b>	<b>Potential, unexploited resources in UIS judged by survey answers</b>
<i>UIS – general</i>	2-3	Initiatives exist mainly energy UIS. Potential for high maturity degree exists.
Focus area		
<i>Transportation - general</i>	2	Unused resources related to transportation available, local port & railway
Shipping	2	Harbour in Köping is low exploited, no load balance of incoming and outgoing shipping
Railway transport	1-2	Railway has potential to be more exploited
Fossil free truck transport	3	There are expanding local actors providing fossil free truck transport solutions
<i>Material - general</i>	2-3	There are recyclers/waste managers providing waste handling, near the region but not present locally. Local recycled material flows are unexploited.
Metallic material	3	Recycling companies collect material in the region with operations near the region.
Electronic waste	2	Local dismantling companies exist but low level of exploitation.
Bio fuel	2	Existing waste from e.g. local agriculture that may become fossil free fuel has low exploitation so far.
Plastics and paper	2	Plastics and paper are not recycled to sufficient degree or economic profit. Development potential exist.
<i>Energy- general</i>	3	Some local collaboration exists but the potential is much higher and therefore considered as unexploited.
Energy efficiency	4	Many companies work intensively for energy savings in their own facilities.
Solar energy	3	Some have started and many thinks of using solar energy. Local suppliers exist and the potential is high. Competence exists in the region for novel solar energy solutions.
Cooling and heating	2	Local sharing of waste heat and cold streams are being discussed. District heating actors play an important role. Competence exists in the region for shared energy solutions.
Charging stations for electric vehicles	2	Some actors already installed charging stations, but shared solutions, possibly solar driven charge stations, are identified as mainly unexploited.
<i>Competence - general</i>	3	The value and conditions for sharing experience and knowledge is rather high but still quite unexploited in the region.
Networks	3	Exist in the region
Cluster	3	Exist in the region
Community	4	The municipalities in Västra Mälardalen promote the UIS and have appointed roles for engagement in the developer and the strategy of the UIS, which result in a high grade of maturity.
Business models	2	Business models have to be developed for each solution, this require competence to be available via the UIS Many actors are engaged and see a value in the UIS solutions.

The obstacles and challenges for each area was summarised in Table 2. For development of more sustainable transportation such as shipping, national economic and regulatory hinders are large. Circular material flows may need more knowledge and innovation support to secure material quality, to raise awareness and commitment. Energy collaboration is mature but may advance if business model development is supported locally and awareness of economic and technical feasibility of novel solutions is spread. Many solutions were discussed in the workshops and the local conditions and opportunities must be visualised for local actors. The competence and innovation actors present in the region needs to enhance collaboration with the symbiosis network and develop knowledge management further, aligned with the UIS sustainable development goals.

The two half day workshops and the interviews resulted in around 15 suggestions for collaboration between the parties participating. A specific example includes use of excess energy from an IT actor to be used for warehouse heating in the harbour. The two actors would not meet in under normal conditions and in their core business. The solution and information exchange led to trust and collective effort to reduce environmental impact while making common business.

Table 2. Restricting challenges/area.

<b>Challenge area</b>	<b>Yes/No</b>	<b>Challenges identified</b>	<b>Comment/Need</b>
Transports	Yes, for shipping	Engagement, regulatory frameworks	Lack of engagement from central management for local transportation solutions. Regulatory frameworks with national fees for shipping.
Materials	Yes, to some extent	Sharing of information	Knowledge of recycled materials and local actors enabling effective local recycling/reuse business
Energy	No	Competence and technical challenges	Competence and local technology networking showing existing technology for energy recovery for heating and cooling. Business models incentivising shared technical solutions. Competence on solar energy use.
Knowledge and competence	No	Information sharing	Innovation clusters and networks exist but can be more active in the UIS. The strategy with challenges and needs identified via the UIS.

#### 4.3. Overall evaluation of UIS

The analysis of the survey results confirms that the UIS fits definitions of regional industrial symbiosis although the maturity according to Golev's et al. [8] model is rather low in some sub-areas. The potential of the UIS is regarded as high since all requisites [5] are present in the studied UIS. Additionally, the municipality are involved and large companies from industries with a long historical background in the region participates.

The UIS is fairly mature and rated as *active* in the collaboration around energy. Material and transportation symbiosis is rather immature and rated as *initialised*. Competence and innovation collaboration needs further research but has high potential according to the evaluation due to clusters and academic actors present in the region.

Analysing the critical factors mentioned in theory, points to high potential for continuous development of the UIS. In the UIS and connected networks/clusters both large and small companies are present. The support from high competence bodies as industry cluster and academic partners exist. Finally, the project has used physical meetings via workshops led by persons that have the role to catalyse and facilitate collaborations and identify common solutions providing win-win situations for resource efficiency on a holistic regional level. None of the symbiosis solutions were believed to be concretised without the UIS workshops.

#### 5. Discussion

The studied UIS is active especially in sharing energy resources. The collaboration in energy can be used to develop also other areas and start sharing of transportation and material for reuse or recycling. Most important have been the physical meetings, but also the common view on the needs, in this case locally driven resource efficiency. At least three solutions proposed are mature, and the implementation of these should be studied in future work. All in all, participants in the UIS are positive to collaborate towards common solutions and confirm the importance of UIS to discuss and realise such ideas. Hinders for such solutions outside the UIS are often organizational, that the solutions are not related to core business and that actors are not in each other's regular networks. Participants at the workshops and interviews will continue to be active members of the UIS. In the region, many actors see value in the UIS and have a positive attitude towards the UIS generated solutions.

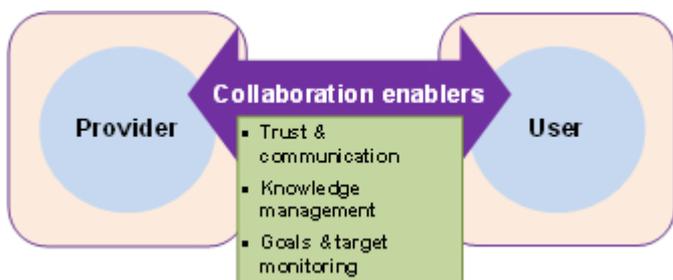


Fig. 3. PSS Collaboration model redrawn from [19].

A collaborative business model must be developed for each solution where resources are shared in the UIS. Although several examples of documented resource efficiency benefits of

applying product service systems (PSS) and servitizing exists [16, 24, 18], linear business models are still predominant, and sustainability must be designed into the PSS business models [25]. Barriers in PSS collaboration has been identified as lack of trust/communication, lack of knowledge, and lack of common goals and targets [18] (see fig.3). An UIS can be a means for sustainability actions when exploited as a forum to formulate common goals and targets, and facilitate trust and communication [6]. It may be important to facilitate common long-term knowledge management and innovation activities within the UIS [12]. More research is required related to develop PSS models for UIS.

The UIS can continue to catalyse innovative business in a proactive way with continuous workshops. It would be advantageous if the innovation support organisations take an active part in this as well as including facilitators in the discussions. The connection to Mälardalen University, and students with competence in sustainable industrial development allow for knowledge transfer from academia. In addition, when regulatory barriers exist, the UIS can be a way to reach regulatory bodies. The UIS-collaboration may also be a way to attract new companies working with local recycling and reuse.

Industrial symbiosis development needs a mean to support sustainable development innovation for both large organisations and SME's. Developed innovation centres (e.g. MITC), with firm foundation both in university and industry, can support translational collaboration [13], and development. By organising the collaboration towards sustainability into development programmes, could give SMEs a connection path into the UIS, the university and funding innovation projects.

Innovation support, face the same challenge as sustainable business development in PSS and UIS: It is a matter of making involved parties build collaboration which have barriers. These barriers can be; lack of community awareness, cooperation, information over the shared resources or commitment to the common sustainability development goals. These can be overcome by UIS activities focusing on increased trust and transparent communication within the network. One specific barrier for UIS development is that especially large companies focus on core business, while UIS often try to utilise non-core resources. It is a challenge to overcome this. By experiencing the engagement in the UIS workshops, the authors hypothesise that the UIS can offer solutions to problems not only addressing core business for one company but for the whole network, e.g. resource efficiency including personal resources, material resources logistic and energy issues.

Only few actors in the presented study are part of each other's value chains or regular energy supply. The UIS bring together actors that can e.g. not only deliver one type of energy but rather receive or provide energy in new forms such as excess heat. Other actors handle similar materials but are in different industry setting, i.e. manufacturing and process industry. Logistics can be used more efficiently if actors can collaborate in co-transport of goods. Resources can be utilised better with an UIS act as a natural meeting points and a facilitator network.

As answers to the research questions, this study shows that UIS criteria and maturity model data can be collected and evaluated by surveys and interviews complemented with

workshop discussions (RQ1). Critical factors for further development are to achieve trust, share information and increase knowledge and awareness in the community, which is common with PSS development (RQ2a). Also, a broad actor composition is important. One way to catalyse solutions is to perform workshops and physical meetings where actors can initiate contact outside their core-business (RQ2b)

During the study the criteria for establishing UIS by Mirata [5] and the barriers described by Golev et al. [8] has been confirmed by participants. All together this case study at large confirms findings in previous industrial symbiosis studies [1, 5, 6, 8, 12]. The evaluation model identified additional development criteria, and the importance of physical meetings between actors were validated by the number of suggestions and in-depth discussions around solutions for resource sharing that took place within the UIS in Western Mälardalen.

## 6. Conclusions

This paper presents the current state and potentials of the UIS, Västra Mälardalens industrial symbiosis. The UIS goal is to support sustainability in terms of resource efficiency in relation to competence, materials, transport and energy. Collaboration challenges and needs have been identified.

Evaluating the UIS concludes that it has a development potential. Based on the surveys, the status of the UIS is evaluated as ‘active’ but not fully developed to ‘forming the future’ yet. Potentials based on a survey and workshops together with statistical background data shows that the region has large potential to develop the symbiosis with active companies and municipality as well as access to local innovation support. The community engagement and actors fulfil criteria’s necessary for further development of the UIS. The personal meetings between people not usually doing business together has generated discussion and initiatives for solutions that would not otherwise be developed. The UIS have potential to be acting as an innovation catalyst, supporting companies to go beyond core business development.

The study contributes with confirmation of previous research and verifies critical elements of an UIS such as a mix of large and small actors, community engagement, innovation support and competence but also physical meetings and appointed facilitating roles for UIS initiatives. It gives qualitative insights into the development of sustainable innovation and business support.

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