

Development of excess heat-based district heating -A case study of the development of excess heat-based district heating in two Swedish communities

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Abstract

This article identifies and elaborates on preconditions, drivers and barriers behind the development of excess heat based systems of district heating in Sweden. Industrial excess heat based district heating systems are considered generally resource-efficient since it could reduce the use of fossil fuels and emissions of greenhouse gases by saving primary energy for district heating companies supplying heat to their heating customers. An increased recovery of excess heat from industrial processes and thermal power generation has great potential to reduce primary energy demands.

Collaboration around heat supply is relatively rare. There is an increase but still, the increase is low compared to the supply of excess heat from the industrial processes within the country. Increased knowledge of the important aspects necessary for the collaborations to evolve could mean greater opportunities to facilitate the development of excess heat based systems of district heating.

The aim of the study is to investigate important preconditions behind the development of excess heat based systems of district heating. It includes two existing cases of excess heat-based district heating systems in two different Swedish communities. The results are analyzed based on previous findings of the emergence and development of industrial collaborations within the research field of Industrial Symbiosis (IS).

The results from the study show that relations based on; trust, honesty, shared visions on common goals, information transfer and joint problem solving are necessary for these collaborations to develop. These features are also important when it comes to the decision making process. This since knowledge through participation from relevant stakeholders within the collaboration is required to understand and translate the common goals and objectives into practice.

In addition, we argue that investment subsidies are important for the future development of excess heat based systems of district heating, as a way to facilitate and encourage the long-time environmental benefits for the parties involved as well as the society at large.

Keywords: *District heating, Excess heat, Industrial collaboration, Preconditions, Resource efficiency*

1. Introduction

Climate change is one of the greatest and most serious environmental problems of today. To be able to stop, or at least slow down the climate changes, it is necessary to reduce the use of fossil fuels and emissions of greenhouse gases. One way of doing this is to replace the fossil fuels with renewable energy and at the same time increase the efficiency of the energy use. When it comes to energy used for heating it is relatively easy to make positive changes. One example of this is district heating whose design is based on water that is heated in a plant and distributed from the heating plant to heat buildings via a district heating grid. The buildings provided with heat have two heat exchangers, which transfer the heat to the water that is circulated in the radiators. The cooled water then returns to the heating plant to be heated again. This is a resource efficient source of heat that can be conducted in a way that generates a low environmental impact (Werner, 2004). The district heating produced in Sweden nowadays mostly comes from energy that would otherwise not be useful. Combustion of fossil fuels becomes more and more uncommon in favor of biofuels.

However industrial excess heat recovery is also one source of energy that can be used in district heating systems. An increased recovery of excess heat from industrial processes and thermal power generation has great potential to reduce primary energy demands (Persson and Werner, 2012). District heating systems based on industrial excess heat is considered generally resource-efficient since it could save primary energy for district heating companies supplying heat to their heating customers (Werner, 2004).

The use of excess heat is also relevant when it comes to the industrial development at the regional level. Separate actors, for example, an industry selling excess heat to a district heating company, can benefit from such collaboration around heat supply. Besides the environmental benefits this can also bring financial benefits as well as improved competitiveness of the companies involved (Gebremedhin and Carlson, 2002).

Industrial collaboration around heat supply is relatively rare. There is an increase but still, the increase is low compared to the supply of excess heat from the industrial processes within the country. However, there are examples of successful similar cases of companies and other organizations exchanging resources which generated improved positive financial and environmental outcomes for the involved organizations and for the society at large (Doménech and Davies, 2009). The most successful cases of collaboration have arisen spontaneously (Chertow, 2007). Chertow (2007) also means that collaboration between companies does not always occur even though the physical conditions for it exist.

Given the discussion above, it is interesting to study the necessary preconditions, drivers and barriers behind the development of these collaborative systems on heat supply. Increased knowledge of the important aspects could mean greater opportunities to facilitate the development of excess heat based systems of district heating.

Therefore the aim of this study is to investigate important preconditions behind the development of excess heat based systems of district heating. Two central research questions for this study were

- Which necessary preconditions must be provided for excess heat based district heating systems to emerge?
- What are the main drivers and barriers in the development of excess heat based district heating systems?

This was investigated through a study on the successful development of excess heat-based district heating systems in two Swedish communities. The results are analyzed based on previous findings of the emergence and development of industrial collaborations within the research field of Industrial Symbiosis (IS). This is further explained within the theoretical framework in chapter 2.

2. Theoretical framework

Industrial Symbiosis (IS) is a subset of Industrial Ecology (IE), which is a relatively new research field that is based on the ideology of nature. IE uses nature as a “reference” to study resource productivity and environmental burdens of industrial and consumer products and their production and consumption systems. IS is a formation of close working agreements between normally unrelated industrial companies or other organizations that lead to resource efficiency (Jensen et al., 2011). For example the working agreements can involve reuse of one company’s by-products as another’s raw material; sharing of power, water and steam supplies, and the sharing of manufacturing capacity, logistics, and expertise (Jensen et al., 2011). IS has a particular focus on cyclical flows of resources through networks of businesses within wider system boundaries. One definition is that IS

“[...]engages traditionally separate businesses in a collective approach to competitive advantage involving physical exchange of materials, energy, water and/or byproducts”. “The keys to IS are collaboration and the synergistic possibilities offered by geographic proximity” (Chertow, 2000).

We argue that excess heat based district heating systems with collaboration on heat supply is an example of IS, since it means that the residue of one business is utilized as a resource by another. Further, understand and explain the mechanisms behind collaborations on heat supply it is interesting to study previous research within the research field of IS.

The most famous example of IS observed is within the industrial district of Kalundborg, Denmark. Kalundborg is an example of self-organized synergies between the companies involved which largely developed in reaction to financial forces and local scarcity of resources (Ehrenfeld and Gertler, 1997) Studies of IS networks, Kalundborg among others, has improved the academic understanding of IS.

The main drivers behind synergies of IS has shown to be business imperative of needing to improve profitability and competitiveness (Ehrenfeld and Gertler, 1997). However, the drivers can also be social, environmental, or regulatory in nature (Chertow, 2007). Regardless of the driving forces behind the development of synergies the development of IS has been shown to result in significant financial and environmental benefits both for the companies involved in a given synergy and the wider society at large (Doménech and Davies, 2009).

IS collaborations usually develop spontaneously (Chertow, 2007). Collaborations, which evolve spontaneously, seem to be more durable and functional than those that are specifically built for IS collaborations (Chertow, 2007). The previous successful cases of IS have served as the inspiration behind planned attempts to create so-called eco-industrial parks. However, attempts to implement the lessons learned in the form of planned attempts of eco-industrial parks have largely failed (Chertow, 2007; Gibbs and Deutz, 2007). There are diverse reasons offered as explanations behind the failures. Yet, the problem, which is widely held to be one of the primary barriers to the development, involves difficulties in generating intercompany collaboration, which is required for companies to commit to the linking of production processes (Gibbs, 2003).

A previous study on the importance of embedded relations within IS collaborations by Uzzi (1997) seems particularly interesting. Uzzi (1997) goes into detail and points at three important organizational preconditions for IS collaborations to be able to emerge. The study describes embedded relations based on trust and personal ties, rather than explicit contacts’ as an important precondition for a successful collaboration around exchanges of energy and resources between organizations. Further Uzzi (1997) means that there are three features characterizing an embedded network of actors; (1) *Trust*, (2) *Fine-grained information transfer* and (3) *Joint problem solving*, which all allows companies to adapt more quickly and to be more flexible to environments characterized by continuous change and complexity. Companies and other organizations involved in embedded networks tend to have a greater chance to gain advantages compared to other forms of governance (Uzzi, 1996).

According to Uzzi (1996), embeddedness refers to “the process by which social relations shape economic action in ways that some mainstream economic schemes overlook or miss specify when

they assume that social ties affect economic behavior only minimally or, in some stringent accounts, reduce the efficiency of the price system”.

3. Methodology

This study includes two Swedish cases of district heating systems based on excess heat, case 1 in Skärblacka and case 2 in Lindsberg. In case 1 the development of the district heating system is a result of the availability of industrial excess heat from the nearby paper mill Billerud and in case 2 the district heating system has developed from a system based on fossil fuels to a system based on excess heat from the carton board mill Korsnäs Frövi. Table 1 presents a compilation of the two cases.

Table 1. Compilation of the two cases, case 1 in Skärblacka and case 2 in Lindsberg

	Case 1 Skärblacka	Case 2 Lindsberg
District heating company	Tekniska Verken in Linköping (Local authority owned)	Linde Energy in Lindsberg (Local authority owned)
Provider of excess heat	Billerud paper mill in Skärblacka within the municipality of Norrköping. It is heat from the mill's bleach plant that is utilized. The energy is used to heat villas, apartment buildings and several public buildings in Skärblacka.	Korsnäs Frövi carton board mill in Frövi. It is heat from the mill's plant that is utilized. The energy is used to heat villas, apartment buildings and several public buildings in Lindsberg.
District heating grid	Owned by Tekniska Verken	Owned by Linde Energy
Amount of energy delivered	20 GWh/year	87 GWh/year
Energy balance (mill)	88 % of the mills combustions consist of renewable fuels. The remaining 12 % is fossil-based fuels. Combustion of oil is only used at peak load.	95 % of the mills combustions consist of renewable fuels. The remaining 5 % is fossil-based fuels. Combustion of oil is only used at peak load
Energy balance (grid)	50% excess heat and 50% steam produced to raise the temperature of the excess heat	87% excess heat

The study includes interviews with several different relevant actors within the two cases representing; the district heating company, the industry providing the excess heat and each local authority in question. Table 2 presents number and types of respondents from each case.

Table 2. Number and types of respondents from each case

	Case 1 Skärblacka	Case 2 Lindsberg
District heating Company	2	3
Industry	2	1
Local authority	1	1
Total	5	5

The objective behind the selection of respondents was to be able to capture the process behind the development of the excess heat based district heating systems and thereby the necessary conditions crucial for the development and the collaboration between the district heating company and the industry. It also aims at determine the main drivers and barriers behind such a collaboration. The selection of respondents, representing the different businesses, also allows a capture of both the industries and district heating companies perceived drivers and barriers of such a collaboration. In

order to provide an understanding of the experienced divers and barriers within the two cases, five respondents from each case were contacted; two respondents representing the industry in case 1 and one respondent from case 2, two representing the district heating company in case 1 and three representing the district heating company in case 2. There were 1 respondent representing the local authority from each case. Besides this, additional written documentation such as articles and reports has been studied.

The interviews performed were semi-structured and executed via telephone during spring 2012. The interview questions were formulated based on previous research that shows that financial incentives are important drivers behind these types of collaborations (Ehrenfeld and Gertler, 1997). Likewise are also organizational aspects such as embedded relations based on trust and personal ties described as important aspects of a well-functioning collaboration (Uzzi, 1997) and thus included in the questionnaire.

The results from the interviews and the additional documentation were divided in two parts, based on the interview questions and the different themes that emerged during the interviews. The first part contains result about the two cases and the emergence and developments of the collaborations. The second part covers clarifying results about the perceived preconditions, driving forces and barriers. This part is further divided in the different themes that emerged during the interviews. The themes are presented in order of importance. The most important precondition, driving force or barrier behind the development of the collaboration's is presented first, followed by the second most important etc.

The analysis and discussion is based on the theoretical framework, presented in chapter 3, of important preconditions, drivers and barriers from previous research within the research field of IS.

4. Results

This chapter contains a summary of the results from the interviews and is based entirely on the respondents' own experiences and perceptions of the progress of each case. First there is a description of the cases and the development of the collaboration divided on the two cases, second follows a presentation of the perceived preconditions, driving forces and barriers. The presentation of the results in the second part is based on the themes that emerged during the interviews. .

4.1. Case description

The following paragraphs contain a description of each case. It also describes the development of the collaborations within the two cases.

4.1.1. Case 1 -Tekniska Verken and Billerud paper mill in Skärblacka

The district heating in Skärblacka is based on excess heat from Billerud paper mill in Skärblacka and distributed by the local authority owned energy company, Tekniska Verken in Linköping AB. Tekniska verken owns the district heating grid in Skärblacka and they are also the heat distributors. It is Tekniska Verken who is responsible for the delivery guarantees to the customers and, if necessary, the contribution of additional energy. Tekniska Verken is also responsible for the heat exchanger inside the Billerud's factory premises. It is essentially the heat in the effluent from the mill's bleach plant that is utilized. The energy used to heat villas, apartment buildings and several public buildings in Skärblacka is energy that would otherwise go to waste. 88 percent of the mill's combustions consist of renewable fuels, the remaining 12 percent is fossil-based fuels. Combustion of oil is currently only used at peak load during extreme cold at wintertime or during unplanned shutdowns in production at the mill.

Billerud began supplying excess heat to the district heating grid in Skärblacka in 2006. The mill's supply of excess heat to the central district heating grid has led to that a number of oil-fired boilers has been taken out of operation, approximately 2500 cubic meters of oil has been replaced by the excess heat from the mill. Behind this development is a government investment grant called Klimp, (Climate

investment program)¹ which Tekniska Verken applied for together with the municipality of Norrköping. They were granted approximately 16 % of the total investment cost of the project. Skärblacka is located in the municipality of Norrköping, therefore, the contact regarding the investment grant was with the local authority of Norrköping.

It was Tekniska Verken who was the initiator of the collaboration with Billerud. They were interested of starting to operate regionally as a way of expanding their business. At first Billerud was not interested in cooperating on heat supply. It is described, both from the energy company and the industry, that Tekniska Verken initially entered the business organization hierarchy of Billerud at the wrong level. Wrong representatives from both organizations came into contact with each other, which led to that they did not understand each other, and to that they did not come forward in the collaboration at that time.

One of the respondents from Tekniska Verken describes that the proposal was put aside for a period of approximately one year before they decided to contact Billerud again. With a better defined proposal where Tekniska Verken could show which benefits, both financial and environmental, the parties could get out of the collaboration they eventually agreed on a joint project that suited both parties. The main reason they finally managed to get on with the process and initiate the collaboration is explained to be that the senior management from the two companies eventually met. One of the respondents from Tekniska Verken describes it this way: *"When we contacted Billerud the second time and went there to present our proposal, we had our company CEO with us to meet their CEO"*.

4.1.2. Case 2 -Linde Energy and Korsnäs Frövi carton board mill in Lindesberg

Linde energy, which also is a local authority owned energy company, delivers district heating to Lindesberg, Frövi and Vedevåg. 90-95 percent of the energy in the local district heating grid comes from Korsnäs Frövi carton board mill. It is heat from the mill's plant that is utilized. The energy is used to heat villas, apartment buildings and several public buildings in Lindesberg. Linde Energy owns the district heating grid and is responsible for the pipes. Korsnäs is responsible for the heat exchanger inside the factory premises. Korsnäs is also responsible for the delivery guarantees to Linde Energy and thereby obliged to compensate for loss of supply. The heat is transported to Linde Energy in Lindesberg over an 18-km long transmission pipeline. 95 percent of the mills combustions consist of renewable fuels. The remaining five percent is fossil-based fuels. Combustion of oil is only used at peak load during extreme cold at wintertime.

The mill's supply of excess heat has led to that a heat pump has been taken out of operation, approximately 4200 tonnes of Liquefied Petroleum Gas (LPG) and 200 m³ oil have been replaced. The consumption of fossil fuels is reduced by 96 percent. Behind this development is a government investment grant called LIP, (Local Investment Program) which Linde Energy applied for together with the municipality of Lindesberg. They were granted 15% of the total investment cost of the project.

The collaboration between Korsnäs Frövi and Linde Energy is a long-term collaboration. The two parties have had a contract for energy supply since 1999, the contract has been renewed one time and is valid until the year 2019. The collaboration started by something, that all of the respondents describes as a coincidence. The former energy manager at Korsnäs was also a member of Linde Energy's board of directors. It was he who noticed that while Korsnäs had problems with their excess

¹ The Swedish Government set aside 8.2 billion Swedish kronor in grants for environmental improvements during the years 1998-2008. These grants were collected in two so called investments programs. The first, LIP (Local Investment Programs), had a view to increase ecological sustainability in general, while the second, Klimp (Climate Investment Program), was targeted for support to investments reducing global warming. The grants funded approximately 10-20% of the total investment cost of the projects (Swedish Environmental Protection Agency, a 2012). In case 1 KLIMP grants were used and in Case 2 LIP grants.

heat, due to increased production, Linde Energy also had problems with their former heat pump, which contained the now banned substance R12 (dichlorodifluoromethane). R12 was before it become banned a widely used refrigerant in heat pumps. Linde Energy was currently in the search for an alternative source of heat. At the same time Korsnäs were exploring the potential of building cooling towers to cool off the excess heat they had from their production. It was the same man, with insight in both businesses that introduced the two parties for each other and made them see the potential of starting collaborate on the excess heat.

According to all of the respondents the collaboration has been good from the start. Both parties saw the potential and what they would gain from starting to cooperate. One of the respondents from Linde Energy expresses that: *"It was love at first sight"*.

4.2. Preconditions, driving forces and barriers

The following chapter presents the perceived essential preconditions, main driving forces and barriers behind the development of the collaboration in the two cases. The essential preconditions of both cases are described quite similar. The results from the two cases are jointly presented based on the themes that emerged during the interviews. As mentioned, the most important aspect of each theme, from the respondent's points of view, is presented first.

4.2.1. Financial Preconditions

The most important precondition is described as financial. One respondent representing Tekniska Verken in case 1 describes that: *"It is important that both parties have something to gain from the collaboration"*. All of the respondents believe that the investment grant contributed to that the project developed in the relatively fast paces it did. According to Tekniska Verken in case 1, they do not know if they would have expanded to the extent they did without the investment grant. According to one of the respondents the investment grant led to a greater confidence to invest and expand to greater extent than they perhaps would have done without it. The respondent from the local authority in case 2 thinks that: *"it would have been difficult to succeed in persuading the politicians to implement the project without the grant"*.

In case 2 a clear business plan and agreement about the financial issues that both parties agreed on was essential. Something that has been important is honesty regarding the financial aspects. The respondent from Korsnäs says that: *"From the energy company's side, they often see excess heat and think that it is just waste and something they shouldn't pay for. The industry, on the other hand, sees it as prime heat that should cost the full price. This difference places the energy company and the industry far from each other and often makes it hard for them to agree"*.

4.2.2. Technical Preconditions

Second most important precondition for collaboration regarding excess heat mentioned in the cases is of technical origin. The necessary technical preconditions, as; reasonable distance between the industry and district heating grid, heat demand, availability of technical solutions etc. had to exist for both projects to be feasible.

4.2.3. Organizational Preconditions

The organizational aspects are described as the third most important precondition in both cases. A clear business plan and agreement that both parties agree on are essential. One respondent from Billerud in case 1 mean that: *"it is a lot about chemistry at the personal level, I believe that is very important ... that there are people speaking the same language and comes along well"*. The same respondent also believes that one of the most basic preconditions is about: *"A willingness to do something innovative and daring to go for something new"*. Yet another respondent from Tekniska verken claims that: *"It is important that this type of collaborative projects is channeled the right way through the company. It is often also that the top-management think that it is –more fruitful to talk to someone at the same professional position that should not be ignored"*.

The basis for a well-functioning collaboration is described as an open relationship with mutual trust and understanding for each other's activities, honesty, willingness, an open mind and a clear and fair business plan. One of the respondents from Billerud in case 1 says that: *"You have to be open and honest to each other, if you get the feeling that the other one earns more from the deal than you do yourself it will not be good"*. The respondent from Korsnäs in case 2 means that: *"The same technical possibility has existed in many other places as well, but without being a success"*.

4.2.4. Financial Drivers

The financial aspects behind the project have been the strongest driver for all parties. All parties mean that the project has been financially profitable.

4.2.5. Environmental Drivers

The environmental driving forces are described as a central issue for all parties. Tekniska Verken in case 1 describes the environmental aspects of the project as a key driver: *"It's a part of our culture ... it is a lot about that this way of thinking is within the walls of the company"*. One of the respondents from Billerud, also from case 1, describes that they from the mill rather see it as they are: *"contributing to something good from an environmental point of view"*. One of the respondents from Linde Energy in case 2 says that: *"Some of the great drivers were to increase the connectivity of the district heating grid and to reduce the municipality's CO₂ emissions"*.

4.2.6. Financial Barriers

The main barriers behind the development of both projects were financial. In case 1 it concerned the breakdown of the investment costs. One respondent from Billerud means that: *"This is not our core business, we put our investments in improving our products, and we cannot start building district heating systems with our relatively small investment budget"*. One of the respondents from Tekniska Verken remembers that they from Billerud said: *"You [Tekniska Verken] have to take the cost and all risks if you are interested in our excess heat"*. Since both parties in case 2 were faced with significant financial investments to solve their initial problems, it seemed to be naturally to share most of the investments. Since Linde Energy is a local authority owned company and since the project meant such a major investment, the issue had to be addressed in the local authority City Council. The respondents from Linde Energy say that they initially felt that it was difficult to convince the politicians of the financial sustainability of the project.

4.2.7. Technical Barriers

The technical aspects are described as the second largest barrier of the project. One of the respondents from Billerud in case 1 describe that: *"one reason that there often is a skepticism about this type of collaboration that involves connections to society, especially from the industries point of view, is that we are very afraid of breakdowns in the production ... if one is a large heat supplier to a society these stops can be very damaging ... then there must be a back-up system"*. In case 2 the main technical barrier was getting permission from all landowners affected by the pipeline from Linde Energy and the mill in Frövi. One of the respondents from Linde Energy describes it this way: *"Some were very skeptical and had comments on the project. There were two who felt that the financial compensation was too low and protested, but eventually they gave in as well"*.

4.2.8. Benefits and Positive side effects

The main benefits of the collaboration are, like the drivers, defined as financial and environmental in both cases. Tekniska Verken in case 1 has better financial conditions for the district heating in Skärblacka, compared to what they would have had otherwise. Another part of the profit is considered to be the fact that they can promote the collaboration as a good environmental investment and thus gain market advantages over competitors in the market. Billerud describe that there was some financial incentive, even if it does not involve any significant financial profits. There was also an environmental incentive from the mill's site. The local authority of Norrköping experienced that the project led to clearer environmental measures within the region.

In case 2 the number of connections to the district heating grid in Lindesberg increased more than expected. The development also led to a new district heating grid in Frövi. A large portion of the profits from the project was used to reduce the price of the district heating towards the customers, which was decreased by about 10 percent. Tekniska Verken in case 1 has, a development of the project in Skärblacka, continued to expand the district heating grid to Kimstad. Kimstad is a community in the municipality of Norrköping, located about 6 kilometers south of Skärblacka. One of the respondents from Tekniska Verken says that: *"We would not have established district heating in Kimstad if we had not established district heating in Skärblacka to begin with"*. Billerud, also in case 1, find the further development of the district heating in the community as positive. One of the respondents expressed that: *"We think that's nice, it means that more and more of the resources available come to use"*.

5. Analysis and Discussion

The collaborations around heat supply in both cases described in this study have increased the financial benefits as well as the environmental performance. The collaborations took off when the two parties within each case got in contact and saw the potential of starting to collaborate. The development of the collaborations has been driven entirely by the actors involved. Through the collaboration the energy companies get to buy cheaper heat while the mills get paid for the excess heat.

The following paragraphs contain an analysis of the results based on previous research on necessary preconditions, drivers and barriers behind the development of IS collaborations. The more specific organizational conditions highlighted as important preconditions by Uzzi (1997) is analyzed in relation to the results with the purpose to provide an understanding of the social mechanisms that shape the decision-making process of companies and relevant actors within the two cases of collaboration on heat supply.

The results show that the collaboration on heat supply started spontaneous in both of the cases. However, in case 1 the energy company Tekniska Verken had a more proactive role in the development. It was Tekniska Verken who drove the development forward and had a clear vision of what they wanted to accomplish. The fact that the collaboration between Tekniska Verken and Billerud not took off at the beginning of the process can be caused by the absence of a common vision and goals. The communication between the two parties was poor in the beginning. The results show that it was because Tekniska Verken initially entered the business organization hierarchy of Billerud at the wrong level.

According to Albrechts (2006) interaction and exchange of knowledge are important preconditions in the decision making process. Exchange of knowledge through participation from both parties' sides is required in order to understand and translate the goals and objectives into practice. The results show that they from Billerud's side initially did not see any personal gains from collaboration. They only saw a number of potential risks of, for example allowing Tekniska Verken into their industrial park. However when the right representatives from both organizations came into contact with each other, it led to that they started to communicate and share information and knowledge. They started to formulate common goals and objectives and the collaboration took off.

In case 2 the energy company, Linde Energy and the Industry, Korsnäs had a common goal and a clear vision from an early stage of the collaboration. They were both facing significant financial challenges, and they both had much to gain from the collaboration. There is a clear difference between how the collaboration within the two cases began. In Case 2, the two parties were more equal in terms of driving forces behind the project. It can be described as a reason behind that the collaboration initially developed towards common goals. Chertow, (2007) as well as Ehrenfeld and Gertler (1997) mean that collaborations that evolve spontaneously seem to be more durable and functional than those who are planned. In addition, the great financial investments in developed technology, established roles, new standards, continuous contact and cognitive routines within the new widened system has led to a future dynamic stability of the studied systems (Geels & Kemp, 2007).

The main driving forces behind both collaborations have been of financial origin. The environmental aspects are also described as an important driver. Nevertheless, all respondents consider that the development in the two cases never would have taken place if it not had been financially viable. Ehrenfeld and Gertler (1997) strengthens this by meaning that financial driven actions are the main reasons behind IS collaborations.

Organizational preconditions, besides the basic technical and financial preconditions, have been necessary for the collaborations to happen and overcome the main barriers. Embedded relations based on trust and personal ties are described as important aspects of a well-functioning collaboration (Uzzi, 1997). Both cases meet the characteristics of an embedded network of collaboration involving the three features Uzzi (1997);

- *Trust,*
- *Fine-grained information transfer* and
- *Joint problem solving*

Uzzi (1996) further mean that companies and organizations involved in embedded networks, having these three features, tend to have a greater chance to gain advantages compared to other forms of governance. Such collaboration has been reported to provide positive financial and environmental outcomes for the organizations involved as well as for the community as a whole (Burström and Korhonen, 2001). These three features are something that the respondents themselves describe as important aspects and reasons why they have managed to get past the barriers, financial as well as technical, which occurred during the course of evolution. Understanding the social mechanisms that shape the decision-making process of companies and relevant actors is therefore crucial in the guiding of industrial actors and policy makers in developing more sustainable industrial systems (Doménech and Davies, 2011).

These organizational conditions have also been important when it comes to the financial issue concerning investment grants. All respondents believe that the investment grant have been important for development in both cases. Some even believe that development would not have happened without the investment grant. Both LIP and Klimp is based on collaborations between different actors in the community for improved environmental performance; Lip -with measures to increase the ecological sustainability and Klimp -for long term investments resulting in reduction of greenhouse gas emissions and increased local participation and initiative. It is the local authority that is responsible for the program and its implementation (Swedish Environmental Protection Agency, b 2012). Based on the features of Lip and Klimp a well functioning collaboration is even more important.

When it comes to *Fine-grained information transfer*, communication, exchange and integration of knowledge have been necessary preconditions in the development in both cases. In case 2 the respondents describe that they have been working closely together through continuous discussions to be able to learn and get insight into each other's businesses. The information transfers between the actors involved can be compared to the loops of learning described by Peschl (2007), who highlights the importance of a feedback loop between the realm of knowledge and the surrounding environment. The actors has trough the feedback loop been able to step out of their normal way of thinking and acting, which is especially important within these two cases, since the actors within each case are significantly different. The feedback loop of learning between the actors involved in each case have made it possible for them to learn about each other's businesses and to see outside their own system boundaries Peschl (2007). This in turn has led to a greater effectiveness and environmental and financial gains for the companies involved as well as for the society at large (Doménech and Davies, 2009). Collaboration in terms of interaction and exchange of knowledge have shown to be important preconditions in the decision making process within joint projects (Albrechts, 2006). This is also important for the building of trust and shared visions, which require time and frequency of contact (Doménech and Davies, 2011). Knowledge through participation from relevant stakeholders within the system of collaboration is in turn required to understand and translate the common goals and objectives into practice (Albrechts, 2006).

In the case of *Trust*, it is described that it has been important to show humility for the other partner's business from the beginning so that nobody feels overshadowed. This seems to be especially important for the energy company, as this type of heating issues do not belong to the core business of the industries. The pricing of the excess heat has, for example, been a major issue in both cases. The heat certainly is waste for the industry, at the same time it is an important resource for the district heating company. Therefore, it should also be priced accordingly. The energy company in case 2, believes that this is a key issue for gaining and maintaining the trust between them and the industry, to be open about what they gain from the collaboration and to price the heat after that. The role of trust in building and realizing well functional collaboration's has previously been widely recognized (Chertow et al., 2008; Gibbs, 2003; Hewes and Lyons, 2008; Jacobsen and Anderberg, 2005).

Personal and emotional relations are also one thing that has shown to be important within the development in the two cases. All respondents mean that personal and emotional contacts and relations play an important role in the collaborations. This is particularly evident in case 1, where it is described that Tekniska Verken initially came into contact with the wrong representatives from Billerud. This led to that they did not understand each other, and to that they did not come forward in the collaboration at the time. This resulted in the Billerud felt insulted, and that the professional relationship was damaged by the emotional and personal. This is strengthened by Doménech and Davies (2011) who mean that personal and emotional ties straighten professional/business linkages.

As for *Joint problem solving* the results shows that common goals and visions, similar to Doménech and Davies (2011) statement, have been important for the development of embedded collaborations based on trust. Doménech and Davies (2011) further mean that more embedded relations develop opportunity to carry out more risky and innovative projects.

Much of the previous research within the field of IS highlights the importance of certain organizational conditions (Uzzi, 1997; Doménech and Davies, 2011; Chertow et al., 2008; Gibbs, 2003; Hewes and Lyons, 2008; Jacobsen and Anderberg, 2005). However, the results from this study clearly showed that the parties involved in the collaborations to a large extent is controlled by the financial conditions concerning the substantial financial investment associated with the technical solutions needed to be able to achieve the development. As mentioned, it is often the financial aspects that are the main driver behind the development of collaboration projects on different forms of resource exchange (Ehrenfeld and Gertler, 1997). However the required substantial financial investments makes the financial aspects a barrier as well. Based on this we believe that investment subsidies can act to encourage investments and facilitate the parties involved seeing the long-time benefits with collaborating. This would not only benefit the parties involved but also the society at large.

6. Conclusions

This study consists of two existing cases of collaboration between a district heating company and a paper mill. These collaborations on heat supply can be seen as examples of IS, since it means that the residue of one business is utilized as a resource by another.

Like Uzzi's study from 1997 study, this study has also shown that Trust, Fine-grained information transfer and Joint problem solving has been necessary preconditions in the developments of the collaborations. In addition, this study also highlights the importance of honesty and shared visions on common goals as necessary preconditions for well functioning collaborations. All these features have also proved to be important preconditions in the decision making process within these types of joint collaboration project where knowledge through participation from relevant stakeholders within the collaboration is required to understand and translate the common goals and objectives into practice.

When it comes to the main drivers and barriers behind the developments of the collaborations within the two cases the respondents highlights financial aspects as being the both the main driver and the main barrier behind the development. Since substantial financial investments often is required we believe that investment subsidies are important for the future development of excess heat based

systems of district heating, as a way of encouraging investments and facilitate the parties involved seeing the long-time benefits with collaborating. This would not only benefit the parties involved but also the society at large.

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