

INDUSTRIAL SYMBIOSIS IN VÄXJÖ

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1. Introduction

This paper is part of the course Industrial Symbiosis on the master level Energy, Environment and Management at Linköping university and is the result of an in-depth study of industrial symbiosis in the city of Växjö, Sweden. Based on information from the Internet and from contact with local actors, i.e. representatives from the municipality and its organs, employees at the local heat and energy company Växjö Energi AB, VEAB, and other major facilities, as well as other enterprises in the area, existing and soon-to-be industrial symbiosis relationships were uncovered.

The initial ambition of this project was to deeply examine a few synergies and to find out how they came about and the benefits they bring. However, as the project developed, a lot of interesting companies and existing as well as potential and tried but failed synergies were discovered. This, and to some extent the fact that no or late contact was established with some companies, resulted in a decision to change the ambition and scope from narrow and deep to more broad and shallow, as both cannot be fitted within the scope of the study.

For this reason, the paper presents an extensive, interconnected and quite messy network with a lot of different actors. Details about their backgrounds, ranging from brief to detailed, including a few motivations and barriers are also presented. The identified possible synergies that were never realized are discussed with the special aim to conclude why they have not yet seen the light of day. An attempt to characterize the different actors' role in the development of the industrial symbiosis network is made to further understand the driving forces of the individual actors, alongside an analysis of the current networks in terms of strengths, weaknesses and future development of the synergistic relations.

1.1 Industrial Symbiosis Definition

Industrial symbiosis could refer to the cooperation of several companies that transform waste materials or energy or other byproducts from one actor to useful resources to another (Linköpings Universitet, 2017). The term could also refer to the collective utility and service solutions that offer higher efficiency in the use of energy and material or to the exchanges of information, knowledge and/or competence between companies, which create additional environmental, business and social value and promote sustainable practices (Mirata, 2017).

Industrial symbiosis closes loops for material flows, a corner stone of circular economy, by reducing the need of virgin materials, and could cut costs for the handling of waste, lessen emissions, lower energy use and create new business opportunities for the parties in cooperation and for those around it (European Union, 2017). The Swedish Environmental Research Institute (2017) claims that industrial symbiosis presents a prospect to increase resource efficiency and adapt to a more sustainable business, both environmentally and economically. Apart from taking advantage of by-products and cooperate in the use of external services, Mirata (2017) add social value as a key aspect, as a mean to new ways of thinking in product development, customer services and terms of products, service and market management.

1.2 Methodology

At first, information and background about the studied region were collected via internet searches to achieve a starting point for the study. A phone interview with Pierre Ståhl at Energikontoret sydost was also made early to gain more information of the area and its companies. Quite many companies have their activities located in Växjö municipality and a lot of time was therefore spent on learning about the companies and their businesses to decide whether they could be of interest to the study or not, and if to contact them to

receive further interesting information or not. Parameters taken in account in the decision whether a company would be of interest or not include their location, core business, size and inputs and outputs. As there were many potentially interesting companies, the biggest such as VEAB and Sundet were focused on from the start. From them some more actors were identified and added to the study through interesting synergies, existing or potential. Further studies on the role of the municipality and Energikontoret and their actions in the work with sustainability as well as results from projects they run, were also made. Google maps, the local newspaper Smålandsposten and websites of companies in the area have been the main internet sources.

Ideally, the studied region would have been examined not only through internet maps at an early stage in the project, but thoroughly and in detail with preferably more than one field visit to gain more knowledge about the region and the companies locations and existing logistic solutions. However, this ambition had to be lowered due to the time limitation and location of the region (read more under "Scope and limitation") and instead the one trip was planned to include interviews with interesting companies and, if time, visit selected parts of the region. The trip included interviews with three actors, VEAB, Energikontoret and an Environment Manager at the municipality of Växjö, which all were carried out in person. Also, a quick look at Sundet from the outside, since no contact was established prior to the visit, was managed. A preferred method for the interviews was face-to-face, although some interviews were conducted over phone and/or email instead. Phone interviews and/or email contact were held with Södra, Lantmännen Reppe, Sundet, Alwex, C3C and ReFarm (fishfarm-project).

All the phone interviews and parts of the interview with VEAB were recorded but never transcribed. During all interviews notes were taken. The interviews were recorded to be able to go back and listen to again, if needed, but there was deemed not enough time to transcribe them. The recordings of the interviews also enabled for the interviewer to focus on listening and formulating follow-up questions rather than taking notes, and for the rest of the group members, who sometimes were absent, to listen to the interview afterwards.

1.3 Scope and limitations

As mentioned, the scope changed a bit during the work to include a lot of actors and synergies instead of digging deep in a few collaborations. The primary focus was then set to the urban area of Växjö, this is mainly due to many companies in Växjö municipality and the time limitation of the project. Thus, only a few actors operating outside the city outlines are included in the industrial symbiosis network. The reason for these being included is that existing synergies with already studied companies were found and then decided to be investigated a bit further.

Face-to-face interviews were preferred but not always possible, mainly due to schedule collision or that no contact was established prior to the field visit. No or late contact with the companies also, to some extent, limited the expansion of the network as well as the possibilities to investigate further in the already discovered synergies. Approached companies where no contact was established was Greenpipe and Stena Recycling. Other companies found but limited away from, partly since none of the already covered companies mentioned or indicated any collaborations with them, partly because they are located in another area of Växjö than the already studied companies, were Balco, Fineco and Aqua expert. Because of the limitations in studied companies, the network presented in this paper can only be considered as a subpart of the industrial symbiosis network of the region.

Other limitations include the location and lack of local knowledge of the studied region. The location together with time limitation hindered multiple visits to the region, which would have been preferred due to lack of

knowledge about the industries in the area at an early stage in the project and the difficulties in organizing all face-to-face interviews on the same day.

1.4 Background

Växjö is located in the southeast of Sweden almost in the middle of the region Småland. The city is surrounded by forest. Historically the forests have been an important resource in the region and the woodworking tradition has been strong in Småland. In the 1920's around 180 furniture factories were located in the region (Möbelriket, 2017). Today, biofuels and material from the forest is a chosen strategy for the municipality in the aim to reduce fossil fuels and the university in the region has a lot of education and research in sustainable forestry and use of the products. For example, the local energy company's electricity and heat production runs entirely on by-products from the forest (read more in section 2.1.2 VEAB) and the Växjö municipality has a wood construction strategy for the building of apartment complexes, office buildings and other constructions. (vaxjo.com, 2017a)

In the beginning of the 20th century, Växjö started growing as an industrial city, after a period of despair and emigration (vaxjo.com, 2017b). By the 1960's the population quickly rose again and industry was blooming, with lumber as a valuable resource for processing and transforming. Around this time, what would later become Växjö University (and then Linnæus University), started as a filial to Lund University. The city was also a military seating until 1997 when the military unit was closed. Today Växjö is among the top 15 leading Swedish cities in logistics (Intelligent logistik, 2017). The list considers the geographic position in relation to the demographic center of Sweden, logistic infrastructure and total area for logistic purposes. Logistic companies like Alwex, Post Nord and DHL are all located in the Växjö.

With a population of almost 90 000 in the municipality the city has about 8 000 business (Johansson, 2017). This indicates that many relatively small businesses are located in the municipality. However, Växjö holds a few industries with local production.

In 1991 Växjö municipality announced the ambition to become fossil free by 2030, something no other city had done before (Slavin, 2015). The announcement made Växjö internationally famous and in 2007 a BBC reportage called Växjö the greenest city in Europe (Törnberg, 2008). The city has since then caught on to this and made "the greenest city in Europe" their official slogan. In 2017 Växjö won the European Green Leaf Award for 2018 (Växjö kommun, 2017a).¹

According to Henrik Johansson (2017), Environmental Manager at the municipality of Växjö and one of the interviewed in this study, one of the drivers that started the environmental work in Växjö was the eutrophication of the nearby lakes. The water gave away a bad smell and had a negative impact on the perception of Växjö as a city and its inhabitants chose to seldom or never be around the lakes. The issue was something that united politicians in Växjö, who decided to take actions. Their work paid off and today the ambition to keep up the environmental work is something that most political parties in the region agree on. For example, over the last 20 years the carbon dioxide emissions in the Växjö region have decreased with 41 % (Växjö Kommun, 2017b).

Växjö municipality does well in taking advantage of the possibility of participating in EU projects and receive external funding from international organizations for trying new ideas, and encourages and helps companies in the region to do the same (Växjö Kommun, 2017c) .

¹ The award is given every year to a European city with between 20 000 and 100 000 inhabitants that show a good environmental record, a prominent work for public environmental awareness and act as a green ambassador towards other cities (comission, 2017).

1.4.1 Biggest actors

In this section, the biggest actors in Växjö covered in this study are presented and their business explained shortly.

VEAB

Växjö Energi AB, in short called VEAB, is an energy and district heating and cooling company which is owned by the municipality. The company runs several combined heat and power plants in Växjö that deliver district heat (DH) and electricity to the municipality. Since 2010 VEAB also produces cooling from the district heat, called district cooling (DC). This allows VEAB to produce electricity without wasting heat during times when heat demand is low. Furthermore, it gives the heat another usage when, as mentioned the demand is low (e.g. during summer) and this is also important since the demand is generally decreasing due to better and more energy efficient houses. Around 20 companies get cooling from VEAB, but the company is constantly browsing the market for more connections and more customers to add to the grid. The district cooling is not yet profitable and VEAB hopes for further growth for cooling demand. Investments in expanding the grid is expensive, which means that there need to be enough demand in a relatively small area for the expansion to be profitable. In addition, an even demand throughout the year is preferable and most of the times necessary for profitable expansion. VEAB has close relationships with Tekniska Verken in Linköping, from whom they receive guiding and experience, especially when it comes to developing the district cooling grid and making it profitable. One unique thing, VEAB uses to reduce the cost for the cooling is taking advantage of Växjö's many lakes by leading their district cooling pipes through them. Philipsson, the division manager district cooling at VEAB, explains that this strategy gives them "free cooling" during winter, but unfortunately the lake is not deep enough and therefore become a bit too warm during summer which sometimes makes the process reversed. (Philipsson, 2017)

VEAB uses two biofuel-based plants today and the raw material consists of wood chips, bark, sawdust and logging residues, for example branches and tops from local forestry (VEAB, 2017). According to David Lander (2017) their production is 99.8 % fossil free, where the remaining 0.2 % comes from the oil they must use when starting the plants. However, they have plans of exchanging this oil to bio-oil to become 100 % fossil free.

Sundet

Sundet is the waste water treatment plant in Växjö and is owned by the municipality. In 2006 the water treatment facility in the southwest area of Växjö started to produce biogas from its own by-product, sewage sludge, and food waste from restaurants (Leo, 2005). Six years later, the municipality began to collect food waste from households and digest it to biogas at Sundet's facility (Energikontor Sydost, 2017a). The biogas facility is built for digestion of the inputs previously mentioned, sewage sludge and food waste, but Sundet is constantly looking for new possible sources of substrate since they want to expand the production of biogas, according to Dahn Delsmo (2017), who is the unit manager at the plant. When the biogas project started, the produced biogas was used for internal heat and electricity need and local buses. Today all the biogas is used as fuel for buses and cars, and Sundet instead buys electricity from VEAB and covers its heat and steam demands with a wood pellet boiler (Delsmo, 2017). Delsmo says that in 2016, Sundet digested 8 306 m³ food waste and 85 363 m³ sewage sludge.

Furthermore, Dahn Delsmo (2017) says that Sundet today is producing around 300 m³ gas/ hour out of a maximum of 350, and they want to and hope for future expansions.

Lantmännen Reppe

Lantmännen Reppe is a company located in two cities in Sweden, Växjö and Lidköping, that processes wheat. They have five main products which is glucose syrup, gluten, ethanol (vodka), starch and animal feed. Their main production is in Lidköping but they have an operation in Växjö that produces glucose syrup from the starch produced and transported from Lidköping. They only produce one by-product from the production in Växjö, which is sludge. (Lindroos, 2017)

Södra

Södra is the largest association for forest owners in Sweden (Södra, 2017) and has its head office in Växjö. Södra has no production (sawmills, pulp and paper mills) in Växjö municipality anymore since the sawmill in Braås in the north of Småland closed.

Alwex

Alwex is a rather diverse corporate group with the core business in distribution, logistics and storage services (Alwex, 2017a). Additionally, Alwex has recycling services and construction products such as concrete and asphalt. The head office and main business are in Växjö where Alwex have 54 000 m² of cool storage area, both for refrigerated and frozen products, as well as storage space for products stored in room temperature (Alwex, 2017b).

Energikontor sydost

Energikontoret is an organization that is owned by its members which are 28 different municipalities, county councils and regions in the south east of Sweden (Energikontor sydost, 2017c). They aim to complete their members' knowledge concerning renewable energy, sustainable transportation or energy efficiency. The most important purpose of Energikontoret is to spread information, create networks and investigate opportunities in the earlier mentioned fields (Energikontor Sydost, 2017d). They participate a lot in different projects, including TRIS and Resolve (co-transportation in the municipality). TRIS (Transition Regions towards industrial symbiosis) is an EU project to raise awareness on IS.

2. Results

In this section the actors and their current, potential and not possible synergies are presented. In *Figure 1* the existing and potential networks are illustrated. The network is then explained from selected actors' point of view.

2.1 Actors – current and potential synergies

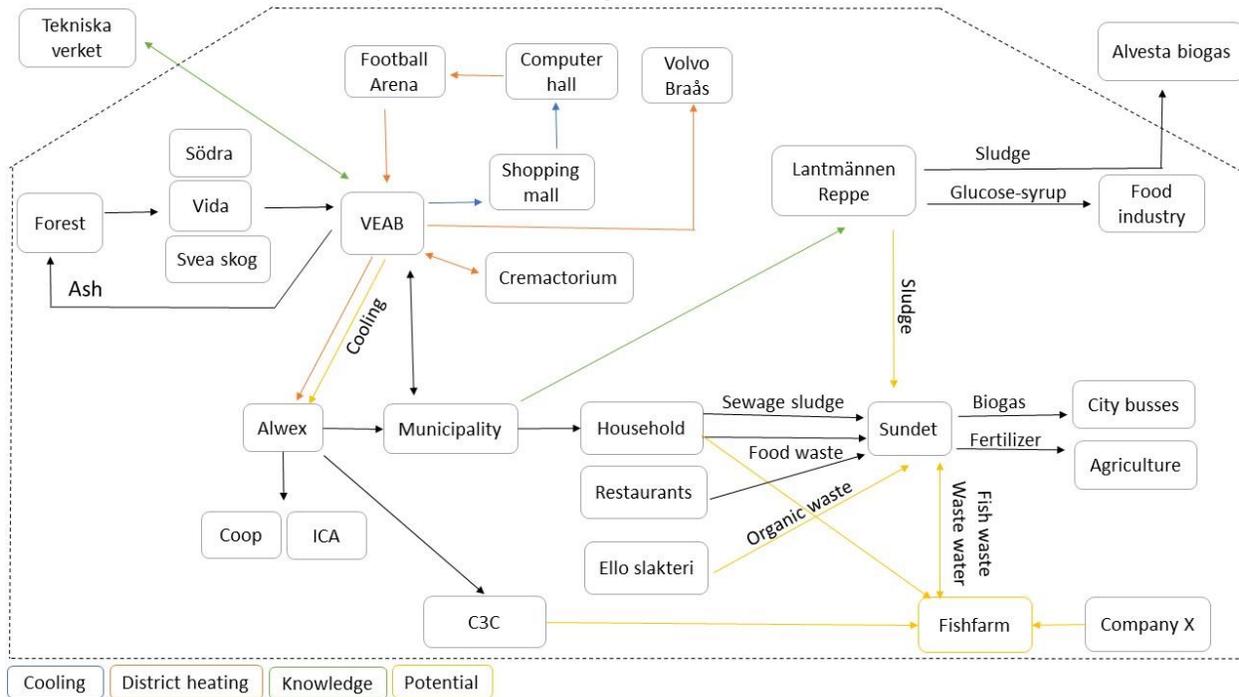


Figure 1. A map of all the current and potential synergies. The dotted line represents the geographical line of the municipality. The yellow lines represent possible synergies that have been identified during the study.

2.1.1 Municipality

As mentioned in the introduction Växjö has deliberately portrayed themselves as the greenest city in Europe. This is a statement that the inhabitants are very proud of and motivates the whole city to do more for the environment, according to the environmental manager Henrik Johansson at the municipality of Växjö (2017). He says that this has an impact on the companies too, and many companies make their site in Växjö their pilot projects for different kinds of green investments. This way, they can say they for example that they have the "greenest production in the greenest city" (as Volvo equipment does). Another example is the grocery store Lidl, who has their "greenest store" in Växjö. Furthermore, Henrik Johansson (2017) hopes that this slogan can attract greentech companies to Växjö.

One way that the municipality is working to reduce the environmental impact is to have co-transportation for all its controlled activities. This is coordinated so that all the deliveries of food, goods etc. is centralized to a warehouse in Räfte. Then the logistic and transport company Alwex delivers all the goods to the different places in Växjö in one route, instead of having a lot of different trucks. This has reduced the amount of deliveries from 1 900 to 350 per week since 2010, according to Henrik Johansson (2017). The municipality had a plan to arrange this type of co-transportation for private actors in the city core as well, since there are frequent truck deliveries of goods daily. The municipality did a mapping of all the deliveries, but in the end

the private companies weren't that interested and the economic perspective became a problem (Johansson, 2017).

As mentioned earlier the municipality is working with a wide range of projects, both local initiatives and EU-projects, and is often involved in many at a time. To be able to achieve the vision of being fossil free, the municipality also encourages and helps companies in the region to apply for EU-projects and financing, to steer the development away from fossil fuels. One company which has been helped is Lantmännen Reppe, who could change from burning fossil based oil to burn bio-oil to cover their heat demand. Examples of EU-projects that Växjö municipality are participating in is TRIS and SESAC. A more local network the municipality is involved in is Sustainable Småland. This is a network together with VEAB, the university and different companies in the region of Småland that together work with sustainable projects, with the aim to develop the region (Sustainable Småland, 2017a). Some projects derived from this network is ReFarm and Tomatsmart (Sustainable Småland, 2017b).

To create an arena for companies in the Växjö region the municipality organizes a network called "Expansiva Växjö". They have meetings once a month when they discuss different topics and there is often an environmental perspective of the meeting. This initiative started in 1993 by the current environmental manager, Malte Sandberg, to get companies to meet and share their environmental work with each other. The initiative was at this time called "Miljöfika" and the companies did only discuss environmental related questions unlike today. It has developed to involve more kinds of questions than those of environmental character and formed "Expansiva Växjö". (Johansson, 2017)

2.1.2 VEAB

The bioproducts VEAB uses in their production comes from local forest owners and other forestry companies where the biggest are Södra, Vida and Svea Skog. By *local* VEAB means within a radius of approximately 100 km (Lander, 2017). VEAB receives around 26 trucks with bioproducts for incineration each day (Lander, 2017).

VEAB mainly delivers DH to the companies for comfort heating, however, Volvo Equipment in Braås uses the DH as process heating. They need district heating around 93 degrees Celsius in one of their production processes and VEAB has increased the temperature of the system in that part of the grid in order for Volvo to be able to use district heating for that process (Philipsson, 2017). This helped them to become the first of Volvo's production sites to be 100 % fossil free (Bärtrås, 2015). After the last production process, the DH water is still warm enough to be used for comfort heating in their building.

VEAB produces almost all the heat in the district heating network themselves. A possible synergy would be for industries to put their excess heat on to the district heating, however, according to the division manager district cooling at VEAB, Philipsson (2017), the barrier here is the type of companies existing in Växjö. Since there are a limited amount of industries and especially industries with waste heat in Växjö the possible synergies are reduced. Today this synergy exists only between VEAB and the crematory. The crematory uses a boiler operating at 800 – 1000 degrees every day, which is a stable and even source of excess heat for VEAB to use. Additionally, the crematory is located relatively far away from VEAB and putting in some extra heat at that point reduces the losses in the network and make sure the customers on the end of the pipe also receive the right temperature. (Philipsson, 2017)

One interesting and quite unique thing with VEAB's district cooling network, is their 3-point practice. David Lander, development engineer at VEAB (2017) explains that the cold water goes from VEAB to the first destination, the shopping mall Grand Samarkand, where it provides cooling. The mall is owned by the Dutch real estate company Eurocommercial Properties and administered and managed by Newsec Asset

Management (Grand Samarkand, 2017). In the same building, the industry Gunnebo, uses the district cooling as process cooling for annealing. From Samarkand and Gunnebo the now slightly warmer water continues to Green Data Center, provides cooling for the computers and takes advantage of the waste heat. At the last stop, the now even warmer water, around 17 - 20 degrees Celsius, is used for ground heating to the football field of Myresjö Arena, to which Växjö municipality contributes with two thirds of the maintenance costs according to Ström (2014), to prolong the season about one month in each end. The water is then recirculated back to VEAB, cooled with waste heat via absorption cooling and the circle starts anew. Wexnet, subsidiary to VEAB, who owns Green Data Center, is expanding and have plans for a new server hall which will then provide more opportunities for similar synergies.

As mentioned in section 1.3.1 VEAB is looking for opportunities to expand their DC and one example of a possible synergy and expansion of the district cooling in Växjö is the ice hockey arena, which they unfortunately lost access to after negotiations. An interesting detail is that the owner of the arena also runs a company who install ventilation and cooling systems and it therefore the company which was contracted to install the climate system in the arena instead of VEAB. (Philipsson, 2017)

Another example of expansion of the DC, which Peter Philipsson, the division manager district cooling at VEAB, (2017) says they have high hopes in, is the new industries developing soon in the Råppe area, close to the airport. If VEAB expand to this area, which they currently only have district heating in, they may also be able to provide the big ware houses in the area with cooling for their cold storages. This, however, needs further investigation since they probably would need lower temperature than the district cooling.

The barriers of expansion both the DH and the DC networks are many, as mentioned before differences in provided and required temperature can be a barrier, but sometimes it is possible to work around it (as in the case of Volvo). Another barrier for VEAB is sometimes the distance to interested customers due to high energy losses while transporting hot water. Lantmännen Reppe, who has their industry in the Råppe area, needs steam or high-temperature hot water in their production. Today Lantmännen has their own heat water boiler which gives them the amount of heat they need. A potential synergy was identified between VEAB and Lantmännen. According to Peter Philipsson (2017) and David Lander (2017) at VEAB though, the distance is too far between the two industries for VEAB to be able to deliver the required temperature. A solution to this problem could be to install a production unit closer to this area, however, to be economically sustainable for VEAB that would require more than one potential customer. Another question is whether this would be more efficient, environmental friendly or give other added values compared to Lantmännen producing their own required steam from their existing bio-oil plant.

Sometimes regulation and geography can also become a barrier for VEAB to expand. An example of this is why VEAB can't deliver DH to Sundet. Between VEAB and Sundet there is a national reserve which means that they are not allowed to install their pipes there (Philipsson, 2017).

2.1.3 Sundet

The biggest driver for producing biogas is the beneficial environmental effects in combination with the municipality's goal to be "Europe's greenest city" and fossil free until 2030 (Leo, 2005). For this, the reason for starting to produce biogas at Sundet was to change the buses from running on fossil fuels to renewable fuel, as a major step to receive their vision to become a fossil free city. Still today all Sundet's produced biogas is used in the local buses however, the contract for the region's buses to use biogas as fuel will terminate 2023, and a change to electric buses is discussed which makes the future for biogas in the region uncertain (Fehrm, 2017). Dahn Delsmo, *Manager water and wastewater treatment at Sundet* (2017), says that he sees a change to electric buses in the future, but hopes for other markets for the biogas such as

personal vehicles and electricity production, although he admits that the market for biogas is a difficult one even today.

The expressed desire of expansion mentioned before, show that Sundet and the municipality believes in a future for biogas. However, there are barriers for expansion and for the moment their biggest one today is limitations in purifying and upgrading the produced gas to fuel gas, and the maximum capacity is the restriction of that process. Furthermore, they have experienced some problem receiving different types of substrate, since their facilities are not built for other inputs than fat, food waste and sewage sludge. For example, they tried to take slaughter house waste but they were not able to process it enough and the big pieces caused problems in their pipes and pumps, which is why they don't have that collaboration anymore. The same goes for the organic waste Lantmännen Reppe obtain as a byproduct from their production, Sundet took it before but when they got problem with their equipment they had to end that synergy. Sundet is of course working on the problem, and hope that they can adapt to the input market better in the future, however the changes require further investments. (Delsmo, 2017)

As mentioned, big economic investments are a barrier, as well as the difficulty in making the business economical sustainable, which it still isn't today in Växjö (Delsmo, 2017). As mentioned before, the market for biogas is difficult and there is also a high competition of the input, organic waste. Dahn Delsmo further explains that there is a lot of organic waste for digestion to biogas on the market, although the competition is high, especially for the kind of substrate Sundet can use due to technical problems mentioned earlier. This is confirmed by Lisa Winnes (2017), who further explains that organic waste also is good for animal fodder and those companies most often have higher capacities of paying for the substrate than the biogas producers.

Sundet is certified according to Revaq which makes them able to sell their by-product from the biogas digestion as biofertilizer (Växjö Kommun, 2017d). This helps the biogas facility work towards economical sustainability.

2.1.4 Alwex

The warehouses Alwex use is owned by a company called Catena who manage and control the heating and cooling of those buildings. Christian Berglund (2017) at Catena says that their cooling units run on electricity and that the waste heat from the units is used in the warm areas of the warehouses. He also claims that they, today, have no waste heat not used within the building. In addition to the waste heat, they use district heating for the comfort heat in the buildings. To the question if they are interested in district cooling, Christian answers that they are open for the discussion, but need to make sure it is technical possible and economical feasible.

In the distribution and logistics area, Alwex works with optimizing their transportations to minimize costs and emissions. As mentioned before, Alwex was involved with coordinating the deliveries within the municipality's operations. Another co-distribution solution they have is transporting the products to Coop and Ica within the same city with the same vehicle, says Tobias Gustafsson (2017). Tobias claims that some years ago, delivering the products to two rival companies with the same truck was unacceptable. However, with today's environment and economical awareness, the solution of co-transport has been agreed on from all three parts as being the best for everyone involved, including the environment.

2.1.5 Lantmännen Reppe

The by-product that Lantmännen obtains from the production in Växjö is an organic material, sludge, which today is transported and sold to Alvesta where they digest it to biogas. According to Thomas Lindroos (2017) at Lantmännen, the reason for not transporting it to Sundet is today economical and if Sundet would want to

take care of it, the possibility exists. Although, as mentioned before, Dahn Delsmo (2017) at Sundet says that they do not accept this sludge due to problems of processing it.

2.1.6 Södra

Since Södra do not have any production in Växjö, they are not a substantial player in the existing, or potential, network. However, they have a small part in the network where the by-products from the local forestry is bought and used by VEAB to produce electricity and district heat. Södra had a sawmill in Braås in Växjö municipality which is now closed down that provided VEAB with some by-products, although they still sell some by-products from their saw mills outside of Växjö municipality to VEAB (Dernegård, 2017). According to Dernegård, the environmental manager at Södra, there is a high demand on the by-products from forestry (such as branches, tops and bark) mostly for energy use but an even higher supply of the same, which brings down the price and Södra sells to the ones paying the best (Dernegård, 2017).

2.1.7 Fishfarm

Sponsored by Vinnova, a pre-study about a fish farm in Växjö has been made with Maria Unell at ReFarm as the project leader. Local news reported that the idea with this fish farm is for it to be highly environmental friendly, provide local job opportunities and locally produced fish for the inhabitants (Söderberg, 2017). The pool will be made from waste concrete by the local company C3C (read more below) and the water will be heated with waste heat from a nearby industry (who still wants to be anonymous so no further investigation could be done here). The fish food will be vegetarian and possibly even food waste from the municipality, although the last part will not be tried at a first stage (ReFarm 2030, et al., 2017) and when asked, Sundet had not heard about the project (Delsmo, 2017). The pre-study concluded that a possibility to recirculate the water and combine fish and vegetable farming exists and would reduce the need of water treatment of the highly nutritious waste water from the fishes and fertilizer to the crops. Another possibility is to grow algae in wastewater, which would reduce the cost of wastewater treatment of municipal water and the algae would become fodder for the fish.

This project is sprung from two other projects coordinated by Energikontor Sydost: TRIS, and a mapping of waste heat in the region Kronoberg (Energikontor Sydost, 2017b)

2.1.8 C3C

C3C is a Växjö based company that makes tank-, frame-, and living systems out of concrete. According to Ida Kånneby (2017), who works as a product developer at C3C, they do not have their own production. Instead they produce their concrete building blocks at local concrete factories where they try to use waste concrete.

When concrete is mixed to be used on a building site it is common that more concrete is mixed than needed. This concrete that is already mixed with water must be used within the near future or other-wise it must be thrown away. This leftover concrete is what C3C call waste concrete. In 2016 C3C used 30 000 ton of waste concrete in their production. A new potential use for these types of concrete blocks are pools for fish farms. To further explore and learn about this new usage they are involved in the ReFarm fish farm-project mentioned earlier. Furthermore, interviewed product developer at C3C, Ida Kånneby (2017), explains that C3C sometimes also produce their building blocks on site at their customer using waste products that are available, like mixing glass in the concrete.

The concrete that C3C uses in the Växjö area comes from Alwex concrete factory but C3C also cooperates with 70 other cement producers in Sweden and Norway. To use local producers of concrete is a strategy that C3C uses to shorten transports (Kånneby, 2017).

Sven-Olof Wikenström (2017), who oversees transports at C3C, explains that another strategy that they use to lower their costs of transportation and environmental impact is to have a close collaboration with haulers to organize co-transports with other companies. Since the concrete blocks are heavy, it is often hard to fit goods for other companies in the same truck. More often C3C tries to use return transports, where they take advantage of and use an empty truck on their way back from another delivery. To make these collaborated transports possible C3C has good knowledge and connections with the haulers they work with.

3. Discussion

In this section the findings from the study is discussed and analyzed from a bigger perspective.

3.1 The network and its development, strengths and weaknesses

The identified network in Växjö seems to have developed on its own, without direct policies or support, making it a robust network. The municipality and most companies have high goals in the environmental field, working with solutions to mitigate emissions as well as restoring and preventing further environmental damage. The biggest driver for the municipality is the protection of the environment and their desire to profile the city as “the greenest in Europe”. For the companies, the biggest driver is of course economical, but caring for the environment is a growing demand from the customer and therefore a green profile works well as a marketing strategy. With this said, the environmental actions and intentions are good and many in Växjö, but they are diverse and not limited to be identified as or striving to be IS, at least not as they were developed. Nevertheless, as IS is growing as a concept and the knowledge is spreading, different actors including the municipality and Energikontoret started to see that companies were working together with a lot of synergies, and as this study has shown the IS network is quite extensive. However, since the composition of companies in the Växjö city area does not contain a wide flora of manufacturing industries but more logistic companies, the developed synergies are not primary with material (although there still exist some) but rather flows of energy and information as well as transportation solutions.

As mentioned, both the municipality and most of the companies that has been looked into seem to share an ambition in environmental improvement. However, for some companies there seems to be a barrier to invest in a collaboration with another company when this is not the traditional way to go, e.g. it might be more convenient for a company in need of refrigeration to invest in their already existing and proven compressor-based refrigeration system rather than investing in district cooling. Our observation is that there's a higher ambition among local companies to take these risks and investments for environmental improvement. Multi-located companies may not feel the same connection to the city, and therefore might not share the ambition to keep Växjö "the greenest city in Europe". Moreover, there might be more difficult for a big company with the headquarter in another city, and possibly a more centralized governance, to use a local solution instead of the company's general technology. Some of the identified companies, such as Catena (the owner of Alwex warehouse buildings), primarily tries to use their waste heat (or other waste products) within the company and therefore reduces their potential to engage in synergies. This of course hinder development of IS but does not mean that it is a bad action, in contrary it might be more resource and energy efficient and is a preferred step prior to looking for other collaborations.

An interesting part of the industrial symbiosis network in Växjö is the energy flow that circle around VEAB's CHP, the shopping mall Grand Markand, WEXNET's server hall, and the football arena Myresjöhus Arena. It is unquestionable a resource efficient way to grant each actor their need of climate control; to combine their different needs in a series without compromising in the quality of the service in an energy cascade. It is duly noted that Växjö municipality has influence in at least two of the chain's actors' decision making (VEAB - who themselves are in charge of WEXNET - and Myresjöhus Arena). It is assumed that the process of establishing such a system would be more difficult without a common voice of authority since communication and trust between the actors, in line with Walls & Paquin (2015), is believed to be significant elements in the cooperation. When the cooperating actors relate to the same company or other actor, the relationships and trust is easier to create and might even already exist, meaning that one big step in developing industrial symbiosis is already done. Whether this structure would be present without the involvement of the municipality is an entirely speculative question. Perhaps the encouraging atmosphere around Växjö would,

sooner or later, motivate VEAB and the other actors to engage in a similar, effective system, but it is clear to see that it would take more effort from the individual actors' sides. With the core business being a constant issue to deal with for each party in the arrangement, it is not completely unimaginable that such a solution would remain unimplemented without the help from the municipality.

The new industrial area that will be built between the airport and Räfte will mainly include logistics companies e.g. mail and packaging company PostNord (Marken, 2017). When planning and building a new industrial area, the opportunity for also planning and developing IS from the start should at least be considered (Boons, et al., 2016). As an example, costs for transportation and expensive infrastructure critical for the potential synergies can be reduced if the included companies are placed close to each other. We believe this is something that could be easily arranged without extra costs if the synergies are identified prior to building the new industries. One barrier for developing IS in this new area though, is the lack of manufacturing companies, which means that the possibility to establish more obvious IS (i.e. sharing material flows) is substantially reduced. However, as this study has shown, there are many examples of less obvious IS in place in Väfte, where the already established logistics companies in the area are included. Hopefully, lessons can and will be learned from this and more IS will be developed within present networks and in and around the new industrial area. Another barrier for planning for IS in the new industrial area is the restriction of where the industries' facilities can be built according to regulations, since some parts of the area need to be kept unaltered, which means nothing can be built there, due to protection of ancient monuments and the airport (Marken, 2017). Still VEAB is seeing an opportunity to expand their DH and DC networks and has already talked to some of the companies in the new industry area to see whether they are interested in VEAB's services or not (Philipsson, 2017). If this opportunity is received positively by the approached companies, or if other synergies are planned, are unknown to the authors. However, we see an opportunity for the municipality to step in and act as an orchestrator and possibly even coordinator to help and encourage development of synergies and collaborations.

3.2 The actors' role in the network

As seen from the presented network in the study, VEAB is "the spider in the web" with their DH and DC network. The municipality, not referring to the inhabitants of Väfte but rather the institution, and to some extent Energikontoret, are also identified as crucial parts with their involvement in a lot of projects that has been the start of some synergies. The difference between these key actors in the identified IS network are the flows that their connections are built on. VEAB could be referred to as the physical anchor of the network. A physical anchor according to Walls and Paquin (2015) is a company with a stable resource flow from where a network can be developed. In this case the resource flow would be their waste heat provided as district heat and district cooling. The municipality, with their extensive knowledge flow, are considered to function as the institutional anchor. This, in line with what Walls & Paquin (2015) writes, is based on their neutrality and the knowledge and support they give as well as their good connections with the involved actors. Additionally, they fit Walls & Paquin's (2015) description of an orchestrator; they are trying to involve all the companies and actors in the region in reaching their goals and ambitions of being "The greenest city in Europe" and fossil free until 2030. The slogan, together with the municipality's engagement and ambition in the environmental area, create a special characterization of the business climate. As mentioned before, the companies use the slogan to their advantage in strategic choices and marketing regarding their "green profile". Maybe it also helps in their open-mindedness to new solutions and collaborations, which stimulates IS. The municipality's engagement and participation in a lot of projects engaging IS is supporting the categorization of them being an orchestrator.

The municipality is also creating a good environment for developing and lubricating IS with their initiative “Expansiva Växjö”. This works as a “platform” for creating good business, and maybe even non-business, relationships and mutual trust between actors. Additionally, knowledge, e.g. experiences and lessons learned, are shared between different companies but also between the municipality and the companies. According to Mirata (2017), this creates a better institutional capacity which help stimulate IS development and create a robust network. This was a great example of an initiative from a champion at that time when it started in 1993. The environmental manager, Malte Sandberg, had connections in Växjö and created this platform for companies to meet and learn from each other’s environmental work to improve their own activities. Though it’s not the same setup today, it’s still a great way to get the different companies to meet to share knowledge and create trust among each other.

Energikontoret has a similar position as the municipality in the sense that it is involved in projects in the region and brings companies and other operations together in the environmental work. In projects like TRIS, Energikontoret tries to find synergies and make the concept IS known to the companies in the region. The organization functions as a sort of coordinator that search for and tries to develop new synergies.

In the end of the flow chain we find the waste water treatment facility, Sundet. The role of the facility is to collect the city’s waste in form of sewage sludge and food waste. Sundet processes the waste and then make a usable product that later can be used by the city in form of biogas and fertilizer. In accordance with Mirata (2017), we identify them as a decomposer in the network.

Another decomposer in the network is C3C. Their business in taking care of wet cement not needed makes sure there are no waste from construction sites and in addition they can build other constructions with it, for example a fish tank for fish farming. Furthermore, the strategy of building with pre-fabricated blocks is that they are reusable if or when a construction is torn down, reducing the need of primary production.

The forest surrounding the city seems to have an impact on Växjö, the industries and environmental actions in the area. The whole city is surrounded by the forest and it can be seen, for example, in the energy production where all the heating and electricity from VEAB comes from biofuel. Furthermore, there are many wooden houses already in place or in construction in Växjö as a part of a wooden building policy and the university has a research department that focus entirely on the use and research of biofuels. Växjö has surroundings characterized by forest areas and naturally this affect the industry in the area but also the municipality’s priorities and preferred solutions (e.g. biofuels), but could Växjö be specifically affected because of Södra, Sweden’s largest association for forest owners, having their head office in Växjö? Would Växjö focus on biofuels both in usage and research, as well as wooden houses to the same extent if Södra did not have their head office in the city? This is not something the project group has investigated further and therefore cannot discuss in more detail, however, we it is identified as an interesting area in need of future research to be determined.

Finally, whether Växjö really is the greenest city in Europe or not can be debated. However, this seems to be a driver for many actors in the municipality and also seems to lead to some degree of self-examination. Discussion, critic and debate, in social media and newspapers all over Europe, of e.g. whether one can really be the greenest city in Europe when there's still a lot of traffic in the city center has influenced the idea of co-transportation as a way to reduce traffic.

Conclusion and further research

We have found a considerable amount of industrial symbiosis in the Våxjö region, and yet we haven't studied all the companies in the region. The synergies in Våxjö are mainly concentrated to heat and cooling from the CHP run by the local heat and energy company VEAB, knowledge exchanges and logistic transportation solutions. A big part in the development towards higher sustainability and greener practices can be credited to the municipality, which has committed to an ambitious goal of being the greenest city in Europe. The networks main actors consist of VEAB as the "spider in the web" and the municipality together with Energikontoret who provides support, knowledge and engagement.

In the study some drivers and barriers for the found synergies have been identified. At first, the municipality's engagement and support, together with Energikontoret's knowledge and the companies' own engagement in the environmental field have been identified as important drivers and a big help in the development of the network. As always, another big driver is the economic benefits, however, some synergies not yet profitable have still developed through help and support from the municipality organization, confirming its big interest in reducing environmental impact.

Identified barriers include big investments, technical limitation as well as lack of proximity (in the case of DH and DC). For some cases, difficulties in making local changes due to a more centralized business model, where identified as a barrier for development of synergies.

This field study developed in to more mapping the existing, potential and not working industrial symbiosis, rather than investigating why and how the collaborations started. To study the found synergies more deeply, how they evolved and the benefits of them would be an interesting field for future research. As well as completing the mapping by studying the rest of the companies in the region. Lastly, the role of Södra as an influencer for the focus on biofuels and wood houses is an interesting topic for future research.

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