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Collaborative development of resource efficient district heating in Sweden

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SAMMANFATTNING

En ökad återvinning av restvärme från industriprocesser är önskvärt då det har potential att avsevärt minska behovet av primär energi. Fjärrvärmesystem baserade på industriell restvärme kan i allmänhet anses som resurseffektiva då de bidrar till en minskad användning av fossila bränslen och utsläpp av växthusgaser. Dessutom finns det ekonomiska fördelar att vinna för de aktörer som ingår restvärmesamarbete.

I Sverige har restvärmesamarbeten mellan fjärrvärmeföretag och industrin ökat det senaste decenniet. Trots detta är dock den outnyttjade potentialen stor i relation till de befintliga mängder restvärme de industriella processerna i landet ger upphov till. Tillvaratagande av industriell restvärme i fjärrvärmenät är i dagsläget ett av de mest kostnadseffektiva sätten att tillhandahålla värmeenergin.

Expansion och nybyggnation av fjärrvärme i nya områden öppnar upp för möjligheten att ytterligare utnyttja industriell restvärme. En viktig aktör för att möjliggöra detta är Sveriges kommuner som har befogenhet att påverka den framtida utvecklingen av energisystemen genom planeringen av nya områden. Även ökad kunskap om hur samarbeten över organisationsgränser utvecklas är önskvärd för att ytterligare öka förutsättningarna för utvecklingen av restvärmebaserade fjärrvärmesystem.

Denna licentiatavhandling undersöker vikten av organisatorisk samverkan rörande uppkomsten av resurseffektiv fjärrvärme. Avhandlingen sammanfattar resultaten från tre artiklar och undersöker, mer specifikt; förutsättningarna, drivkrafterna och hindren bakom uppkomsten och utvecklingen av restvärmebaserade fjärrvärmesystem i Sverige, både utifrån fjärrvärmeföretagens och industrins perspektiv. Avhandlingen diskuterar även hur den svenska kommunala planeringspraktiken kan tillämpas för att förbättra förutsättningarna utvecklingen av resurseffektiv fjärrvärme.

Från de inblandade aktörernas synvinkel är det främst ekonomiska aspekter som lyfts fram som viktiga bakom utvecklingen av restvärmesamarbeten. Andra aspekter av organisatorisk karaktär som visat sig vara viktiga för utvecklingen är relationer baserade på förtroende, ärlighet, gemensamma mål, informationsutbyten och gemensam problemlösning. Dessa aspekter har visat sig vara nödvändiga för utvecklingen av långsiktigt hållbara och framgångsrika restvärmesamarbeten. Organisatoriska aspekter är också viktiga vad gäller beslutsprocessen eftersom kunskap genom deltagande av samtliga aktörer krävs för förståelse av de gemensamma målen, vilket i sin tur är en förutsättning för att kunna omsätta målen i praktiken.

Rörande utveckling av nya restvärmebaserade fjärrvärmesystem visar studierna, inom ramarna för denna avhandling, att fjärrvärmeföretagen generellt bjuds in att delta sent i den fysiska planeringsprocessen. En tidigare dialog mellan de kommunala fysiska planerarna och fjärrvärmeföretagen skulle kunna underlätta utvecklingen av nya restvärmebaserade fjärrvärmesystem. Vidare, för att öka förutsättningarna för restvärmebaserade

fjärrvärmesystem bör man inom ramarna för den fysiska planeringen även ta närliggande befintlig industri med överskottsvärme som en biprodukt av sin produktion i beaktning.

Införande av investeringsstöd skulle förmodligen främja utvecklingen av restvärmebaserade fjärrvärmesystem ytterligare, vilket också potentiellt skulle innebära långsiktiga miljövinster för de aktörer som deltar i samarbete, liksom för samhället i stort.

ABSTRACT

An increased recovery of excess heat from industrial processes and thermal power generation could significantly reduce energy demands. Industrial excess heat-based district heating systems are generally considered resource efficient because they reduce the use of fossil fuels and the emissions of greenhouse gases. In addition, collaborating actors can gain financial benefits.

In Sweden, although collaboration around heat supply has increased recently, the amount of excess heat that is utilized is low compared to the amount created by industrial processes. Using excess-heat recovery in district heating grids is currently one of the most cost-effective ways of providing additional heat to district heating systems.

Expansion and new construction of district heating systems in new residential areas can be seen as an opportunity to further use industrial excess heat. Sweden's local authorities can influence the development of energy systems used for new residential developments. Increased knowledge about how collaborations evolve could be used to develop strategies that could encourage the development of excess heat-based systems for district heating.

This licentiate thesis examines the role of organisational collaboration when it comes to the emergence of resource efficient district heating. The thesis summarises results from three articles and investigates the preconditions for, drivers behind, and barriers to the development of excess heat-based systems for district heating in Sweden. These investigations focus on both the district heating companies' and industries' points of view. The thesis also discusses how Swedish spatial planning practice could improve the conditions for resource efficient district heating.

Important preconditions for excess-heat collaborations to develop, from the actors' points of view, are mainly financial. However, relationships based on trust, honesty, shared goals, information transfer, and joint problem solving are also necessary for such collaborations to evolve and develop into long-term successful excess-heat collaborations. These features are also important when it comes to the decision-making process, because knowledge gained through the participation of stakeholders is required to understand common goals and objectives and to put these into practice.

As for the development of new excess heat-based district heating systems, results show that the district heating companies generally participate late in the spatial planning process. An earlier dialogue between local authority planners and district heating companies could facilitate the emergence and development of new excess heat-based district heating systems. Furthermore, to facilitate the use of excess heat-based systems, planning should also take into account any nearby industry that produces excess heat. In addition, investment subsidies could encourage the development of excess heat-based systems for district heating and provide long-term environmental benefits for collaborating actors as well as for society at large.

ACKNOWLEDGEMENT

This Licentiate thesis is a concluding summarisation of my almost three years as a researcher. It has been a progressive, challenging, frustrating, as well as fun and interesting project.

My supervisors, Olof Hjelm and Sara Gustafsson, deserve special thanks for their support during this thesis project. Your knowledge and commitment, along with our fruitful discussions, have been very valuable in the development of my research and of me as a researcher. I owe you big time!

Jenny Ivner who introduced me into this topic and who also was my first supervisor deserves special thanks as well.

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Last, but definitely not least, I thank Marko, my soon-to-be-husband (!), for just making everything in life easier and for bringing lovely Nåmi into my life. You make me the happiest woman on earth!

LIST OF APPENDED ARTICLES

Article 1 - Persson, S., Hjelm, O., Gustafsson, S., (2012). Preconditions, Drivers and Barriers behind the Development of Excess Heat-Based Systems for District heating. *(Presented at the Greening of Industry Network Conference, Linköping 2012 – Submitted to a second round of review to the Special Volume of the Journal of Cleaner Production for the GIN Conference 2012.)*

Article 2 - Persson, S., Hjelm, O., Gustafsson, S., (2013). Industry's Perspective on Preconditions, Drivers and Barriers behind Excess Het Supply Collaborations with the District heating sector. *(Manuscript)*

Article 3 - Persson, S., Hjelm, O., Gustafsson, S., Ivner, J., (2013). Spatial planning as a tool to facilitate district heating expansion. *(Submitted to Local Environment.)*

MY CONTRIBUTION TO THE ARTICLES

Article 1: Major contribution – both data collection and writing were achieved with support and guidance from Olof Hjelm and Sara Gustafsson.

Article 2: Major contribution – both data collection and writing were achieved with support and guidance from Olof Hjelm and Sara Gustafsson.

Article 3: Major contribution – both data collection and writing were achieved with support and guidance from Olof Hjelm, Sara Gustafsson, and Jenny Ivner.

RELATED PUBLICATIONS

Persson, S., Ivner, J., (2011). Uncovering Industrial Symbiosis in Sweden: **-** Exploring a possible approach. *(Presented at the World Renewable Energy Congress, Linköping 2011.)*

Ivner, J., Persson, S., (2009). Fysisk planering och fjärrvärmeexpansion i praktiken: Förstudie om beslutsprocessen vid kommunal fysisk planering och fjärrvärmeexpansion i nyexploaterade områden. *(Presented at the Swedish District Heating Association's distribution day 2010.)*

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1. INTRODUCTION

The global environmental situation is becoming increasingly critical, as global warming is undoubtedly one of the greatest environmental problems of the day. Solving the climate issue is one of humanity's greatest challenges. The energy sector has a large impact on our climate and accounts for a large part of the total greenhouse gas emissions, both globally and in Sweden, making energy conversion one of the most topical issues on the political agenda.

Because Sweden has long and cold winters, most of the energy in Sweden is used for heating. The most common form of heating in Sweden is district heating, accounting for just over half of all space heating. Because district heating has a long history and high delivery reliability and Sweden has a history of consistent climate and energy policies, district heating has gained a uniquely strong position within the Swedish heating market (Swedish District Heating Association, 2009).

District heating has many advantages that cannot be provided by small-scale heating solutions. For example, large-scale biomass combustion produces less pollution and is more efficient than small-scale systems (Werner, 2004). The Swedish government has highlighted district heating as an important source of heat (Government Bill 2008/09:162, 2008) and has developed and invested in various national instruments in the form of subsidies and grants to facilitate local development of district heating within Swedish municipalities. Systems of district heating – based on renewable fuels, excess-heat recovery, and/or heat from waste incineration is an important environmentally-sound energy supply and an important mechanism for future development of the energy supply, both in Sweden and internationally.

Because Sweden has a tradition of large energy-intensive manufacturing industries – such as paper and steel mills – that generate large amounts of excess heat (Cronholm et al., 2009), these industries could use this otherwise-wasted industrial excess heat in district heating systems. Sweden is among the world leaders in using excess heat; it is estimated that approximately 50% of excess heat from large energy-intensive industries is used. The theoretical potential for the use of excess heat is estimated to be approximately 9,500 GWh (Swedish District Heating Association, 2002).

Despite the fact that Sweden is at the forefront when it comes to industrial excess heat-based systems of district heating, there are even more ambitious political goals in place. For example, one goal is to ensure that all excess heat above 55ºC be fully recovered (Swedish Energy Agency, 2010). In addition, technological developments have led to new and better technology for utilising low-temperature excess heat.

The use of excess heat is also relevant when it comes to industrial development at the regional level. Actors, such as an industry selling excess heat to a district heating company, can benefit from such collaboration concerning heat supply. In addition to the environmental benefits, this approach can also bring financial benefits as well as improved competitiveness for the companies involved (Gebremedhin and Carlson, 2002) as the industries are paid for a product that they otherwise would have been forced to find ways to cool, yet another expense. In

many cases, district heating companies are given the opportunity to buy excess heat at a lower price than the market price of primary energy.

Fulfilling the goal that all excess heat over 55ºC should be used by 2020 will likely require the emergence of new industrial excess-heat collaborations. Collaboration, however, requires companies and other organisations to share their resources and/or services, an approach that is not always used, even though the physical conditions for it exist (Chertow, 2007). One barrier to such collaboration is the fact that industries do not tend to operate outside of their core businesses. In the context of prevailing conditions and political objectives, industries' willingness to supply their excess heat should be of interest to the general public, in spite of these barriers. However, there are examples of companies and other organisations exchanging resources to improve financial and environmental outcomes for themselves and for society at large (Doménech and Davies, 2009).

Expansion and new developments of district heating systems in new areas can be seen as an opportunity to further utilize industrial excess heat. Such development of resource efficient systems of district heating, based on excess heat from industries, is in line with the political agenda. In cases of expansion and new development, effective collaboration between industry and the district heating sector is once again required. In addition, the involvement of a third player, the local authority, is also compulsory.

District heating's expansion has slowed during the past decade, however, as the most economically profitable areas for district heating are already connected to grids. In Sweden, district heating mostly occurs in urban areas, where the residential- and service-sector building heat market is largest (Forsaeus Nilsson et al., 2008). This geographical concentration arises because the typical users of district heating are commercial, public, and multi-family residential buildings located in urban areas that have a high heat demand, a situation that results in low distribution costs for district heating (Reidhav and Werner, 2005). Heat-sparse areas unfavourable for district heating normally consist of suburban single-family houses or small villas. The reason for the unfavourable situation within these areas is economic, that is, the revenue from heat sold is low compared to the investment cost for establishing a local distribution grid (Forsaeus Nilsson et al., 2008).

Local authorities have significant opportunities to influence the design and location of residential areas through their spatial planning and energy plans; if done strategically, through a greater focus on the most effective energy solution for the area, these plans can facilitate the expansion of district heating (Ranhagen, 2008). By considering energy issues associated with the municipal spatial planning of new settlements, the requirements for district heating can be included early in the development stage of new residential areas. The location and the design of residential areas can influence how district heating expands. Sweden's local authorities have a central role to play in moving the energy system towards sustainability by using effective, renewable energy supplied at competitive prices (Government Bill 2008/09:162, 2008). In Sweden, local authority planning and construction are governed by the PBA (Plan and Building Act). Thanks to a municipal planning monopoly, local authorities have great potential to influence the future development of the energy system. Through far-sighted

planning and urban development, local authorities have the ability to promote actively sustainable energy systems and infrastructure (Ranhagen, 2008). By also taking excess heat from local industries into account during municipal spatial planning, municipalities can influence the heat supply to the planned new area's level of resource efficiency. Yet, this influence requires knowledge gained through the involvement of different interested stakeholders with expertise in their specific fields (Ivner et al., 2010). Strategic planning and management through the involvement of different stakeholders depends on effectively communicating goals and objectives (Emmelin and Kleven, 1999).

These two research fields have much in common: both excess-heat collaborations and strategic spatial planning require collaboration across organisational boundaries. In both cases, it is important that the perceived benefits for all the actors involved are considered (Palm and Ramsell, 2007). To realise common interests in collaborations across organisational boundaries, all actors involved must feel that they have something to gain and that they are working together in a co-ordinated way towards common goals and interests (Börzel, 1998).

The aim of this thesis is to examines the role of organisational collaboration in the emergence of resource efficient district heating. To address this aim, two research questions have been formulated:

- What are the preconditions for, the drivers behind, and the barriers to heat-supply collaborations?
- How can municipal spatial planning be used to facilitate the emergence of new resource efficient systems of excess heat-based district heating?

1.1 LIMITATIONS

This thesis focuses on the different actors involved in the studied collaborations. The overall aim and research questions are designed to address the different actors' perceptions of the investigated situations and phenomena. The different studies within each of the articles have been carried out from a Swedish perspective, under the prevailing Swedish conditions and current Swedish legislation. Nevertheless, they yield useful lessons that can be applied internationally and to other areas of inter-organisational collaboration. This thesis does not address the national investigation into the introduction of Third Party Access (TPA) to district heating grids, because TPA yet has not been implemented.

2. WHAT IS DISTRICT HEATING?

The most typical part of a district heating system is the massive grids that are buried under earth, streets, roads, and lawns (Swedish District Heating Association, 2009). Water heated inside a district heating plant carries heat to practically all connected heating grids. In Swedish district heating systems, the combined length of these grids is now almost 18,000 kilometres. The pipelines consist of two pipes: the flow pipe (hot water under high pressure on the way to the customer) and the return pipe (cold water sent back to the heating plant where the water is heated again in a closed loop). The temperature of the water in the flow pipe is between 80°C and 90ºC. The temperature of the water in the return pipe is between 40°C and 50ºC. Each customer has a heat exchanger that transfers the heat to their radiators and hot water taps.

Heat density – i.e., the measurement of heat used per metre of pipeline – is the most important figure indicating the competitiveness of district heating (Swedish District Heating Association, 2009). The heat density is especially important when it comes to planning of developing new district heating grids. Since the 1960s (when it reached its peak), density has fallen. This decrease is mainly because district heating has been extended to less densely populated areas. District heating is a system that is particularly well suited to the urban community. The Swedish heat market's turnover during a normal year is barely 100TWh. District heating accounts for over 50% of the market, electric heating just under 30%, oil 5%, and other heating sources (natural gas, wood, geothermal, and solar) just over 10% (Swedish District Heating Association, 2009). In Sweden, all major cities have district heating systems. Of Sweden's 290 municipalities, 270 use district heating (Swedish District Heating Association, 2009). For a long time, the district heating plants were owned and governed by local authorities. As a result of deregulation in the 1990s, major private energy companies acquired many of the district heating plants previously owned by local authorities. More than half of the district heating supply goes to apartment buildings and up to 90% of the apartment-building market has district heating (Forsaeus Nilsson et al., 2008). The district heating market share for single-family homes, however, is considerably lower. This low share is due to the fact that the concentration of heat demand is lower in single-family areas, resulting in high distribution losses (Reidhav and Werner, 2005).

2.1. THE SWEDISH HISTORY OF DISTRICT HEATING

Developed in the late 1940s, district heating in Sweden (Swedish District Heating Association, 2009) provided an opportunity to produce heat and electricity in district heating plants. The Swedish tradition of collaboration has been crucial to this development. In contrast to individual heating solutions, district heating was about collaborating to solve common problems. Today, more than 60 years later, district heating has a uniquely strong position in the Swedish heating market. As mentioned in the introduction, district heating accounts for more than half of all space heating in the country (the European average is just under 10%).

District heating has a large market share although Sweden has never had a national district heating policy (Swedish District Heating Association, 2009),. District heating has been the

result of consistent energy and climate policies. These policies include taxing fossil fuel use while encouraging and subsidising less environmentally damaging heat supply solutions.

At first, it was not the environment and the vision of a sustainable society that were the driving forces behind the development (Swedish District Heating Association, 2009). It was rather the possibility to generate electricity and heat in the same process in combined heat and power plants (CHP). Heat and electricity was also the focus when Sweden's first municipal district heating system was developed in Karlstad 1948. The plant delivered electricity and heat to a newly built foundry. During winter, seven new residential buildings with 120 apartments were connected to the grid. A relatively short time after the development in Karlstad, many other cities followed (Swedish District Heating Association, 2009).

The real breakthrough for district heating came after the 1973 oil crisis (Swedish District Heating Association, 2009). During these years, the Million Programme, which is the term for housing construction in Sweden between 1965 and 1975 with the aim of quickly build a million homes and improve housing standards, was completed and could be directly adopted and connected to district heating. The housing shortage of the time was acute, caused by high levels of migration to cities. Between 1975 and 1985, sales of district heating doubled. At the time, Swedish district heating plants delivered 35 TWh per year. In the 1980s, a slight decline was observed as several nuclear reactors began operating and electricity prices were relatively low. By 2013, however, the situation had changed again: district heating now accounts for nearly 50 TWh heat per year.

In the 1990s, environmental and climate policy grew stronger. Between 1998 and 2008, the Swedish government set aside 8.2 billion Swedish kronor in grants for environmental improvements. These grants were managed through two investment programmes: LIP (Local Investment Programs), aimed at increasing ecological sustainability in general, and Klimp (Climate Investment Program), which targeted support for investments that would reduce global warming. A large portion of the district heating developed during this time period was developed as a result of LIP and Klimp (Swedish Environmental Protection Agency, 2010). The grants funded approximately 10-20% of the total investment cost for the projects (Swedish Environmental Protection Agency, 2012b).

2.2. RESOURCE EFFICIENT DISTRICT HEATING

Initially, coal was the most common fuel used for district heating. But then, in the 1950s, oil began to take over (Swedish District Heating Association, 2009). By the 1973 and 1979 oil crises, reducing dependence on oil became a national priority, so the government decided to encourage the use of other fuels. In many cases, this priority meant that district heating plants began using coal as their main fuel, although peat and biomass were also used. In 1980, oil accounted for more than 90% of total district heat production; however, by 1988, it accounted for just 14%. Over time, more district heating plants began to use a mixture of fuels. The mixture consisted of both old and new fuels: peat, biomass, excess heat from industry, and even solar energy. For the district heating sector, the heat pump was the most widespread new technical solution of the 1980s. In the 1990s, environmental and climate policies began to affect behaviours. From the political side, the development was affected through special

taxes, as carbon dioxide and sulphur taxes on fossil fuels were introduced. These policies meant a significant increase in costs for district heating plants based on coal, whereas plants using biofuel were not taxed as heavily. These strategies marked the beginning of a major and concerted shift from fossil fuels to biofuels within the entire district heating sector. Given that large amounts of excess heat are produced by industrial processes, the physical conditions are already in place for the further development of industrial excess heat-based district heating systems (County Administrative Board, 2011).

As mentioned in the introduction, the primary energy source used in traditional district heating plants can be supplemented with industrial excess-heat recovery (Figure 1). An increased recovery of excess heat from thermal power generation and industrial processes reduces the demand for primary energy (Persson and Werner, 2012). Since these systems provide heat using energy that would otherwise be wasted, excess heat-based district heating systems are generally considered resource efficient (Werner, 2004).

Within the framework of this thesis, the term "resource efficient district heating" is used to denote district heating systems that are not substantially based on primary energy, such as coal or biomass, "resource efficient" refers to district heating systems based on industrial excess heat.

The difference between a traditional district heating system and a district heating system based on industrial excess heat is simply the energy used to heat the water in the district heating grids. Traditional systems require a district heating plant and energy from, for example, coal, oil, or biomass that is heated inside the district heating plant and transported to consumers via the grid. District heating systems that use industrial excess heat require that a heat exchanger be connected to the industries supplying excess heat. The heat exchanger transfers the industry's excess heat in the effluent to usable energy storage for district heating (Figure 1).

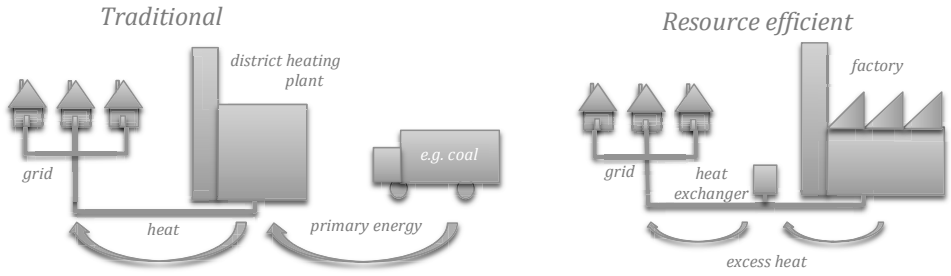

Figure 1. Difference in primary energy use between a traditional system and a resource efficient district heating system based on industrial excess heat.

3. SWEDISH SPATIAL PLANNING LEGISLATION

In Sweden, local authorities have primary responsibility for spatial planning. According to the PBA, local authorities are supposed to use a number of different planning institutions when planning a new residential area. The comprehensive plan and the zoning plan are the most important plans that address the PBA (SFS 2010:900, 2010).

Covering the entire geographical area of the municipality, the comprehensive plan guides authorities on how to use land and water areas and how to preserve and develop the built environment (SFS 2010:900, 2010). Although not legally binding, the plan allows local authorities to adapt the process, its scope, and its details. Such planning is an on-going process, so the comprehensive plan is constantly being updated. At least once every four years, the local government evaluates whether the plan is still up-to-date or whether it needs to be modified. According to the PBA (ibid), the local authority must consult with interested parties, such as district heating companies, when considering changes to the comprehensive plan.

The development of a zoning plan can begin when the local authority has an up-to-date comprehensive plan. Often, the zoning plan, which is legally binding follows the guiding principles agreed on in the comprehensive plan, but since the comprehensive plan is not legally binding, the zoning plan sometimes conflicts with the comprehensive plan (Lundstöm, 2010). The zoning plan regulates where development can and cannot occur. The local authority may indirectly control how and where certain types of energy facilities are constructed by limiting where buildings can be placed and how they can be oriented. A local authority, for example, may require the densification of a planned area to increase heat density, a prerequisite for district heating (Lundstöm, 2010).

Before work on the zoning plan begins, a plan programme may be needed that briefly examines the circumstances and visions. Figure 2 in section 5.3 shows the major steps in the planning process. The local authority decides whether a plan programme is needed before the actual development of the zoning plan starts. The plan programme includes starting points and objectives for the plan, and its aim is to broaden the zoning in regard to the relevant stakeholders' experiences and opinions. If a plan programme is considered prudent, interested parties are invited for consultations; if not, the development of a draft begins immediately (SFS 2010:900, 2010). If the plan is likely to have significant environmental impacts, the consultation is carried out so that it complies with environmental regulations (SFS 1998:808, 1998; SFS 2010:900, 2010). When consultation occurs, the assigned time for review is at least three weeks. After these three weeks, the comments are compiled in a consultation report. All interested parties – public, private, and individual – are given the opportunity to make additional comments on the draft plan proposal. The local authority's proposal in response to the comments is compiled in a revised report. After the municipal council board adopts the zoning plan, the decision becomes final within three weeks, unless it is appealed. Once the decision has been reached, implementation and exploitation can begin (ibid).

4. THEORETICAL FRAMEWORK

Within the framework of this thesis, it is of interest to understand the essential mechanisms behind the formation and development of inter-organisational networks in which different actors collaborate. However, previous research on the development of excess heat-based district heating is generally quite technical-oriented. Nevertheless, earlier research into different technical solutions for using excess heat from industrial processes often highlights organisational aspects as important in realising the inter-organisational collaboration that is necessary for development (Arnell et al., 2012). And yet, earlier research into the organisational aspects of development is very sparse in district heating literature. Current knowledge about how excess heat produced from industrial processes can be used in district heating is also limited (Difs et al., 2009).

This thesis relies on Industrial Symbiosis (IS) to study the collaborative development of excess heat-based systems of district heating. IS is not a single theory, but rather a research field that combines several theories. These are used to explain the phenomena studied in this thesis. The theoretical framework for this thesis is constructed using these theories and they are also used to analyse and discuss organisational preconditions for industrial collaborations that are similar to the cases investigated in this thesis. Other theories such as economic theories of how business transactions developed could also conceivably be used. However the collaborations studied in the context of this thesis do not only implicate business transactions between the companies involved. IS, which has a multi-disciplinary approach, helps in explaining the underlying phenomena behind the development of the studied heat supply collaborations.

Additionally, research on strategic spatial municipal planning is used to examine how district heating issues are addressed in the municipal spatial planning of new residential areas and how Swedish planning legislation could be adopted to facilitate the expansion of new resource efficient district heating systems. This chapter contains a description of the two research fields primarily used in this thesis.

4.1. INDUSTRIAL SYMBIOSIS

Industrial Symbiosis (IS) has been developed as a subset of Industrial Ecology (IE), which is a relatively new research field based on the ideology of nature. IE uses nature as a "reference" to study resource productivity and the environmental burdens of industrial and consumer products and their production and consumption systems. IS can make resource use more efficient by forming close working agreements between normally unrelated industrial companies or other organisations (Jensen et al., 2011). For example, these working agreements may involve one company using another company's by-products as raw materials. In addition, IS can also include companies sharing water and steam supplies, manufacturing capacity, power sources, logistics, and expertise (Jensen et al., 2011). IS focuses on cyclical flows of resources through networks of businesses within wider system boundaries.

One of the most famous examples of IS is an industrial district in Kalundborg, Denmark. The Kalundborg example consists of self-organised synergies between companies. The development of industrial synergies was a reaction to financial forces and a local lack of

resources (Ehrenfeld and Gertler, 1997). In the Kalundborg case, the collaboration, which involved water and steam, resulted in both substantial and minor environmental benefits as well as financial benefits (Jacobsen, 2006). Studies of IS networks, Kalundborg among others, have improved the academic understanding of IS (Ehrenfeld and Gertler, 1997).

The strongest drivers behind IS synergies are the need to improve profitability and the need to improve competitiveness (Ehrenfeld and Gertler, 1997). However, other drivers can also be social, environmental, or regulatory (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 and society at large (Doménech and Davies, 2009).

There are two forms of IS collaboration – planned and unplanned (Baas, 2011). Unplanned IS is the basis for self-organisation, whereas planned IS refers to the intentional organisation of activities that produce results beyond those that benefit the companies initiating the IS link (Baas, 2011). Usually, IS collaborations develop spontaneously (Chertow, 2007). Collaborations that evolve spontaneously seem to be more durable and functional than those that are specifically engineered as IS collaborations (Chertow, 2007). Successful cases of IS have served as the inspiration for planned attempts to create eco-industrial parks. However, attempts to implement the lessons learned in the form of eco-industrial parks have largely failed (Chertow, 2007; Gibbs and Deutz, 2007). These failures have been explained in a variety of ways, yet the problem, which is widely held to be one of the primary barriers to development, apparently involves difficulties generating inter-company collaboration, a requirement for companies that want to share production processes (Gibbs, 2003). These kinds of planned synergies require a more fruitful eco-industrial strategy to build upon existing waste and energy interchanges on a wider spatial scale (Chertow, 2007; Gibbs and Deutz, 2007).

Collaborations based on exchanges of energy and resources among organisations require embedded relations based on trust and personal ties, rather than explicit contacts (Uzzi, 1997). Uzzi defines embeddedness as 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 behaviour only minimally or, in some stringent accounts, reduce the efficiency of the price system. (Uzzi, 1996)

Three organisational preconditions are highlighted as being especially important: (1) trust, (2) fine-grained information transfer, and (3) joint problem solving (Uzzi, 1997). These preconditions allow companies to adapt more quickly and to react with greater flexibility to environments characterised by continuous change and complexity. All of these features have also proven to be important preconditions for the decision-making process for joint collaboration projects, wherein knowledge gained via the involvement of relevant stakeholders within the collaboration is required to understand and realise common goals and objectives in practice (Albrechts, 2006). These conditions allow companies to adapt more quickly to environments characterised by continuous change and complexity. Companies and

other organisations involved in embedded networks tend to have a greater chance of gaining advantages compared to other forms of governance (Uzzi, 1996).

Although the preconditions for, drivers behind, and barriers to the creation and development of inter-organisational collaborations are often considered and are widely used concepts within IS literature, there are no clear definitions of these concepts. Therefore, the definitions found in Oxford Dictionaries (2012) are used in this thesis:

> A Precondition is a condition that must be fulfilled before other things can happen or be done (a precondition for peace).
>
> A Driver is a factor that causes a particular phenomenon to happen or develop (the hope of achieving such monopolies becomes the main driver of investment).
>
> A Barrier is a circumstance or obstacle that keeps people or things apart or prevents communication or progress (a language barrier or the cultural barriers to economic growth).

In the context of this thesis, the necessary preconditions for collaboration deal with the essential aspects that must exist in order for the collaboration to develop and emerge. The drivers and barriers, on the other hand, involve aspects of the potential positive and negative consequences of collaboration. These concepts are further described in article 1:

> Necessary preconditions are about the basic premises behind collaboration, the conditions that must be fulfilled before other things can happen or be done […] An example of a necessary financial precondition is that there must be available investment capital […] The drivers are the factors that encourage collaborations. A driver, for example, could be the potential for financial gain from the collaboration in the long term. […] The barriers are the circumstance or obstacles that could prevent collaboration. For example, a barrier could be significant investment costs. However, in this sense, all three aspects depend on each other. In some cases, it may be that the absence of preconditions hinders development despite strong driving forces. In other cases, strong barriers and a lack of drivers hinders development despite the fact that the preconditions are provided.

4.2. STRATEGIC MUNICIPAL SPATIAL PLANNING

The focus of strategic planning is on framing decisions, actions, projects, results, and implementation (Albrechts, 2006). Additionally, strategic planning also incorporates monitoring, feedback, adjustment, and revision in its efforts to accomplish these aims, both in the short-term and the long-term (Albrechts, 2006; Bryson, 1995; Bryson and Roering, 1988; Faludi and Korthals Altes, 1994; Gibelli, 2003; Mintzberg, 1994; Poister and Streib, 1999).

Spatial planning basically concerns the location, intensity, form, amount, and harmonisation of land development required for various space-consuming functions, such as other infrastructure systems, residential houses, municipal buildings, etc. (CEC, 1997; Chapin,

1965; Cullingworth, 1972). However, spatial planning is a very complex process for local planning authorities. This complexity exists because the planning processes basically deal with large amounts of technical knowledge and scientific theories that must be coordinated with the different actors, different views, and different values of society at large (Nilsson, 2007). Hence, the complexity of spatial planning must be considered when planning.

Rational and strategically managed planning depends on effectively communicating goals and objectives, and the effective disclosure of goals and objectives requires the understanding that there are many ways to achieve goals and objectives (Emmelin and Kleven, 1999). Knowledge is emphasised as an important precondition for realising an understanding of these goals and objectives. This knowledge can be gained through the participation of different stakeholders with expertise in their specific fields (Ivner et al., 2010). Stakeholders' expertise also creates an awareness of both driving forces and obstacles.

Addressing district heating issues within the municipal spatial planning of new residential areas first requires understanding what the goals and objectives mean in practice (Ivner et al., 2010). As a second step, it is important to design the planning process in a way that encourages implementation. This is important because implementation only happens when a plan is accepted by the actors involved – i.e., when they consider the plan legitimate (Ivner et al., 2010). For actors to be convinced that a plan is legitimate, it should anticipate barriers to implementation, such as technical or economic constraints. Therefore, a strategic planning process should encourage all actors to participate in the process and provide them with opportunities to learn about the issues, potential problems, and potential benefits associated with the project under consideration.

For spatial planning to be effective, the process should have broad support in the community (Jersenius and Smideman, 1995). In terms of its gaining acceptance and its ability to generate public support, planning can be improved through participation. Furthermore, participatory planning can also simultaneously promote social justice and environmental sustainability. Acceptance and action on the part of private actors is important when implementing plans (Ling et al., 2002; Rydén, 2006). There are various ways to encourage public participation (Gilljam et al., 2003; Webler and Tuler, 2006). For example, by describing the characteristics of "good participatory practice" as a process in which all stakeholders are included, participants find the interactions meaningful, information is shared openly and readily, and stakeholders are willing to find solutions to mutual problems.

5. THE RESEARCH PROCESS

This thesis is based on three articles that, combined, address the overall aim and research questions. As described in section 1.1, this aim is supported by two supplementary research questions. The following chapters present the appended articles, their different aims, their empirical foundations, their contributions to this thesis, and their methodology.

5.1. CONTRIBUTION OF THE APPENDED ARTICLES

This section presents a brief summary of the appended articles and which research question(s) they address (Table 1).

Table 1. Contribution of each article in relation to the research question

	RQ1	RQ2
Article 1	X	
Article 2	X	
Article 3		X

5.1.1. Article 1 – Preconditions, Drivers and Barriers behind the Development of Excess Heat-Based Systems for District heating

Aim: The first article aims to identify and elaborate on the preconditions for, drivers behind, and barriers to the development of excess heat-based district heating systems in Sweden.

Empirical foundation: This study includes two realized Swedish cases of this kind of heat collaboration. In case 1, the development of the district heating system is a result of the availability of excess heat from a nearby paper mill. In case 2, the district heating system has developed from a system based on fossil fuels into a system based on excess heat from a carton board mill. Table 2 presents number and types of respondents form each of the two investigated cases.

Table 2. Number and types of respondents in each case: case 1 and case 2 (article 1)

	Case 1	Case 2
District heating company	2	3
Industry	2	1
Local authority	1	1
Total	**5**	**5**

Contribution: This article contributes knowledge about organisational preconditions that needs to exist in order for excess-heat collaborations between industries and the district heating sector to emerge and develop into long-term collaboration projects. The article also presents results about common drivers behind and barriers to such collaborations, both from the industries' and the district heating sector's points of view.

5.1.2. Article 2 Industry's Perspective on Preconditions, Drivers and Barriers behind Excess Het Supply Collaborations with the District heating sector

Aim: The second article examines what is required for industries producing excess heat to collaborate with the district heating sector concerning heat supply. More specifically, this article investigates the industries' perceived preconditions for, drivers behind, and barriers to entering into such collaborations.

Empirical foundation: The second study is based on interviews with respondents from 16 industries that all produce excess heat as a by-product without being part of heat supply collaboration with another actor. These industries are active in a variety of fields, such as pulp and paper, steel, chemicals, hazardous waste processing, recycling, and biofuels.

Contribution: This article's contribution consists of findings concerning the industries' perceptions of a possible excess heat-supply collaboration with the district heating sector. The article provides new knowledge about the main drivers behind and barriers to possible heat-supply collaboration and what conditions the industries perceived as necessary for a possible collaboration to emerge and develop.

5.1.3. Article 3 – Spatial planning as a tool to facilitate district heating expansion

Aim: The third article examines whether, and how, district heating issues are addressed in the municipal spatial planning of new residential areas. In addition, this article discusses how Swedish planning practice could facilitate the expansion of district heating systems.

Empirical foundation: The third study includes an investigation of the spatial planning process in six typical Swedish municipalities with a population between 18 000- 57 000. However, the ownerships of the district heating companies in these municipalities differs: in two of these municipalities, the district heating companies are wholly owned by a local authority; in two of these municipalities, the district heating companies are partially privately and partially publically owned; and in two of the municipalities, the district heating companies are privately owned. The objective behind the selection of district heating companies with different types of ownership was to be able to capture a possible difference between the planning processes within the different cases. Table 3 presents number and types of respondents form each of the six investigated cases.

Table 3. Number and types of respondents in each case: cases 1 to 6 (article 3)

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Spatial planner	1	1	2	1	1	1
Energy and climate advisor	1	1	1	1	1	1
District heating company	1	1	1	1	1	1
Developer						1
Total	**3**	**3**	**4**	**3**	**3**	**4**

Contribution: This article shows that for a more strategic and sustainable municipal spatial planning, the district heating company as well as other stakeholders should participate early in the process, including providing input at the comprehensive plan level so as not to miss out on important exchanges of knowledge on the meaning of the goals and objectives and how to

achieve these goals and objectives. An earlier dialogue between the local authorities and the district heating companies would also lead to a broader acceptance of the plan earlier in the planning process. The results indicate a slight difference between the different types of ownerships; the municipalities that have public-owned district heating companies, brought the district heating company officials into the planning process slightly earlier than the cases with partially privately- and partially publically-owned district heating companies and the cases with solely privately- owned district heating companies.

5.2. METHODOLOGY

The methods used for each article were literature reviews and interview studies, as described in the following sections. See appended articles 1, 2, and 3 for a more detailed description of the methods used for each article.

5.2.1. LITERATURE REVIEWS

Several literature reviews were performed during the course of this thesis project, from spring 2011 to autumn 2013. Because this project focuses on the development of district heating in different ways, the main and initial literature review performed during the first phase of this project concerned the basics of district heating: the history behind it, its technical aspects, its scope nationally and internationally, its advantages, limitations, etc.

Having gained knowledge of the basics of district heating systems, the following literature reviews involved excess-heat collaborations between industry and the district heating sector. However, as very little has been done in the research area of this type of industrial excess-heat collaboration, it is of great interest to investigate what other areas of research have learned in terms of inter-organisational collaborations within the energy sector. The research field of Industrial Symbiosis (IS), described in section 3.1, has been widely used and explains the organisational phenomena in articles 1 and 2. Swedish spatial planning legislation, along with research related to strategic planning theory, was mainly used in article 3.

The reviews included several sources, such as scientific articles, reports, websites, licentiate theses, and PhD theses. As purposed in Yin, (2009), throughout the process, the information has been read in a critical way to understand what audience it was written for and with what purpose. Initially, related keywords were used to narrow down the search to relevant literature. Examples of keywords used are district heating, industrial excess heat, Industrial Symbiosis, inter-organisational collaboration, and strategic spatial planning, all central to the aim of this thesis. The objective behind the selection of keywords of the literature reviews was to find research that focused on collaborative organisational aspects behind the development of resource efficient systems of district heating.

When searching for information, it is important to identify its source and date to value its reliability (Holme and Solvang, 1996). Where possible, the information was triangulated using several different sources. The opportunity to use different data sources is a major strength in the validity of the study (Yin, 2009), as triangulation means multiple sources of evidence in the collection of material for the study.

5.2.2. INTERVIEW STUDIES

All of the interviews in the three studies were semi-structured and conducted via telephone during the spring of 2009, the autumn of 2011, and the spring of 2012. Semi-structured interviews are characterised by open-ended interview questions that allow respondents to speak freely on specific themes. This type of interview also allows for follow-up questions that encourage the interviewees to expand on their responses (May, 2001). The semi-structured interview provides greater freedom than the structured interview and is not perceived as being as strict. Nonetheless, an interview guide with basic questions is usually formulated before the interview. As purposed in (Aspers, 2011) interview guides were formulated based on the results of the earlier literature studies.

The way respondents were selected was designed to capture the gap in knowledge presented in each of the appended articles. For articles 1 and 3, interviews were conducted with two groups of stakeholders representing different parts of the investigated collaboration. This selection allowed a capture of both parties' perceptions of the collaboration. Article 2 consisted solely of interviews with one group of stakeholders because the aim of the study was to examine one specific group of stakeholders' perceptions about possible collaborations. As a result of requirements from some of the respondents included in article 1 and 2, a document with the main focus areas for the interview was sent to each and all of the respondents in advance. Since none of the respondents from Article 3 had any requirements about, in advance, be informed about the main focus areas for the interview no document was sent.

All interviews were recorded and transcribed word by word. However, mumble, repetitions and other words or sounds from the respondents were not included in the transcripts. A transcription of an interview can be seen as an interpretation by the person transcribing and as a way to make the information more manageable (Kvale, 1997).

5.2.3. ANALYSIS OF THE EMPIRICAL DATA

The empirical data from articles 1 and 2 concerning perceived preconditions for, drivers behind, and barriers to heat-supply collaborations were divided into themes that emerged from the interviews.

Article 1, which deals with existing heat collaborations, provides more developed results regarding the environmental aspects and side effects of heat collaborations than article 2, which deals with potential heat collaborations. The results from articles 1 and 2 have been analysed using earlier IS research.

In article 1, the theoretical framework is mainly based on previous findings by Chertow, Ehrenfeld and Gertler, and by Uzzi (Chertow, 2000; Chertow, 2007; Chertow et al., 2008; Ehrenfeld and Gertler, 1997; Uzzi, 1996; Uzzi, 1997). As this theoretical foundation proved helpful in answering the research questions in article 1, it was considered appropriate to use a similar theoretical framework for article 2. The theoretical framework of article 2 was also supplemented with results from article 1. Regarding the analysis of the empirical data for article 3 and the third interview study, which includes a survey of the municipal spatial planning process in a number of Swedish municipalities, the empirical data were compiled

based on the different steps in the planning process described in PBA (SFS 2010:900, 2010) and the results were analysed based on the research field of strategic planning and Swedish planning legislation.

To fulfil the overall aim of this thesis, the empirical data from all three interview studies were compiled and analysed based on the two main research fields described in the theoretical framework – IS and strategic planning theory. As with previous research on IS collaborations, the first two appended articles – article 1 and article 2 – argue that industrial excess-heat collaborations can be seen as a simple form of IS because the by-products of one business are used as a resource by another. Therefore, it is useful to study previous IS research as a way to understand and explain the mechanisms behind supply collaborations concerning excess heat.

Previous findings about the emergence and development of industrial collaborations are used to identify preconditions for, drivers behind, and barriers to industrial excess-heat-supply collaborations. The analysis is further developed through strategic spatial planning theory, which allows for an analysis of how Swedish planning legislation could be adopted to facilitate the development of resource efficient systems of district heating within new residential areas by taking existing sources of industrial waste heat into account during the spatial planning process.

5.3. REFLECTIONS REGARDING CHOICE OF METHODS

Literature reviews are important features of a study (Andersen, 1998) in terms of both the formation of the aim and the research process that follows. Andersen (1998) believes that systematic literature reviews are essential for good results. In the case of this thesis, literature studies have been an on-going and important process during the course of its development. Literature reviews have been the foundation of all the appended articles, as well as part of the overall aim and research questions within this thesis. These reviews have been necessary in contributing knowledge about district heating in general, organisational collaboration issues and Swedish planning legislation, in particular, as well as other related research, such as business models.

The choice of qualitative method – semi-structured interview studies – has clarified the overall nature of the studied collaborations. The qualitative method also helps addressing both the different aims of the three appended articles as well as the overall aim of this thesis. The qualitative research approach has contributed to a deeper understanding of the different stakeholders active within the inter-organisational collaborations studied. A quantitative method would not have provided the same opportunities. The use of semi-structured interviews, however, created good opportunities to gain a deeper understanding of the respondents' answers by asking follow-up questions, which, in turn, contributed to this objective.

The selection of respondents for each appended article has likely influenced the results. It may be that different individuals choose to emphasize different parts of a studied phenomenon. It may be that the results would have been different if the choice of respondents had been different.

The fact that the interviews were conducted via telephone instead of in person may also have affected the answers. Without conducting a face-to-face interview, it is difficult to make a thorough assessment of a respondent (Bryman and Bell, 2007). For example, during face-to-face contact, an interviewer can read an interviewee's body language and other non-verbal behaviour, assessments that cannot be made over the telephone. Telephone interviews are simpler to arrange, however, and take less time than face-to-face interview sessions with each respondent. Additionally, the interview questions used within these different interview studies are not considered to be of such a nature that further information gleaned from body language or other non-verbal behaviour would contribute anything of importance in relation to the different aims of the articles as well as the overall aim of this thesis.

As mentioned in the previous sections (4.2.1 and 4.2.2), the different literature reviews and interview studies were carried out between 2009 and 2013. If any of these literature reviews or interview studies were to be repeated at a later date (e.g., ten years after they were first conducted), the same results could not be guaranteed because circumstances could change the conditions of the cases studied.

The summarised results from each of the interview studies would probably also differ if there were significantly more or fewer respondents. The selection of respondents may also have affected the outcome of the results. Given that individuals perceive things differently and have different ways of expressing themselves, to some extent the answers would probably have been different if other respondents had been asked the questions.

6. ORGANISATIONAL PRECONDITIONS FOR THE DEVELOPMENT OF RESOURCE EFFICIENT DISTRICT HEATING

The following chapter presents the main results from the literature review and the different studies within this thesis. Section 6.1 presents the main results from article 1, section 6.2 presents the main results from article 2, and section 6.3 presents the main results from article 3.

6.1. PRECONDITIONS FOR, DRIVERS BEHIND, AND BARRIERS TO THE DEVELOPMENT OF EXCESS-HEAT COLLABORATIONS

Based on the results from the interviews in article 1, four different themes have been identified and grouped into four themes. These themes which are presented in the different paragraphs below are; financial, technical, organisational and environmental. However, there is also a fifth paragraph, containing benefits and positive side effects of the two studied collaborations. Given that the respondents often mentioned the significance of financial aspects in the development of collaborations concerning excess-heat supply, these appear to be very important. The technical aspects behind such collaborations are also relatively often mentioned as important. The results from article 1 indicate that the respondents did not believe that organisational and/or environmental aspects had the same relevance as financial and technical issues.

6.1.1. Financial aspects

When it comes to existing collaborations concerning heat supply, article 1 shows that financial preconditions is seen as very important. Both the industry supplying excess heat and the buyer of the heat (the district heating company) must have something to gain financially.

In one of the heat-supply cases, all of the respondents believed that the investment grant they were given contributed to the project's relatively fast-paced development. According to the district heating company respondents in case 1, they did not know whether they would have expanded to the extent they did without the investment grant. As described in section 2.1, investment grants influences the extent of and at what rate these types of projects develop. This is supported by one of the respondents which mean that the investment grant inspired confidence in investing and expanding to a greater extent than they perhaps would have done otherwise. In addition, investment grants often help persuade politicians to implement a project that is financially supported by an investment grant.

The results from article 1 also showed that the industries supplying excess heat were initially concerned about the breakdown of the investment costs. In one of the cases, one industry noted that since supplying heat was not part of the core business of the industry, they were initially uninterested in investing their money in these kinds of projects. The other industry in the other case studied, however, was faced with significant investment costs from the outset. As a result of increased production, the industry somehow needed to invest in a solution that would cool their excess heat. Therefore, in this case, it seemed natural to share most of the investment costs. The financial aspects of such projects are also both the strongest drivers and the main barriers to implementation.

6.1.2. Technical aspects

As mentioned, other important preconditions for collaboration concerns technical issues. The necessary technical preconditions – such as a reasonable distance between the industry and the district heating grid, heat demand, and the availability of technical solutions – needed to exist for both projects to be feasible. Technical aspects are also described as important barriers to the project's implementation.

6.1.3. Organisational aspects

As for organisational aspects, a clear business agreement that both parties agree on has been essential to development in both cases. An open relationship characterised by mutual trust and an understanding of each other's activities is described as the basis for a well-functioning collaboration. This type of business relationship should be based on honesty, willingness, an open mind, and a clear and fair business agreement. A clear business agreement concerning financial matters that both parties agreed on was essential. Obviously, both parties must trust one another when dealing with financial responsibilities and rewards. Article 1 shows that the organisational preconditions have been of great importance for the collaborations to overcome the main financial and technical barriers.

6.1.4. Environmental aspects

The environmental aspects of heat collaborations were described as a central issue for all parties. Obviously, the financial aspect is always most important, although environmental aspects are also described as being key drivers. In this context, however, collaboration projects have been seen as contributing to improved environmental performance without any additional financial costs – i.e., all parties involved gained financially from the collaborations.

6.1.5. Benefits and positive side effects

The main benefits of the collaborations are described as financial and environmental. In one of the cases, the energy company had better financial conditions for the district heating compared to what they would have had otherwise. Another benefit is that they can promote the collaboration as a good environmental investment and thus gain market advantages over competitors. In this case, another positive development has been that the district heating grid has been expanded to serve a community located about six kilometres south of the original grid.

In the other case, the local authority's assessment was that the project had led to clearer environmental measures within the region. In the same case, the number of connections to the district heating grid increased more than expected. The development also led to a new district heating grid in a nearby community. A large portion of the profits from the project was used to reduce the cost of district heating for customers (a reduction of about 10%).

6.2. INDUSTRIES' PERCEIVED PRECONDITIONS FOR, DRIVERS BEHIND, AND BARRIERS TO THE DEVELOPMENT OF EXCESS-HEAT COLLABORATIONS WITH THE DISTRICT HEATING SECTOR

When it comes to potential excess-heat collaborations, the financial and technical aspects once again appear to be very important. As with article 1, article 2 show that organisational

aspects are perceived as being less important than financial and technical aspects. However, as mentioned in section (5.2.3.) the results from article 1 and 2 differ regarding findings about environmental aspects and side effects of excess heat collaborations. Since article 2 deals with potential none-existing cases there are no findings on environmental aspects or side effects of excess heat collaborations

6.2.1. Financial aspects

The most common reason why the industries examined in article 2 do not supply excess heat to district heating grids is financial. Heat-supply collaborations with the district heating sector must be financially viable to be implemented. Most of the industries, however, believed that securing long-term financial investments should be relatively easy. The problem is that the repayment periods for these types of investments are too long to facilitate implementation. The final investment calculations do not appear to apply to these types of long-term investments. Furthermore, the industries noted that such collaborations would mean that they could market their companies as environmentally responsible, a feature that many of their present and potential customers might consider valuable.

A clear and transparent business agreement between the industry and district heating company is another significant aspect. A business agreement with equal terms is important for developing long-term sustainable excess-heat collaborations with the district heating sector. However, as long as the investment does not involve financial losses there may be factors, such as; environmental considerations, environmental profiling, and energy strategies, other than those of a financial nature that ultimately determine whether a company invests in a heat-supply partnership.

6.2.2. Technical aspects

The main technical barrier was identified as the absence of an existing district heating grid nearby; the industries highlighting this as a problem are all located outside urban areas. A lack of knowledge about the amount of excess heat produced as well as inadequate amounts of excess heat are other technical barriers preventing heat-supply collaborations with the district heating sector. The fact that Sweden is a country with large variations in seasonal temperatures is described as another problem that complicates collaboration with the district heating sector.

6.2.3. Organisational aspects

At the time of the interviews, all industries had recently investigated their ability to supply excess heat. Just how thoroughly the possibilities were examined varied significantly. In about half of the cases, the initiative originated with top management. In some cases, the industries had experienced a lack of interest from the district heating company.

The perception of the importance of personal contacts and relationships in the development of excess-heat collaborations differed among the respondents. Some believed that they have no significance, whereas others believed that they might be significant. However, most of the respondents believed that personal contacts and relationships at the professional level were beneficial in terms of the exchange of information. Some felt that transparency and openness contribute to a greater consensus and better understanding. As noted by the respondents,

establishing personal contacts and relationships requires communication and the sharing of information – a time-consuming undertaking. Another respondent believed that personal contact with anyone from the other company could provide insight into their business, generating access to informal information.

6.3. PLANNING RESOURCE EFFICIENT DISTRICT HEATING IN SWEDEN

Articles 1 and 2 mainly discuss the preconditions for, driving forces behind, and barriers to the development of excess heat-based systems of district heating. Article 3, on the other hand, examines whether and how district heating issues are addressed in Swedish municipal spatial planning. This article also discusses how Swedish spatial planning legislation could be adopted and developed to facilitate the expansion of district heating in new residential areas.

The municipal spatial planning processes in all of the investigated cases in article 3 started without any involvement from the district heating companies or any other interested stakeholder. This lack of involvement meant that there was no external dialogue early in the planning process. The comprehensive plans were all designed with capillarity in focus, to better use existing infrastructure from the surrounding areas. None of the respondents representing the district heating companies within the investigated cases were consulted during the development of the comprehensive plans.

When it comes to the development of zoning plans, the results show that when there is an interest in building new residential areas, the initiative often comes either from the local government or from developers via the local government. In each of the six cases studied, the degree of influence exerted by the district heating company on the zoning plan differed. However, none of the respondents in any of the cases referred to the plan programme as a step in their planning process. In case 1, the district heating company was contacted when the development of the zoning plan began (Figure 2). In contrast to the other municipalities, this company was involved in the planning from a relatively early stage before any decisions or proposals concerning building were presented in the plan.

Another case involved a relatively new zoning plan group with representatives from a number of companies in the municipality. Through that group, the district heating company was provided with information about the upcoming planning projects during the drafting of the zoning plan (Figure 2). In yet another case, the local authority's housing company seems to have been the only link between the local authority and the district heating company.

District heating issues are described as important to take into account when planning, but are not critical, as heating can be provided in other ways. Yet there are many other issues – e.g., public transport solutions and proximity to water, sewage, sanitation, and other services – that are important.

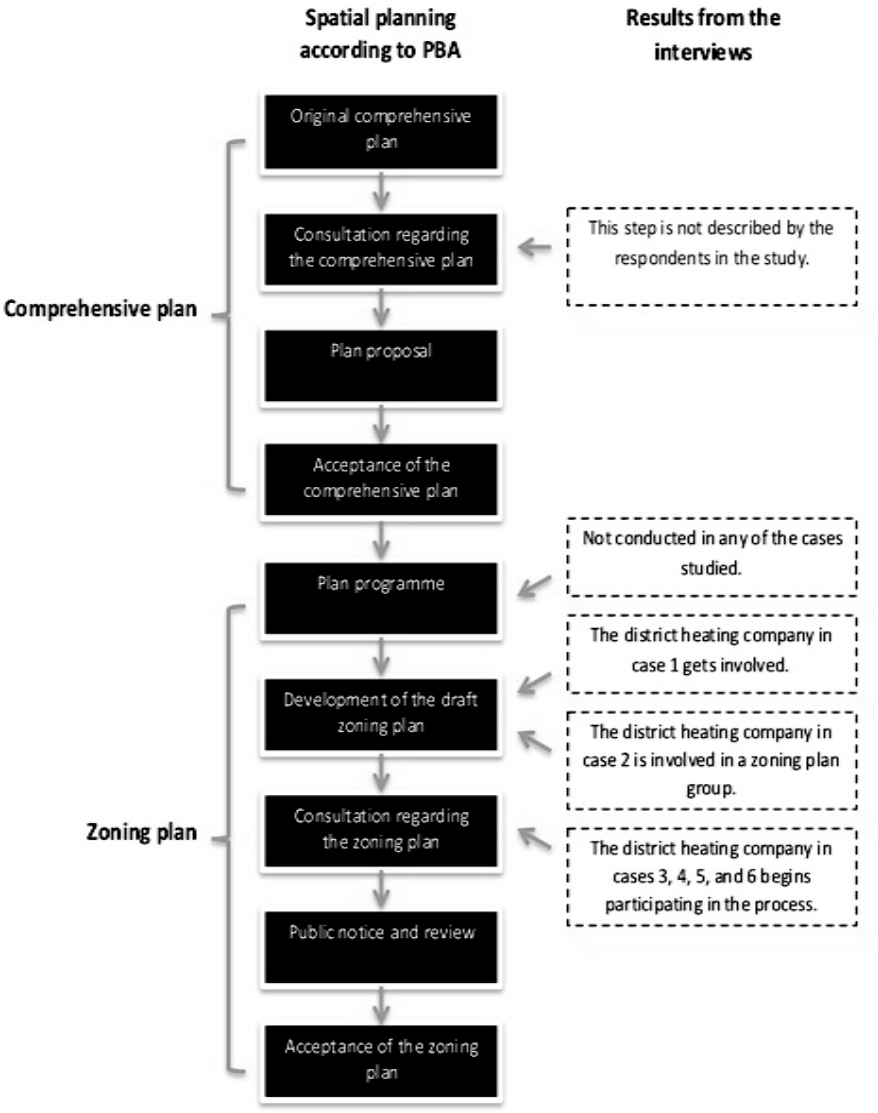

Figure 2. Results from the interviews in article 3. Major steps in the planning process that the district heating companies in the six studied cases are involved in/excluded from.

The district heating companies felt that it was difficult to influence spatial planning, as they had limited influence when it came to the location of the new residential area, a condition that is particularly difficult to change late in the remittance stage of the planning process. Dialogue between the local authorities and the district heating companies was relatively sparse.

The first draft of the zoning plan was sent out to several stakeholders, including the district heating company, for comment. In the majority of cases, it was in this stage that the district heating company became involved in the planning process, making it possible for them to

contribute their knowledge and exert their influence. The actual decision-making process began when the district heating companies were included in the planning process. The district heating companies evaluated the profitability of connecting the planned area to the district heating grid (Figure 2).

According to the respondents, it is generally most profitable to expand district heating systems in densely populated areas. In addition, all of the respondents from district heating companies noted that the expansion of district heating to planned residential areas outside city centres and the expansion of existing district heating grids is further complicated by the fact that new houses are more energy-efficient.

7. DISCUSSION

This chapter discusses the summarised results from the three appended articles. The first section (7.1) addresses RQ1 and the third section (7.3) addresses RQ2. As described in the previous section (4.2.3), the theoretical framework of article 2 partly builds on the results from article 1.

7.1. PRECONDITIONS FOR, DRIVERS BEHIND, AND BARRIERS TO HEAT-SUPPLY COLLABORATIONS

Financial aspects are often the main drivers behind the development of collaboration projects (Ehrenfeld and Gertler, 1997). As in previous research, the three articles in this thesis confirm that the financial aspects are important aspects both in terms of being important preconditions and drivers behind the development of excess heat-based district heating systems and in the municipal spatial planning of district heating in new residential areas.

Table 4 presents a summary of the main factors identified as key factors behind the development of excess heat-based collaborations. The table is based on results from article 1 and 2. All identified preconditions, drivers and barriers are classified as either Financial (F), Technical (T), Organizational (O) or Environmental (E)

Table 4. Preconditions, drivers and barriers classified as Financial (F), Technical (T), Organizational (O) or Environmental (E).

Preconditions for, Drivers behind and Barriers to development of heat supply collaborations	
Preconditions	**Available financial funding(F), Reasonable distance between the plants(T), Trust(O), Fine-grained information transfer(O), Joint problem solving(O), Honesty(O), Shared visions on common goals(O),**
Drivers	**Economic profitability(F), Environmental image(O), Reduced environmental impact(E),**
Barriers	**Lack of financial funding(F), Large investment costs(F), Lack of an existing district heating grid(T), Distance between the plants(T)**

As for the development of industrial excess-heat collaborations between industries and the district heating sector, the results of both articles 1 and 2 show that the financial aspects are crucial for collaboration. For these types of collaborations to emerge, both parties should conclude that such collaboration would be financially beneficial. However, the same articles show that the financial aspects are also the main barriers. As for the technical aspects, they are like the financial also described as both important preconditions for, as well as great barriers to heat supply collaborations.

Irrespective of how respondents perceive the impact of financial and technical aspects, they view organisational aspects as significant when it comes to collaboration. Article 1 shows that the organisational preconditions had to exist for the collaborations to overcome the main

financial and technical barriers. Interaction and the exchange of knowledge are important preconditions in the decision-making process. The exchange of knowledge through mutual participation is required to understand the goals and objectives and to put them into practice (Albrechts, 2006). Embedded relations based on trust and personal ties are described as important aspects of a well-functioning collaboration (Uzzi, 1997). For example, article 1 shows that organisational preconditions such as trust, fine-grained information transfer, joint problem solving, honesty, and shared visions concerning common goals have been necessary for collaborations to overcome technical and financial barriers. Companies and organisations involved in embedded networks also tend to have a greater chance of gaining advantages as compared with other forms of governance (Uzzi, 1996).

The important organisational preconditions described in article 1 include effective communication and the exchange and the integration of knowledge. In turn, these led to greater efficiency as well as to environmental and financial gains for the companies involved and for society at large, which is something that also is highlighted by Doménech and Davies (2009). In addition to Uzzi (1996, 1997), article 1 also shows that it is important for partners to show humility from the outset, so that both parties feel equally important to the success of the project. This show of respect seems to be especially important for pulp and paper companies, as heating issues are not part of their core business. Article 2 confirms this, showing that it is important that collaborations develop on equal terms. The role of trust in building and realising well-functioning collaborations is widely acknowledged (Chertow et al., 2008; Gibbs, 2003; Hewes and Lyons, 2008; Jacobsen and Anderberg, 2005). However, to achieve the condition of trust Article 1 shows that honesty is an equally important component.

In addition, article 1 also highlights the importance of shared visions on common goals as preconditions for well-functioning heat supply collaborations. These features combined, have also proved to be important preconditions in the decision making process for joint collaboration projects where knowledge through participation of stakeholders is required to understand the common goals and objectives and to translate them into practice (Albrechts, 2006).

The results from articles 1 and 2 show that there is a clear difference in respondents' perceptions of the importance of organisational aspects. In article 1, the respondents have experience with this kind of excess-heat collaboration and therefore have a clear understanding of the importance of continuous and clear communication across business boundaries. Both these cases include respondents who mention the importance of clear business agreements that provide opportunities for both parties to gain from the collaboration. However, the results from article 2 (which only includes respondents from different industries with unexploited excess heat and without any experience of heat collaboration) show that some respondents do not recognise the importance of these organisational aspects in the same way.

The importance of personal relationships in business collaborations has also been noted (Doménech and Davies, 2011). As the results in article 1 show, these organisational aspects

can also help overcome the quite widespread unwillingness on the part of industries to enter into heat-supply collaborations with the district heating sector.

7.2. STRATEGIC SPATIAL PLANNING AS A TOOL FOR FACILITATING DISTRICT HEATING IN NEW RESIDENTIAL AREAS

The results from article 3 show that the preconditions for excess heat-based district heating in new residential areas are set through the development of the zoning plan. However, since the district heating companies and other interested parties only have the opportunity to influence the outcome of the plan when all decisions, in principle, have already been made, the preconditions are not realised through interaction and the exchange of knowledge, which according to Albrechts (2006) are important aspects in the decision-making process.

As Figure 2 shows, the majority of district heating companies in article 3 were not invited to participate in the planning process as early as they (ideally) should have been. Their only task as remittance bodies is to determine the profitability of district heating in the planned area. This kind of interaction limits integration and communication between the local authority doing the planning, the district heating companies, and other relevant stakeholders. Strategic spatial planning should focus on framing decisions, actions, projects, results, and implementation, which requires monitoring, feedback, adjustment, and revision (Gibelli, 2003). Regarding the Swedish spatial planning practice, this means that knowledge from several actors involved, including district heating companies, would lead to well-informed decisions about actions and projects, which in turn could lead to a more substantiated implementation. However, in order to implement this way of working with spatial planning in the longer term, monitoring, feedback, adjustment, and revision is required.

The knowledge gained through participation by different stakeholders is required both to understand goals and objectives and to put them into practice (Albrechts, 2006). The results from article 3 show that the planning process in the six studied cases leaves out some steps described in the PBA (SFS 2010:900, 2010) (Figure 2). For example, the local authorities do not consider the plan programme to be important. This lack of interest means that an important opportunity for the district heating company to influence the zoning plan is lost. As a result, the district heating company, together with other interested parties, first enters the planning process when the zoning plan is already complete (Figure 2). This delay in involvement probably contributes to the lack of interaction and communication among the district heating companies, other stakeholders, and the spatial planners. Because the district heating companies, among other stakeholders, are not invited to participate early in the planning process, the opportunity for non-expert stakeholders to gain expert knowledge is lost and the final decision made will thereby not be an "informed decision".

Perhaps Swedish planning legislation is not specific enough regarding the different steps, their content, and their purpose within the planning process. This lack of specificity allows local authorities to form their own interpretations of the legislation, so that the planning process does not follow the legislation as intended. There are no general practical guides, that the six municipalities within the framework of article 3 used, that describe how planning should be conducted and how the development of plans should proceed. Moreover, local

authorities' own interpretations of the legislation mean that important steps can be skipped. As stated in article 3, this failure to adhere is probably due to a lack of knowledge about the significance of these steps and to a lack of knowledge about and understanding of how other professions can contribute important knowledge during the process. However, the lack of communication between local authorities and other interested stakeholders may, in part, also be explained by differences in professional cultures (Håkansson, 2001). Such differences may also explain the unexploited potential of heat-supply collaborations in Sweden. To a large extent, the organisational preconditions are equally dependent on the inter-organisational collaborations required both for the expansion of district heating and for the exploitation of excess-heat recovery for district heating.

This method of conducting spatial planning means that important knowledge from relevant stakeholders – e.g., district heating companies and citizens – risks getting lost. It also means that the acceptance of the plan may not get passed down to future landlords and the district heating companies.

7.3. STRATEGIC SPATIAL PLANNING AS A TOOL FOR FACILITATING THE EMERGENCE OF NEW RESOURCE EFFICIENT EXCESS HEAT-BASED DISTRICT HEATING SYSTEMS

Based on the results from all three articles, this section presents suggestions for a developed planning process that could improve the conditions for excess heat-based district heating in planned new residential areas.

To achieve more strategic and sustainable municipal spatial planning that also takes existing sources of industrial excess heat into consideration, an earlier dialogue between local authorities and district heating companies is required. Furthermore, to facilitate excess heat-based district heating systems, planning should also take into account any nearby industry producing excess heat as a by-product of its production. The district heating company (and other stakeholders) could participate early in the process, providing input at the comprehensive plan level (Figure 3), so as not to miss out on important exchanges of knowledge about the meaning of the goals and objectives and about how to achieve these. An earlier dialogue among all involved parties could also lead to broader acceptance of the plan earlier in the planning process.

The plan programme could be a useful tool in this process. As described in chapter 2.3, the local authority decides whether a plan programme is needed for the development of the zoning plan. Developing a plan programme would force local authorities to invite district heating companies together with other stakeholders to interact earlier in this process. The plan programme could also possibly create an opportunity for industries to participate in the planning process (Figure 3). This forced interaction would stimulate earlier communication and collaboration, which would probably also help bridge gaps in knowledge and link the interests of local authorities and district heating companies and possibly also the interests of industries producing excess heat. Through the plan programme, municipalities have a unique opportunity to contribute to establishing the initial contact between district heating companies and industries.

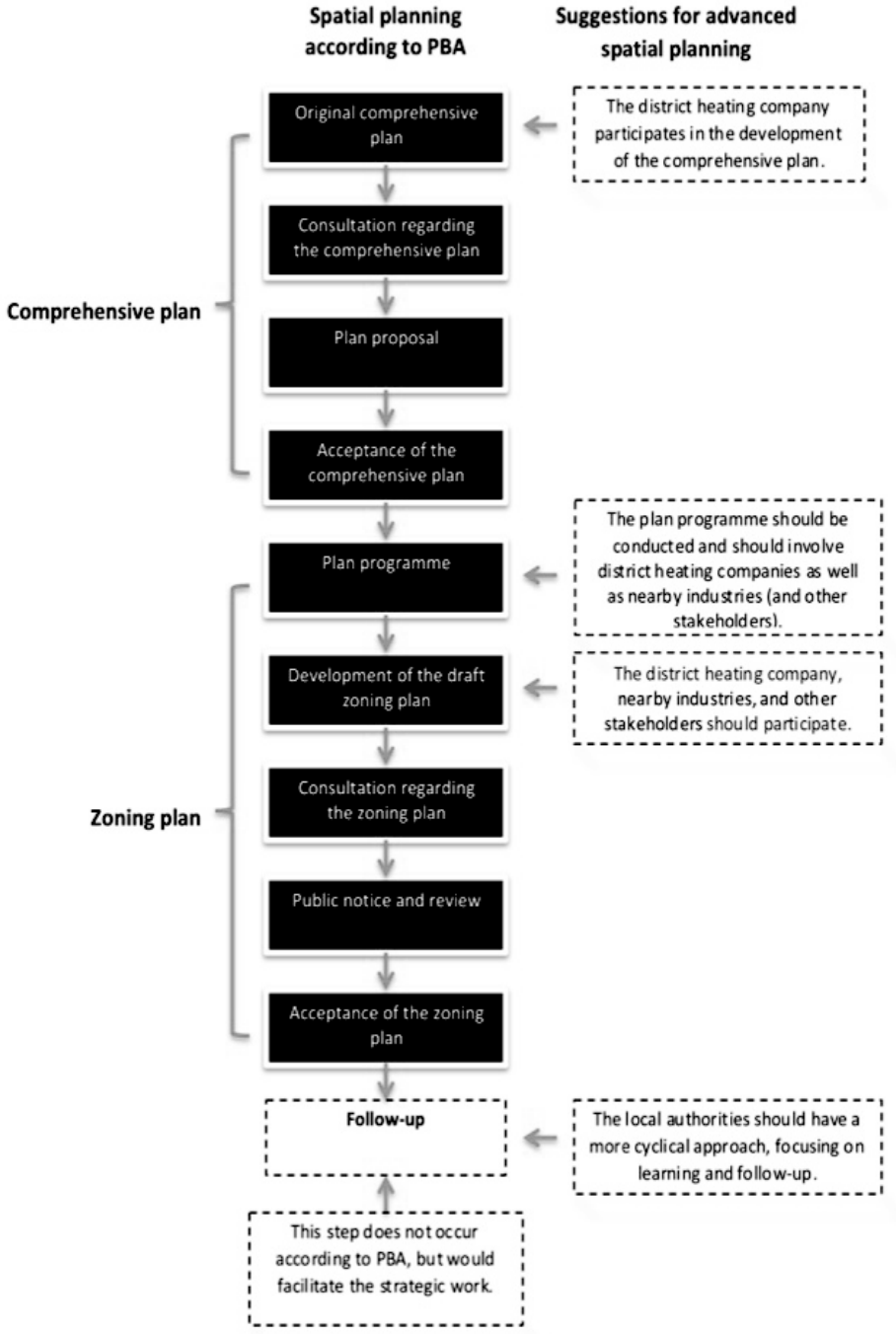

Figure 3. Suggestions for a developed planning process for district heating companies and industries producing excess heat. Major steps in the planning process that could facilitate the development of excess heat-based district heating within a planned residential area.

If the local authorities mentioned in article 3 would start to develop plan programmes together with interested parties from the outset of the development of zoning plans, situated knowledge from the public could be exploited. This arrangement could also create an opportunity for the district heating company to contribute its knowledge on how to facilitate excess heat-based district heating. Spatial change depends on skilled planning, politically legitimate decision-making, and the realisation of stated goals. A multidimensional approach is required because of the subsystems of expertise, where politics and economy are linked (Mäntysalo, 2000).

Planning would also benefit from a more cyclical approach. It would be preferable for local authorities to focus more on learning and monitoring by following up the planning process, (the last step in planning is shown in Figure 3.) This approach would provide greater knowledge about how to create a strategic planning process with broad participation. Recurring elements in the processes dealing with monitoring and evaluation would probably be beneficial to the local authorities. However, it is known that Swedish planning processes are characterised by very weak links between performance management and strategic spatial planning (Hjelm et al., 2011). Article 3 concludes that planning could become more strategic with a greater focus on framing decisions, actions, projects, results, and implementation. However, this incorporates monitoring, feedback, adjustment, and revision, both in the short- and long-term (Bryson, 1995; Bryson and Roering, 1988; Faludi and Korthals Altes, 1994; Gibelli, 2003; Mintzberg, 1994; Poister and Streib, 1999).

Taking the results from all three appended articles into account, it is clear that there are great opportunities to facilitate the emergence and development of excess heat-based district heating systems through municipal spatial planning. Long term excess heat collaborations between industries and district heating companies requires certain organizational conditions such as; trust, fine-grained information transfer, joint problem solving, honesty, and shared visions of common goals. This increased knowledge about these important preconditions can be used to facilitate further development of similar cases of excess heat collaborations. By also taking existing industrial excess heat into account within municipal spatial planning, the conditions for expansion could be further improved. Excess heat-based district heating systems, involving heat-supply collaboration between industries and the district heating sector, would also help overcome the financial obstacles related to profitability described in article 3. Heat-supply collaborations have been proven to create financial advantages for all parties involved as well as for the community as a whole (Burström and Korhonen, 2001).

The importance of certain organisational conditions is highlighted by a number of previous studies (Börzel, 1998; Chertow et al., 2008; Doménech and Davies, 2011; Gibbs, 2003; Hewes and Lyons, 2008; Jacobsen and Anderberg, 2005; Kenis and Schneider, 1991; Powell, 1991; Uzzi, 1997; Volpe et al., 1996). Article 3 concludes that common goals and visions, similar to those noted by Domenech and Davies (2011), are important in the development of embedded collaborations based on trust. Domenech and Davies (2011) further concluded that embedded relations create opportunities for more risky and innovative projects.

However, the results from all three articles within this thesis show that these processes are largely controlled by the substantial financial investment associated with technical solutions.

As mentioned, it is often financial aspects that are the main drivers behind the development of collaboration projects (Ehrenfeld and Gertler, 1997). As for the expansion of district heating in new residential areas, article 3 shows that a district heating company requires financial revenue from a sufficient number of heat customers in the planned area before it is willing to invest in the construction of a new district heating system, or in the expansion of an existing grid. Regardless of the ownership of the district heating company, the investment must be financially justifiable for the district heating company to expand its operations.

It is clear that the substantial financial investments required make financial aspects a major barrier to excess heat collaboration. The results from articles 1 and 3 show that financial investment subsidies have had a positive impact on the development of collaborations concerning excess-heat supply and on the inclusion of new district heating grids in new residential areas. A reintroduction of some kind of financial investment subsidy for these kinds of investments, such as the LIP and Klimp grants, could encourage investment and help the parties involved see the long-term benefits. Both the LIP and Klimp grants were based on collaborations between different actors in the community to improve environmental performance. These collaborations help reduce the financial risks associated with the large investment costs. The local authority was responsible for the programme and its implementation (Swedish Environmental Protection Agency, 2012a). A similar investment subsidy could stimulate further interaction between the interested parties.

8. CONCLUSIONS AND IMPLICATIONS

This licentiate thesis contributes with new knowledge on the role of organisational factors regarding the emergence of new excess heat-based systems of district heating and how it can be facilitated, both from a theoretical and practical perspective.

By applying theories within the area of Industrial Symbiosis (IS) on the excess heat-based district heating sector a better understanding of the preconditions for, drivers behind and barriers to excess heat collaborations was obtained.

The identified preconditions for excess heat collaborations are organisational, financial, and technical. These are also factors that have been identified as the main barriers. Concerning the drivers behind the development of these collaborations financial and environmental aspects have been identified as important.

Applying concepts from IS on heat supply collaborations also gives a developed theory of the organizational preconditions. In addition to Uzzi's (1997) findings on trust, fine-grained information transfer and joint problem solving, this thesis also highlights honesty and shared visions of common goals as important preconditions for the emergence and development of excess het collaborations.

Collaborations based on interaction and exchange of knowledge through participation are important preconditions for creating trust and shared visions of common goals among actors involved in inter-organisational collaborations. Despite this, actors involved in these kinds of collaborations often indicate financial aspects as the single most important consideration.

However, the identified organisational preconditions – trust, fine-grained information transfer, joint problem solving, honesty, and shared visions of common goals – have shown to be of great importance in terms of overcoming the technical and financial barriers associated with both the expansion of district heating and the exploitation of excess-heat recovery for district heating.

Collaborations concerning industrial excess heat supply could help overcome the financial barriers of profitability that hinder the expansion of district heating in the planning of new residential areas. This is due to the fact that industrial waste heat is relatively cheap in comparison with primary energy. However, because the financial investments required often are substantial, a reintroduction of some kind of investment subsidy would likely encourage further investments. These types of subsidies are important for the future development of excess heat-based district heating systems.

Investment subsidies are also important from an environmental point of view since the utilization of industrial excess heat reduces the need for primary energy. Even though the environmental aspects are described as important drivers behind these types of developments, the image of being an environmental responsible company seems to be a stronger driver. That is, a company associated with environmental issues can gain marketing advantages. The environmental benefits as a result from the two studied cases within the framework of this study are described as a positive spin-off of the development at large.

By taking available surrounding sources of industrial excess heat into account during municipal spatial planning, Sweden's local authorities have great potential to further facilitate the emergence of excess heat-based systems of district heating through the municipal planning monopoly. Yet, this way of planning requires knowledge gained through the involvement of different interested stakeholders with expertise in their specific areas.

However, for the local authorities to achieve a strategic planning process in the long run, a more cyclical approach is needed. To gain greater knowledge about how to create a strategic planning process with broad participation local authorities needs to focus more on learning, monitoring and evaluation by following up the planning process through feedback, adjustment, and revision, both in the short and long-term.

9. FUTURE RESEARCH

This thesis suggests several areas for future research. For example, future studies could examine innovative solutions, including excess-heat-supply collaborations with industries and/or other companies producing excess heat as a by-product of their main production, both large- and small-scale. An additional parameter could be the development of customised business offerings as a way to promote the potential new services that these heat collaborations would entail.

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