

Exploring the

Industrial Symbiosis

in Linköping, Sweden

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2012-10-15

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Lidköping has come a long way regarding creation of synergies for material and energy flows that may be found in the region. Some of the symbiotic connections have incurred for financial reasons, while others of environmental or regulatory reasons. By continuing on the same track, Lidköping has the potential of becoming an industrial symbiosis region of great notion.

Description of the site

Lidköping is a small town situated at the southern banks of Vänern, the third largest lake in Europe, in the south of Sweden. The town was founded in 1446 and is currently the home of 26 000 people. Lidköping houses an industry and harbour area in which several industrial symbiosis (IS) synergies have developed. Below are some examples of companies and administrations that are located in Lidköping and involved in the symbiosis.

The department of waste management

The department of waste management at the municipality of Lidköping is responsible for the collection of household waste from the inhabitants of Lidköping and also manages a minor fraction of industrial waste. The department is also responsible for the collection of sludge from the municipal waste water treatment plant and the sewage cesspools which are not connected to the municipal sewer system. Furthermore, the department is in charge of a waste disposal plant in Lidköping which includes a landfill, a recycling centre and a manual sorting facility.



Figure 1. Waste disposal plant.

Combined heat and power plant

The combined heat and power plant (CHP plant) in Lidköping is the main distributor of heat in the region. It's a municipal company which also owns the district heating system. The production started in the mid 1980's with the combustion of waste to produce heat. The reason consisted of two needs: a need for central heating system to reduce the domestically produced heat and a need to enable dispose of the waste streams from the city.



Electricity wasn't produced until the 2000's. The plant gets paid to dispose of the waste that comes from Lidköping but also from other regions and countries. Because the plant is owned by the municipality it has to apply by the rules of public procurement and due to the same reason it doesn't have any interest in profits.

Swedish Biogas International

The roughly two year old biogas plant located in Lidköping is a cooperation between many actors including Swedish Biogas International (SBI), Göteborg Energi and the municipality of Lidköping. Together, they produce liquid biogas and regular, compressed biogas used as fuel for vehicles. SBI owns and operates the biogas production plant and is in charge of the biogas production from raw material to the upgraded biogas. After this, the biogas is sent “over the fence” to Lidköping Biogas (owned by Göteborg Energi and the municipality of Lidköping) who liquefies some of the biogas before it’s distributed to the region as fuel for trucks. A minor part of the biogas is also distributed in the region as compressed biogas by FordonGas (owned by Göteborg Energi and DONG Energy).

The raw material mainly consists of waste streams from the food industry in Lidköping with surroundings. Since the biogas is marked by the Nordic Eco label, the raw material needs to fulfil a number of tough requirements, and SBI cannot use all the different kinds of raw materials that are available for their production. This limits their ability to produce biogas from certain sources of waste. In addition to biogas, the site also produces a great deal of nutrient-rich digestion residue which is used as fertilizer by local farmers.

Lantmännen Reppe

Lantmännen Reppe’s business concept is to create value from wheat. With wheat as the main raw material the company produces a number of products and is constantly seeking new applications and markets for them. Today, the main outputs are wet and dry animal feed, glucose syrup, gluten, ethanol and raw material for production of biogas.

To sustain the production the company needs steam which is supplied by the CHP plant next door, as well as wheat with high levels of protein and starch which is bought from a number of suppliers in the region. The production also requires electricity and a large amount of water for different applications, and a large share of this water is bound by the products, especially in the wet animal feed.



Figure 3. Lantmännen Reppe.

Existing synergies

Figure 4 shows the main actors in the synergistic connections in Lidköping and their most significant in- and outputs of materials and energy. The picture also illustrates the complexity of the connections and the synergistic linkages between these companies. Furthermore the quantities of the flows of materials and energy are presented to the extent they could be identified. The nodes (boxes) represent the different companies as well as the inhabitants of Lidköping, and the farmers in the region.

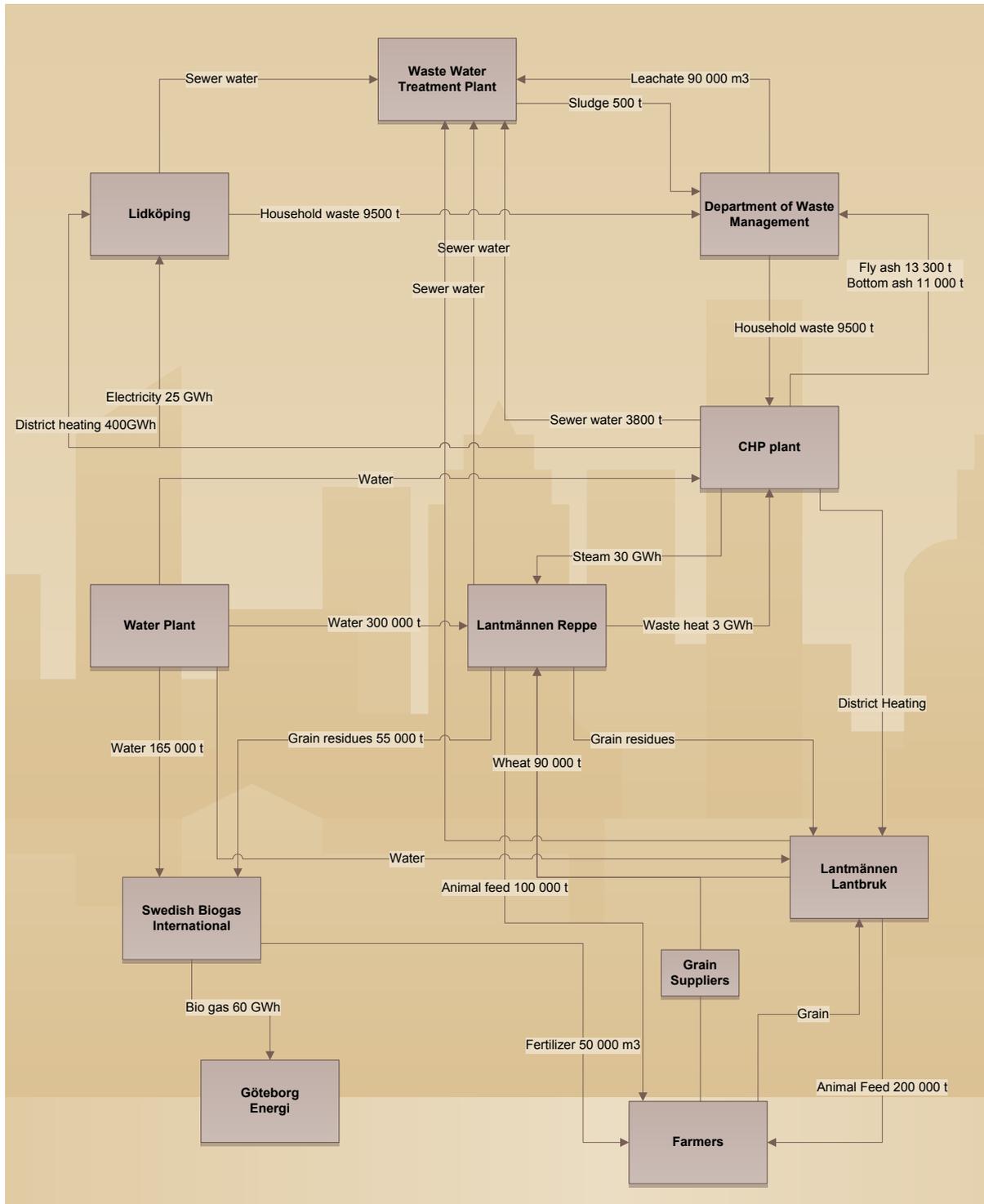


Figure 4. The annual main inputs and outputs of existing synergies. Identified quantities are presented.

The department of waste management

As is shown in the picture the department of waste management is involved in a number of synergistic connections in the region. It collects household waste and sludge from the city of Lidköping and the waste water treatment plant. The sewage is mixed with wood chips and sold, together with some of the household waste, to the CHP plant for incineration. The fly ash left over from the incineration is then returned to the department of waste management to be landfilled and some leachate is brought to the waste water treatment plant for cleaning. The bottom ash is used as construction material at the landfill.

These exchanges of by-products mean that less household waste and sludge is landfilled and is instead used for production of electricity and district heating. Hence, household waste as fuel has economical benefits for the companies and the environmental benefits from recovering the energy in the waste as opposed to being landfilled are significant. This exchange also leads to reduced emissions due to the change of fuel in the production of electricity and district heating and the reduction of small boilers across the city. The possible synergies between the CHP plant and the department of waste management, the monopoly on the district heating network and the access to household waste as raw material is what made the investment in the CHP plant possible.

Lantmännen Reppe

Lantmännen Reppe's main input is wheat which is bought from suppliers in the region. The production also requires steam which is delivered from the CHP plant across the street as well as water from the water plant. The spare heat is sent back to the CHP plant and because it still has a high temperature it will be delivered to the district heating network. If this synergy wasn't present the heat would be wasted. It also results in less fuel being used in the CHP plant when producing district heating. The water that is not absorbed in the production is sent to the waste water treatment plant for cleaning.

The company also delivers residues from their production to SBI as raw material for production of biogas and to the local farmers as animal feed. These exchanges have economic benefits for Reppe as their by-products now generate income instead of costs for landfill taxes or fees to the waste management department. Furthermore, the energy and nutrients in the by-products are now fully used. There was, however, a great resistance from the farmers to use this kind of feed before it became common. Lantmännen Reppe, therefore, had trouble maintaining their production because they were unable to remove their waste.

Swedish Biogas International

SBI receives the majority of its inputs from actors in the region. The water needed in the production of biogas is delivered from the municipality's water plant. Used water is delivered to the waste water treatment plant. By-products from Lantmännen Reppe and similar companies in the region are used as raw material. The company also receives some other inputs such as electricity and grains to produce biogas. A by-product from the biogas production is fertilizer which is sent to the farmers in the region.

Combined heat and power plant

The main objective of the CHP plant is to produce electricity and district heating for the city of Lidköping. To do so, the company incinerates the household waste collected by the department of waste management and receives some waste heat from Lantmännen Reppe. The company also produces some steam and electricity for Lantmännen Reppe and sends the fly ash and bottom ash to the waste management plant.

The symbiosis between Lantmännen Reppe and the CHP plant is mainly favourable due to large use of steam. The exchange leads to reduction of emissions from the CHP plant since the company has invested in substantial treatment of the fumes. There are also economic benefits for the CHP plant. Reppe provides a secure base load for the CHP plant and Reppe, in return, doesn't need to invest in a combustion chamber. Though Reppes steam demand only represents 10 % of the total energy delivered by the CHP plant the value of the steam is higher than the value of district heating, which makes it important for the CHP plant. The CHP plant is the only producer of heat for the city, and therefore the focus is to maintain a steady and secure delivery of heat to Lidköping.

Enabling factors, drivers and challenges for synergy development

A few factors that might have driven and enabled the synergies to develop have been identified. First of all, the fact that a large part of the synergies involves actors in the agricultural business can be considered as an enabling factor rather than a coincidence. There are a lot of elements in the traditional agriculture that can be compared to industrial synergies. Recycling of fertilizers and a maximized use of each resource has always been keystones in every farmers business. With this in mind Lantmännen Reppe can be considered as an anchor in the symbiosis in Lidköping, creating demands for energy and water and usable by-products and wastes. Furthermore, the municipality of Lidköping seems to be an important actor in the symbiosis. Through implementation of district heating and a CHP plant, Lidköping has succeeded in creating environmentally favourable conditions for industries to operate in. Through green marketing and environmental awareness the municipality might attract new actors to the region creating possibilities for synergy development. In addition, the municipality has been able to communicate and coordinate collaboration between the actors in the region. Other identified drivers are policy regulations and laws regarding environmental issues, which have enabled new technology, fostered internal improvements and supported the development of synergies in the region.

By funding parts of some of the projects that are part of the IS in Lidköping, the governmental investment programs LIP (Lokala investeringsprogram) and KLIMP (Klimatinvesteringsprogram) have also supported the symbiosis. The most important of these projects is the expansion of the CHP plant (54 000 000 SEK, 23 % of total investment) and the construction of the biogas plant run by SBI (17 250 000 SEK, 30 % of total investment). The investments contributed to a reduction of 24 000 tons respectively 18 000 tons of carbon dioxide equivalents. The expansion of the CHP plant supports IS since it enables the plant to incinerate more of the household waste from the department of waste management and the construction of the biogas plant obviously has acted as a support to IS since the plant is an important part of the symbiosis.

There are also several smaller projects funded by LIP and KLIMP which have possibly supported the IS in the region since they have facilitated the use of either district heating or the use of biogas in Lidköping, causing an increase in the production demand for the CHP plant and the biogas plant which will increase their demand for raw material or fuel. If the increased

demands of fuel or/and raw material have been provided by waste or by-products in these plants, the smaller projects also have supported the IS.

Unfortunately a few general obstacles for industrial symbiosis in the region have also been identified. One example of an obstacle is that several of the actors are part of larger groups of companies and the power to make decisions may be at head offices somewhere else. Another example is the lack of a continuous dialogue between companies. Also, the area consists of a variety of businesses rather than a homogeneous industry which in some cases aggravates the cooperation between companies. This is based on the lack of knowledge of other companies. Since there are few process industries in the area, competence usually has to be attracted from other regions. More concrete examples of drivers and challenges for the different actors follow below.

The department of waste management

Historically, the main driving forces for synergies with other companies have been policy regulations, laws and restrictions. Some examples are the landfill taxation and the EU hierarchy for waste management. However, policy regulations may also be a challenge since it can limit their ability to do business as they like, for example it complicates synergies with the CHP plant regarding the fly ash since it's not allowed to use in Sweden.

There are also some economical barriers for synergy developments in the area. The department of waste management would like to exchange sewage with the CHP plant, but economic considerations favour household waste above sewage as fuel. Besides, "feelings of disgust" among the personnel on the CHP plant regarding the sewage also complicates this particular synergy.

Combined heat and power plant

Long-term contracts with the department of waste management made it possible to realize the large economical investment in a new boiler. It was mainly the high demand for district heating combined with a desire to reduce the amount of waste landfilled which led to this cooperation. The sudden high demand for district heating was a result of actions taken to improve the air quality in Lidköping for environmental reasons. This was achieved by replacing many oil-fired boilers used for domestic heating, which caused considerable air pollution, by the CHP plant. There were also some political motives for the continued extension of the district heating network, since the social democratic government at the time wanted to have full control over the heat production. Another driving force may be the fact that the CHP plant has no interest in making profits.

Swedish Biogas International

There's a good supply of raw material in the area for biogas production and several synergies have evolved between different actors due to this, for example the synergy between SBI and Lantmännen Reppe. SBI has only one customer for their product (Lidköping Biogas) and the production site was built to provide biogas for public transport in Gothenburg, requested by Göteborg Energi through Lidköping Biogas. The company requires the gas to be marked by the Nordic Eco label which has been a driving force to establish some of the existing synergies. This was a strategic decision made by Göteborg Energi to position them as an environmental caring company.

However, since the biogas is marked by the Nordic Eco label SBI cannot use whatever material used in regular biogas production, for example rest products which still might be considered as food of any kind. This limits the potential of creating synergies with local actors but is not considered as a problem since the biogas plant is currently running at full capacity.

The municipality of Lidköping

Naturally, the municipality of Lidköping is involved in a number of ways with the local actors, usually by the law of public procurement. The law has in many ways been a driver for reducing the environmental impact from companies involved with the municipality by affecting how they do business. For example, gradually higher requirements on the environmental performance of vehicles used in services for the municipality may have contributed to the evolution of new technology, i.e. biogas driven vehicles.

Simultaneously, this law may be a barrier for local synergies and synergies with smaller companies to emerge. Among other things, it states that no company can be excluded from competing because of their location. This might harm the relationships with local actors which usually require a higher price for its products or services than larger companies do, and thus acting as a barrier for IS.

Lantmännen Reppe

Nowadays Lantmännen Reppe has a very well established network of synergies, but before the synergies were established Reppe had a hard time producing at full capacity since the company could not find appropriate use for its by-products. In making the by-products in to valuable animal feed and biogas feedstock, Reppe has not only kept production going but can also generate income from their by-products. Hence, the drivers for the synergies have mostly been economical.

Future plans and/or possibilities for the area

There are several plans regarding future possible synergies in the area that are examined by the involved companies and administrations. There are also several possibilities that were discovered by the authors during the field work and that could be of interest for further investigation. The plans and possibilities are described below.

Recirculation of phosphorus

The sludge produced in the waste water treatment plant could be used as fertilizer for agricultural production. The sludge has a high content of phosphorus, which is a finite resource, and the recirculation would reduce the need of commercial fertilizers. This is not possible today because of customer reluctance due to the source of the sludge. These attitudes would have to change to make this synergy possible. Another obstacle is that the sludge could contain high values of heavy metals and medicines, and this kind of synergy is restricted today due to regulations.

Another possibility is to build a separate waste water treatment plant for the waste water which originates from industrial production. This would create a pure fraction of sludge that shouldn't face the same reluctance as the municipal sludge. Lantmännen Reppe is currently sending its waste water to the municipal waste water treatment plant, and by building an own waste water treatment plant the company could sell the sludge for biogas production and use the remains as fertilizer for agricultural production. This expansion would reduce the strain on the municipal waste water treatment plant, and create the same environmental benefits as for the municipal sludge. However, today there is no shortage of capacity in the municipal waste water treatment plant, and the exchange may not be favourable from an economical perspective due to the municipal water treatment plants economy of scale.

Increased biogas production

The department of waste management is currently examining the possibility of separating the household waste into organic and combustible waste fractions, and process the organic waste into biogas. Furthermore, the region contains several food distributors and manufacturers who are able to supply a large amount of waste which could be used for production of biogas. The local biogas plant produces biogas that is marked by the Nordic Eco label, which doesn't allow household or food manufacturers waste as inputs.

This means that the department of waste management and food manufacturers would have to send the organic waste outside the local area or build a new plant. Another opportunity could be to add a production line at the existing local biogas plant which would produce biogas that isn't Nordic Eco labelled. Unfortunately this requires a large investment and it creates the risks of odour problems. Additionally, SBI's current building permit doesn't allow this kind of expansion.

The household waste needs to be separated before being processed into biogas. This can be done in several ways. One way is to use optical sorting i.e. machines automatically identify and sort out bags of a certain colour. The department of waste management is currently investigating the possibility to build an optical sorting facility in cooperation with other municipalities.

Separating the household waste reduces the amount of waste that is available for combustion in the CHP plant. The remaining combustible waste fraction is dryer and provides a better energy exchange. However, if the household waste is replaced by combustible waste in a greater magnitude, this would require a modification of the boiler.

Fly ash in cement production

A possible synergy is to use the fly ash as an input in cement production. This would reduce the amount of waste landfilled and the associated environmental problems, and reduce the environmental problems associated with the extraction of the input that is replaced by fly ash. However, fly ash contains heavy metals and this kind of synergy is not possible today due to regulations. In order to use fly ash in cement production the legislation needs to change. The change could lead to economical and environmental effects, both for the cement factory and the CHP plant.

District heating and electricity

One possible synergy is to connect the biogas plant to the district heating system, mainly by using the condensate and waste heat from the processes. The gas pipelines need to be heated, which is currently done by using electricity, but it would be possible to either connect it to the district heating or to use waste heat. The use of district heating would reduce the electricity used, hence creating an environmental benefit and reduce the cost. There are two setbacks for this expansion: it adds to heat consumption when the demand is high and it's a large investment.

Biogas production requires a large amount of electricity. Thus, the excess heat from the processes could also be used to manufacture electricity for internal use. Whether it is economically or environmentally beneficial hasn't been investigated in this case. But the large investment needed could be deterrent.

New facilities or actors

A major connection to the food industry could provide advantages for production of biogas. There are many companies in the region with organic waste that could supply raw material for

the biogas plant. This supply could either be utilized by building a new production line at the current biogas plant, or by building an entirely new plant.

A product that is usually not seen as a by-product is carbon dioxide. If a greenhouse was implemented in the region, the collection of carbon dioxide from the biogas plant or the CHP plant could, in combination with manure or sludge, be used to enhance plant growth. The greenhouse could, in turn, provide the local food industry with raw material. This could create a region known for its sustainable food and energy production.