Conversion to a Circular Industry

Success and limiting factors to convert Högdalen Industrial Area into an eco-industrial park

Karin Bywall

Timmy Rosendal

Handledare:
Cecilia Sundberg

AL125x Examensarbete i Energi och miljö, grundnivå

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Abstract

The concept of eco-industrial parks is a way to minimize environmental impact and resource use from an industrial area, and in this study the concept is applied to Högdalen industrial area in Stockholm. An interview study has been conducted with key actors in the area, which found for instance that there were a good cooperation will among the actors and some material and energy exchanges occurring. This was then compared to a literature study of the limiting and success factors of the development of an eco-industrial parks. A quarter of the identified factors were determined to have good prospects, a fifth was partly fulfilled, a fifth had bad prospects, a fifth was unknown and 15 % was unknown but relevant to uncover in this stage of development. For the future, it is suggested that: more interviews should be done with more actors in the area, Cleantech Högdalen should change focus to develop an eco-industrial park, more energy and material flows should be mapped and to gather information of unknown and relevant factors. The conclusion of this study is that there is potential to develop Högdalen Industrial Area into an eco-industrial park but there are some knowledge gaps about the quantitative minimization of resources and environmental impact.

Sammanfattning

Konceptet eco-industrial parks bygger på att minimera klimatpåverkan och resursanvändning från ett industriområde, i den här studien är konceptet applicerat på Högdalens industriområde i Stockholm. En intervjustudie har utförts i området, där nyckelaktörer har intervjuats, studien visade bland annat att det är en generellt sätt god samarbetsvilja i området samt att några energi-och materialutbyten sker. Intervjustudien har jämförts med en literaturstudie av framgångsfaktorer och begränsande faktorer för utvecklingen av en eco-industrial park. En fjärdedel av de identifierade faktorerna har goda utsikter, en femtedel är delvis uppfyllda, en femtedel har dåliga utsikter, en femtedel är okända och 15 % är okända men relevanta i detta steg av utvecklingen. För framtiden föreslås intervjustudier med fler aktörer i området, Cleantech Högdalen bör ändra sitt fokus till att utveckla en eco-industrial park i området, fler energi- och materialutbyten bör kartläggas samt att information bör samlas om de faktorer som är okända och relevanta. Slutsatsen av studien är att det finns en potential att utveckla Högdalens industriområde till en eco-industrial park men att det är kunskapsluckor kring den kvantitativa potentialen att minimera resursanvändning och således också klimatpåverkan.

Foreword

This report is a result of a bachelor thesis within the Bachelor of Science programme in Energy and Environment at KTH Royal Institute of Technology. Our wish is that this report will form a basis for continuous work with the concept of Eco-Industrial Parks in Högdalen Industrial Area, as well as in the country as a whole, to face the upcoming challenges and develop a competitive sustainable industry. This report is dedicated to future work at the department of Industrial Ecology at KTH Royal Institute of Technology.

Karin Bywall and Timmy Rosendal
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1. Introduction

In 2015 The United Nations formed the so-called Sustainable Development Goals, an agenda for a global sustainable development (ICSU & ISSC, 2015). The twelfth goal is to “ensure sustainable consumption and production patterns”, including targets towards efficiency in resource usage and waste prevention. According to Greadel & Allenby (2010) we need to change the technology-society-environment relationship and understand that the planet imposes limits. This is due to the limited amount of resources and the limited capacity to absorb emissions from our industry. One of the concepts that could be used to address these issues is the concept of industrial ecology, which applies the theory of ecosystems from ecology on industrial systems, and therefore calls them industrial ecosystems (Glavič, 2007). The key purpose of industrial ecology is to close the linear material and energy flows throughout the industrial systems so that they become circular (Greadel & Allenby, 2010) (Lowe & Evans, 2010). There are several definitions to industrial ecology, and Greadel & Allenby (2010, 32) defines the concept as this:

“Industrial ecology is the means by which humanity can deliberately approach and maintain sustainability, given continued economic, cultural and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal.”

Within industrial ecology, one of the key concepts is industrial symbiosis (IS). In biology symbiosis means that two unrelated species exchange energy, material or information in order to both gain positive effects (Chertow, 2000). When this theory is applied to industrial ecosystems, it is businesses that form a mutually beneficial relationship. This leads on to the term “eco-industrial park” (EIP), which is a community of companies that collaborate in order to gain enhanced environmental, economic and societal performance which leads to benefits that are greater than the sum of individual benefits (Glavič, 2007). Significant environmental and economic benefits have been confirmed in several quantitative assessment studies but there are some uncertainties with the chosen reference state, the environmental impact assessment and the data that often is incomplete (van Berkel, 2007).

This report will have a focus on the concept of EIPs, and on one of the many industrial areas in Sweden, namely Högdalen. With starting point in the strategic plan documents of Stockholm accepted in 2007 by the Stockholm municipality, an initiative to make Högdalen Industrial Area (HIA) a sustainable industrial area of world class until 2020 was started. The city of Stockholm founded this initiative and the project was assigned to the Stockholm Business Region Development (SBRD), who in 2012 made a mapping of the area and its opportunities to become a sustainable industrial area of world class (DFHS, 2014).

In order to make HIA a sustainable business area, the concept of EIP could be applied to HIA, but does the area have the right conditions to form an EIP? There is literature on the subject of EIP, but mostly case studies of already formed EIPs, which is not the case of the HIA. The purpose is to convert an already existing industrial area into an EIP that could be, according to Chertow & Ehrenfeld (2012), classified as a retrofit industrial park (RIP). There is some literature on RIPs, especially from a research program in Korea called "Korean Nation Eco-Industrial Park Development Program", which will be reviewed in this report.

1.1 Aim

Identify the potential to increase resource efficiency to minimize the environmental impact from Högdalen Industrial Area with methods and experiences from the field of industrial ecology and the sub-concept of eco-industrial parks.

1.2 Objectives

The main objectives of this report is to:

- identify the primary energy and material flows within the area, and compare them to each other.
- identify success and limiting factors for the development for an EIP
- determine focus areas to investigate further because they are possible to advance in or there is a lack of knowledge in that area
- identify common interests and potential conflicts of interest between stakeholders in the area
- determine how to raise awareness of the EIP concept among the stakeholders in HIA

2. Methods

2.1 Literature study

To get an updated overview of the emerging field of industrial ecology especially oriented on industrial symbiosis and eco-industrial parks, literature on the area has been investigated. This method has also been used to get an updated view of HIA and the businesses active in the area. Related research and reports within the area of eco-industrial parks and HIA makes the underlying material of this study. The chosen literature is based on scientific reports and journals written by researchers within the field of industrial ecology as well as from the social networks in HIA and is a selection of the literature within the area from KTH Primo and Google Scholar.

2.2 Interviews

To ensure a realistic view of the businesses in HIA, the literature study is complemented with interviews of key figures within the main industries and also from the existing social networks in HIA. The persons that were interviewed were Niclas Åkerlund (Fortum), Kjell Hellman (SITA), Mattias Gustafsson (EcoTopic), Karin Sundin (Vantör), Bernt Fernström (Högdalsgruppen) and Irena Lundberg (Cleantech Högdalen). In the report the interviewees will be cited as the companies they represent. The interviews have the purpose to include the industry's' point of view on the on-going project of Cleantech, their view of future opportunities, possible conflicts of interest in HIA, their energy and material flows and also organizational structure. The so-called key actors that were chosen in this study based on the social networks in HIA as well as the companies' size with respect to number of employees and obvious flows of energy and material presented in chapter 4.

The method that was used was a semi-structured interview with questions areas, follow up questions and open questions (Eriksson, 2016). The questions were formed to partly identify large flows of energy and material flows and partly to answer against the success and limiting factors presented in the literature study about EIPs in chapter 3.1, Table 1. From these factors questions were formed regarding energy and material flows, symbiotic business relationships, economic value added, awareness and information sharing, organizational and institutional setups and also technical. The questions that were formed worked as a general template, but for each interviewee they were adjusted, both before and during the interview, unrelevant questions were removed or replaced by a more relevant question.

Though the core of the each interview were the same. The interviews have been summarized and all relevant information is presented in Chapter 5.

3. Literature study: Eco-industrial park

The concept of industrial ecology as well as industrial symbiosis was first coined in 1989, and more specifically, in the the journal Scientific American by two of the research and development staff at General Motors (Chertow & Park, 2016).

"Wastes from one industrial process can serve as the raw materials for another, thereby reducing the impact of industry on the environment" (Frosch & Gallopoulos 1989)

By this, Frosch and Gallopoulos describe the core of industrial symbiosis, where one's waste should be seen as resources for someone else (Chertow and Park, 2016). The same year, 1989, the first trueborn example of industrial symbiosis was recognized in the city of Kalundborg, Denmark. Since the 1960's the city had developed an industrial cooperation network between the industries where resource exchanges were central. The city was labelled with "industrial symbiosis" in 1989 and the industrial cooperation created sustainable industrial development, where economic, social and environmental benefits were made.

Chertow & Ehrenfeld (2012) have identified three stages of a self-organizing industrial ecosystems; Sprouting (Stage 1), Uncovering (Stage 2) and also Embeddedness and institutionalization (Stage 3). The Stage 1 is characterized by a beginning of resource exchange for different reasons such as resource security or economic efficiency. This may not be visible to an observer and the actors just sees this bilateral exchange as any other material flow they have. In order to sustain this stage, the private benefits must be greater than the private costs, as long as this condition is fulfilled the companies will be indifferent to if they are trading with someone in the nearby area or not. Thus few of these early symbiotic exchanges continues to develop into a IS network.

Stage 2 is characterized by that the created positive environmental externalities are uncovered, or discovered, often by actors that have other interest than the pure private transactions. A champion is necessary in order to move from the sprouting stage to the uncovering stage, to help people to go together and develop the IS further. A coordinating organization should be formed that should promote the early stage of IS. It is important that these institutions represent the different companies, but also governments and universities. Stage 3 consists of an institution that has been created in earlier stages and has become more established during this stage is intentionally driving the expansion of the network.

A community of businesses that collaborate in order to gain enhanced environmental, economic and societal performance that are greater than the sum of individual benefits is called an EIP (Glavič, 2007). Among the EIPs there are a few categories according to Chertow (2000); the two most applicable to HIA are; "Category 3 IS - Among nearby firms in a defined industrial area" and "Category 4 IS - Among nearby firms not collocated". What distinguish them are mainly the geographical placements of the businesses and firms involved in the collaboration. Category 4 is characterized by the type of exchange that presupposes the already existing businesses and link them together, but with the opportunity to fit new businesses. The main example of this type of EIP is Kalundborg where the collaborating businesses are not located next to each other, but within about a two-mile-radius. Category 3 is based on collaboration between businesses that are located within a defined area and can be created from either a new development park or a redesign of an existing industrial area.

In Korea there is an initiative called The National Plan for Eco-Industrial Park Development, where the goal is to convert existing industrial parks to eco-industrial parks along with RIP (Chertow and Ehrenfeld, 2012). The purpose was to update the existing infrastructure, reduce costs within the businesses and to identify new business opportunities by analysing the energy and material flows within the areas. The risk when engineering a retrofit is that the norms and values about the resource exchange have not been completely enclosed. Social relationships and exchanges serve as a good base for creating a retrofit, as these are things that the engineered retrofit does not necessarily create. Success will come to the parks that accept the values that enable collaboration between firms and businesses.

3.1 Success and limiting factors

This section of the report is composed of information from two articles, Pak et al. (2016) and Sakr et al. (2011). The first is an evaluation of the first phase in the National Eco-Industrial Park Development Program in Korea, which purpose is to retrofit Korea's industry into EIPs (Pak et al., 2016). This transition process is developed in three different phases, where the first phase is to transform pilot IS into EIPs and this began by doing an analysis of the strengths, weaknesses, opportunities and threats (SWOT) in the industrial areas. There were five pilot sites included in the first phase of the program, with five different conditions, which can indicate that this is a universal approach to use in the retrofitting process of any industrial areas. Four categories were identified for future EIP projects in Korea and other countries; technical, economic, legal/regulatory and social factors.

The second article by Sakr et al. (2012) made a literature study of the experience that has been made around the world in EIP projects, as a basis for a case study of doing such project in Egypt, but the factors are intended to be used worldwide. The authors found that a significant number of EIP projects have failed, and identified six categories of key success and failure factors: symbiotic business relationships, economic value added, awareness and information sharing, policy and regulatory frameworks, organizational and institutional setups and lastly technical factors. One concept that the authors argue has been neglected in the development of an EIP is the champion; a leader that inspire and keep people motivated, with a vision and charismatic properties, which resolves conflicts and make everyone strive towards a common goal.

Table 1. Success and limiting factors for the development of an EIP

Factors	Success	Limiting
Symbiotic business relationships	- The importance of the presence of a champion [1] - Issues of trust, good personal relationships and cooperation between companies [1] - Existing social networks between companies [1] - Relationships needs to evolve over time with the engagement of a champion [1] - Active participation of stakeholders such as: local, regional and national government agencies, business associations, labour unions, educational and research institutions, multi-disciplinary expert and NGOs [2] - A healthy balance between of the different stakeholders interests [2]	- Lack of company interest in EIP development [1] - The EIP project are initiated from the local or regional government as a way to improve the local economy [1] - Thinking that physical by-product exchange is the most important part of an EIP [1]
Economic value added	- All the firms in a cooperations need to gain benefits such as reduced cost/expenses and/or profit increase [1] - A willingness to invest money, resources and time to develop an EIP	- Companies could find the investment in collaboration with other companies financially risky or unsound [1] - The benefits could not be enough reason to form a

	among the stakeholders[1] - Government funding have the purpose to help companies to examine the economic benefits of an EIP [2] - Government funding were used to draw private investment and scale-up the IS projects[2]	symbiotic relationship[1] - Lack of finance of projects [1] - The government finance the whole cost of planning the EIP [1] - The government funds the cooperation projects in the area to realize industrial symbiosis [2]
Awareness and information sharing	- Important that the champion, in an early stage, educate the community in the EIP principles and present successful case-studies[1] - Networking and organizing workshops and conferences with key organizations and individuals[1] - Launch information websites [1] - Involve universities[1] - Effective structures for continuous technical assistance to guide small and midsize companies so that they find the right information and technology [1] - A coordinative function to support the management of inter-company information flows, to find recycling opportunities and provides assistance and coordination[1] - Start with focusing on establishing projects with low costs and high benefits[1] - An efficient and transparent system for information exchange[1] - Made a model case to convince other of the benefits of the EIP concept[2]	- Companies that are unaware of EIP principles and benefits or not engaged in the EIP project [1]
Policy & regulatory	- Governmental policies should have an enabling role, and provide political,	-EIP principles are not supported by the current

	educational, infrastructural and coordination support[1] - Environmental legislation needs to be in sync with the principles of EIP, which means that is should encourage by-product utilization[1] - EIPs needs to be integrated into the country's national strategy and liked to sector strategies, budgets and in the local stakeholder community [1] - An overarching legal framework for the EIP program was conducted which especially empowered local EIP centres to gather information of energy and material flows in the industrial parks [2]	regulations [1] - High involvement of the government can make the companies lose interest in the EIP project [1] - The use of industrial-by-products were limited by regulation [2] - Regulation also limited the development of a resource sharing network in a larges context [2]
Organizational and institutional setups	- Each involved firm should include the planned bilateral exchanges into the organizational structure of the company and also in the overall management of the park [1] - There is an infrastructure and ICT that makes information exchange and collaboration easier [1] - Already existing cooperation between firms, as a base for IS [1] - If the company in the community is a subsidiary- company and the headquarter company has a well established environmental management system or social responsibility system or if the subsidiary company has independent decision- making power [2] - At the organizational level: the workload, eagerness and attitude of the managers and the culture of the company needs to be positive for IS [2]	- Competitive relationships among the companies in the community [2] - Behaviour barriers that causes low level of inter-company cooperation [2]
Technical	- Already existing material, waste and energy exchange among some companies in the area [1]	- There is missing a international standard to define EIP [1]

		- Lack of technical know-how to identify and evaluate IS opportunities [1]

Source: [1] Sakr et al., 2011. [2] Pak et al., 2016.

3.2 Network Analysis

IS systems are complex, which can make them vulnerable to distributions even if they only affect one industry, called a node, in the system (Chopra & Khanna, 2014). It is necessary to analyse the function and structure of a system in order to get an internal understanding of it, and a way to do this is to use network analysis due to that the flows in the system form a network (Zhang et al, 2015). Network analysis is also used to understand the relationship among the industries, or nodes (Chopra & Khanna, 2014). There are two main methods, social and ecological network analysis, where the first has its origin from the study of humans communicate in social networks and the second from the study of flows within ecosystems (Zhang et al, 2015).

According to Chopra & Khanna (2014) centrality measures such as (1) stress centrality, (2) betweenness centrality and (3) degree centrality can be used in order to gain information about the most central nodes in the system regarding several network properties. (1) Stress centrality determines the local criticality for a node, and should be low in a system with high resilience. (2) Betweenness centrality determines the importance of a node on the IS network if the betweenness centrality is high it indicates that the node has high influence on the flow of information between the different nodes. (3) Degree centrality determines how many flows that goes in and out of a node, a high value of degree centrality indicates that many flows goes in and out of the node and that says something about the importance of this node and the system's vulnerability.

3.3 Pinch Analysis

Pinch analysis in its form of creating integrated networks has developed from the 1970's (Kemp, 2007); it is a method of optimizing energy and water consumption. Kemp (2007) illustrates pinch analysis by a chemical system standing of energy flows that had six transfer units, used 1722 kW as heat and 654 kW as cooling. After pinch analysis was applied, the number of heat transfers were four, the energy needed for heat were 1068 kW and no heat for cooling were needed. This is then the optimized system with regarding energy use. These energy targets by pinch analysis are absolute thermodynamic targets as they show the amount of energy the process or system would need if it was designed optimally.

Pinch analysis can be used to create intercompany process integration and according to a study presented in Boix et al (2015) a methodology in four steps can be used in the case of cost savings:

- “The identification of relevant processes for energy integration, that is to say heating and cooling demands and sources.
- The collection of data relative to costs:investment cost for heat exchangers and cost of piping systems.
- The heat integration between processes using an optimization tool
- The analysis of allocation savings using different game theory methods to evaluate the total savings for each company under several scenarios.” (Boix et al., 2015)

Process integration is a source of increasing energy efficiency in energy-intensive industries, pinch analysis can then be used to systematically match flows among industries with each other (Hiete et al., 2012). The possible energy savings increase with the amount of energy as well as with the number of flows, symbiotic networks, make energy savings possible also in small and midsize industries, though this will also bring new challenges as piping distances. A network where all member companies gain more benefit with the network than without would also keep partners together and probably keep partners from leaving the network.

4. Literature study: Högdalen Industrial Area

HIA is located 10 kilometres south of Stockholm Central and about one kilometre from the local town centre of Högdalen. The centre consists of Högdalen subway station, bus stations, stores, a cafe and apartment buildings. HIA comprises of three main roads where two of the roads are the only way in and out of the area. The area was built between 1950 and 1970 and is purely a business area where the buildings are characterized by facades that are painted, plastered or corrugated iron (Riksantikvarieämbetet, 2006). HIA is marked in Figure 1, where A is the centre of Högdalen. B is a subway depot owned by Stockholms Lokaltrafik (SL), C is the partly publicly owned combined power and heating plant Fortum Värme, D and E are two waste retrieval plants, one public, Vantör and one private, SITA.

Figure 1. Map of HIA. A. Högdalen town centre. B. Subway depot. C. Combined Heating and Power Plant. D. Retrieval plant. E. Retrieval plant. The green area is undeveloped land or parks, the grey area is commercial areas, the orange area is residence and the blue area is HIA.

4.1 Companies in Högdalen Industrial Area

Generally in HIA there are many small companies. As shown in Table 2, almost 60 per cent of the companies have less than 10 employees, many of them in the service industry. Except for service, most companies are active in smaller industries as construction, cars, engines and textile. The bigger companies are active within energy, architecture and consulting, service and installation industry and waste, along with other specialized industries.

Table 2. The companies in HIA (SBRD, 2012)

Business sector / Number of employees	0	1 - 4	5 - 9	10 - 19	20 - 49	50 - 99	100 - 199	No data
Industry	3	12	10	14	8	1	0	1
Service	5	16	13	8	2	1	0	0
Energy and waste	2	0	0	0	2	0	1	0
Other	0	3	0	0	0	0	0	5
Total	**10**	**31**	**23**	**22**	**12**	**2**	**1**	**6**

4.2 Key actors

The companies within HIA who have obvious large flows of energy and material have been chosen as key actors in Högdalen in this study. The companies that were not chosen lacked obvious large energy and material flows. The key companies together with the existing networks for cooperation in the area were investigated further.

4.2.1 Cleantech Högdalen

Cleantech Högdalen is a network of environmental technology companies (Cleantech Högdalen, n.d.a) that were initiated by Stockholm Stad. The goal with the project is to make HIA a sustainable business area of world class until 2020 (Cleantech Högdalen, 2014). Partners in the network are both part of the private and public sector along with the academy. The official partners are SBRD, IVL Svenska miljöinstitutet, SP, KTH Royal Institute of Technology, Länsstyrelsen Stockholm, Stockholm Cleantech, Svensk Solenergi, Tillväxtverket and Högdalsgruppen that is the local business network in HIA. Since Cleantech Högdalen was formed, projects about energy efficiency, green projects regarding green spaces, gardens and recycling have started.

The vision with the energy efficiency project was to create smart nets and cooperation within energy in the area, to create integrated and collective owned systems and to invest in local renewable energy resources along with collective energy procurements (Cleantech Högdalen, n.d.b). So far design proposals and technical quotes have been brought forward concerning technical solar projects and an open district heating project (Lundberg, 2016), but the project manager Irena Lundberg have experienced some difficulties when trying to initiate the projects in HIA.

The green projects have the aim to integrate the business area with the local town centre as well as creating new jobs for unemployed. The green projects include green spaces, local gardens and improved recycling. (Cleantech Högdalen, n.d.c) Design proposals and technical quotes were brought forward concerning green walls and roofs, indoors farming as well as for a composting project. The present stages of the green projects are; (1) one underground vegetable farm will start in 2016. (2) A pilot project to produce biochar from garden waste is in the stage of building permits and is planned to start in 2016, which will be described more under 4.2.4. (3) A green roof is about to be constructed on top of an industry building. (4) A pilot project for composting organic waste has been done with the grocery store COOP; the project is finished and reported. (5) A city farm is established and a farming network is created. (6) A rooftop greenhouse is planned to be realized in 2016. (7) There will be a green wall and a solar roof at the public waste retrieval plant; the implementation is planned in 2016. (Lundberg, 2016)

4.2.2 Högdalsgruppen

From the 107 companies listed in Table 2 about 60 are members in the local network Högdalsgruppen. Högdalsgruppen was created in 1977 and has since then influenced the area within infrastructure planning, commerce, environment and quality, safety and business development (Högdalsgruppen, n.d.).

4.2.3 Waste and energy

Fortum Värme is a Scandinavian company, the Swedish part of the company is partly owned by Stockholm Stad (Fortum, n.d.). Fortum Värme have a combustion plant in HIA where they combust domestic waste and industrial waste and turn it into district heating and electricity and deliver it to the southern parts of Stockholm.

SITA is nowadays a part of the international company SUEZ that works with recycling and waste management. SUEZ have about 1100 employees spread in over 60 locations in Sweden and 80 000 employees internationally (SUEZ, n.d.). The company have a retrieval plant in HIA where they receive commercial waste, combustible waste, sortable waste, metal and pure gypsum (SUEZ, n.d.).

4.2.4 Stockholm Vatten

Stockholm Vatten is a prominent company in Sweden within water and sanitation. The company's water and sanitation department is by 98 % owned by Stockholm Stad and 2 % owned by Huddinge Municipality (Stockholm Vatten, n.d.). Stockholm Vatten runs the retrieval plant Vantör in HIA as well as one plant for garden waste (Stockholm Vatten, 2015a).

The waste department of Stockholm Vatten is fully owned by Stockholm Stad (Stockholm Vatten, n.d.).

Stockholm Vatten have started Stockholm Biochar Project in HIA that aims to produce biochar and heat from park and garden waste and use it in the city of Stockholm as soil. Biochar has the ability to sequester carbon dioxide from the air. (Stockholm Vatten, 2015b) The project leader is EcoTopic, a company that is specialized in biochar (EcoTopic, 2016).

5. Interview study: Högdalen Industrial Area

The interview study has three major sections; energy and material flows, the social relationships and the organizational structure of the interviewees' organisations. Six interviews has been conducted, one for each actor that has been identified in chapter 4.2.

5.1 The energy and material flows in the area

In this section, the interviewees' energy and material flows will be recognized.

5.1.1 Fortum

Fortum uses domestic and industrial waste for their energy production and dross waste and flyash are generated in the process, in proportions that can be seen in Table 3. Domestic waste consists, according to Forum, primarily of unsorted plastic, paper and food waste, but also some garden waste, glass and metals. Industrial waste consists of demolition waste and residues from recycling centres, and is mainly paper, wood and plastics. There is a lack of data about the proportion of the different fractions in relation to the total input of material. Fortum produces heat and power, and the amount of GWh produced can be studied in Table 4 but the proportions are also here unknown. It is assumed that Fortum also consumes heat and power, but there is a lack of data on this area. All the values are from the year of 2015.

Table 3. Material flows Fortum Värme Högdalen.

Material	In [metric tonnes]	Out
Domestic and industrial waste	750 000	-
Dross waste	-	7500
Flyash	-	3500

Total	750 000	11000

Table 4. Energy flows Fortum Högdalen.

Energy	In [GWh]	Out [GWh]
Heat and electricity	No data	3 327
Total	No data	3 327

5.1.2 SITA

SITA is managing waste from all over Stockholm, and sells some of the combustible waste to Fortum Högdalen. SITA receives white goods from Vantör. The input and output flows for 2015 can be studied in Table 5. The reason why the output flow is larger than the input is because there is some storage of waste on the facility and because some of the waste lies outdoors it can absorb some water. It is assumed that SITA both consumes electricity and diesel, and SITA sells electricity to Vantör but there is a lack of knowledge of the quantities as seen in Table 6.

Table 5. Material flows SITA

Fraction	In [metric tonne]	Out [metric tonne]
Finely crushed wood, paper and plastics	-	23000 (12500 to Fortum Högdalen)
Chipping from recycled wood	-	17900
Coarse crush	-	16500 (12700 to Fortum Högdalen)
Unsorted	32 100	-
Combustible waste	12 800	-
Wood	16 000	-
Filling	5 600	7100
Plaster	2 000	2100
Metal	4 100	6100
Cable granulate (milled cables)	600	-
Electronics	27	450 (to Kista)
Corrugated paper	13 400	13200

Office paper	2 400	1800
Stretch wrap (for pallets)	800	600
Plastic containers	7 000	6900
Glass containers	44 900	44500
Paper containers	16 200	17000
Metal containers	1 900	2000
Electronics	1 200	1600
Hard plastics from industry	300	800
Plastics from recycling centre	700	600
Magazines	700	-
Magnetic scrap	-	900
Waste to landfill	-	7800
Total	162727	170850

Table 6. Energy flows SITA

Energy	In [GWh]	Out [GWh]
Electricity	No data	No data
Diesel	No data	No data
Total	No data	No data

5.1.3 Vantör

The material flows of 2015 is presented in Table 7 is for both the plant for recycled waste and for garden and park waste, the input and output are the same due to there is no accumulation taking place. Further Table 8 shows the electricity that Vantör used in 2015, and the diesel consumption of the hook lifts and wheel loaders. Vantör does not produce any energy.

Table 7. Material flows Vantör.

Fraction	Input and output [metric tonne]
Residual waste	2444.01

Combustible waste	5536.71
Wood	8059.49
Sticks	119.77
Upholstery furniture	544.35
Porcelain and windows (disposed)	1882.55
Asbest (disposed)	18.82
Treated wood	542.49
Soil and stone	323.01
Landfill	9128.18
Magazines	142.8
Corrugated paper and cardboard	591.58
Metal	2329.52
Car batteries	21.166
Glass	0
Soft plastic	0
Hard plastic	0
Tires	102.64
Plaster	743.82
Electric waste	775.62
Total	33285.36

Table 8. Energy flows Vantör.

Energy	In [kWh]	Out [kWh]
El	206 687	-
Diesel	429 700	-
Total	636 387	-

5.1.4 EcoTopic

EcoTopic has not yet launched their pilot facility, but the estimated material and energy flows when the facility is up and running are presented in Table 9 and Table 10. The energy efficiency of the process to produce biochar is 85-90 %. The park and garden waste will come from Vantör. There is some lack of data in table 10, which needs to be further investigated.

Table 9. Material flows EcoTopic

Material	In [metric tonne]	Out [metric tonne]
Park and garden waste	1 300	-
Biochar	-	300
Ashes	-	0.1
Total	1 300	300,1

Table 10. Energy flows EcoTopic

Energy	Input [kWh]	Output [kWh]
Electricity	100,000	-
Biogas (LPG)	No data	-
Biomass	No data	No data
Heat	-	No data
Total:	No data	No data

5.1.5 Summary

The largest input flow of material is associated with Fortum, and the largest output flow with SITA: Fortum also has the largest output of energy of the key actors, because they are the only primary energy producer. There is a lack of data on energy consumption, and therefore hard to draw any conclusions. Figure 2 shows the known energy and material flows between the different actors and the city of Stockholm.

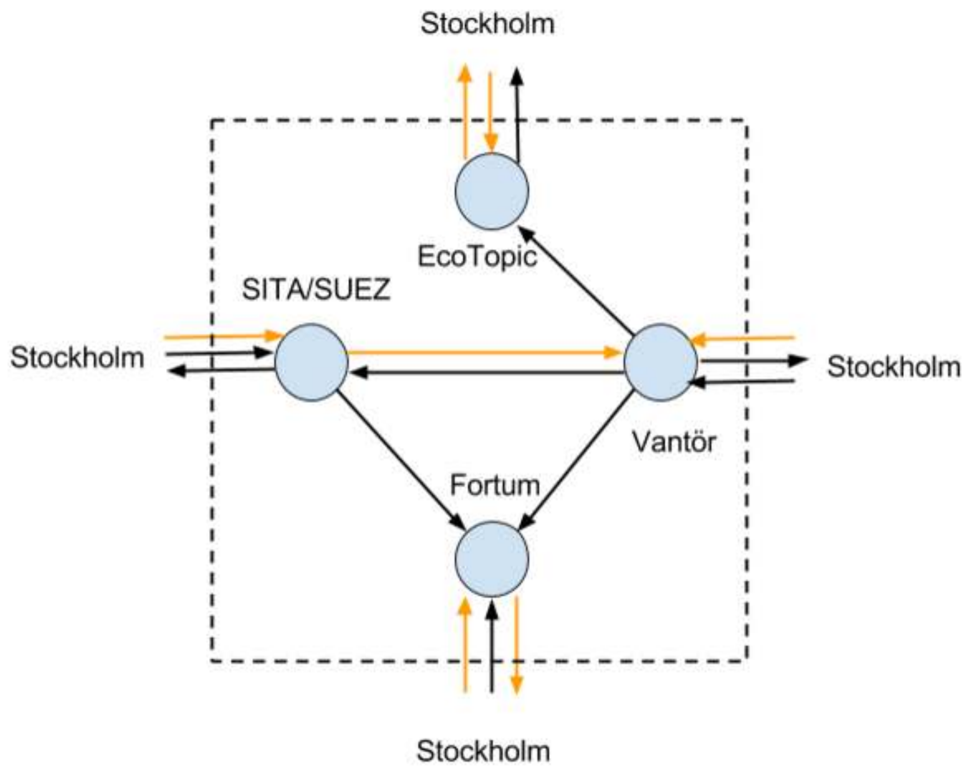

Figure 2. Energy (orange arrows) and material (black arrows) flows between the key actors and the city of Stockholm.

5.2 The social relationships

The part that follows will go through the relationships of the different actors and their willingness to cooperate with each other.

5.2.1 The will of cooperation among the actors

All the actors thought that the general will of cooperation in the area were good, with three reservations. One claims that the smaller companies where more eager to cooperate than the larges ones. The second thought that the limited amount of time inhibits cooperation between companies in the area. The third thought that there was a lack of interest from some companies. Högdalsgruppen do not have a good relationship with the authorities, and especially mentioned is Trafikkontoret due to the measures taken on parking in the area. All of the actors that were interviewed, except EcoTopic and Vantör, were aware of the local business association, Högdalsgruppen, and named it as a platform for the companies to meet each other to discuss common matters and to exchange information. Fortum, Cleantech Högdalen, Vantör and EcoTopic mentioned the Cleantech cluster as a network for cooperation and information exchange.

5.2.2 The already existing cooperation between the actors

Högdalsgruppen has had an increase in activity in the past two or three years and this is because of two things: firstly the feeling of being neglected among the companies in the area by the municipality of Stockholm, secondly the commitment of the chairman of Högdalsguppen. Högdalsgruppen have regular meetings, once every or every two months, and the chairman also meets the different companies in the area frequently.

Fortum and SITA have an extended cooperative relationship, because they both are potential customers to each other, and they are in the same industry. SITA sells their waste that cannot be recycled to Fortum for them to incinerate, and Fortum sells district heating to SITA. They also exchange plots with each other, and take common measures to improve the local environment. EcoTopic cooperates with Fortum, The City of Stockholm, Stockholm Vatten, and Bloomberg with their biochar project. Vantör has their business on SITA's plot, sells their combustible waste to Fortum, sends their white goods to SITA and will provide EcoTopic with garden and park waste later on.

5.3 The organization of the actors

This part describes the goals of the different actors, how they see their future in the area and where the decision-making concerning the actors takes place.

5.3.1 The goals for the actors businesses

Cleantech Högdalen wants more companies to move into HIA, especially companies in the environmental technology industry, in order to renew and differentiate the area. They also want to improve the environment in the area and have tried to formulate goals for energy use, but did not succeed in realizing them. The project manager of Cleantech Högdalen is fundraising in order to finance different environmental technology project in HIA. Högdalsgruppen aims to help the companies in HIA, and focuses now to improve the local environment, to improve the infrastructure and to make the companies to do more business with each other.

Fortum has four pillars that serve as foundation for their organization, were the first is about the safety of the staff. The second is about the environment, which controls how much they pollute. The third is that they manage the waste they have taken responsibility for in order to avoid having household waste in the streets. The fourth goal is about a continuously deliverance of district heating to their customers. EcoTopic has a goal of producing heat to 400 apartments and 1500 tonnes biochar, which will bind carbon dioxide from 3.500 cars back into the ground. Vantör uses the waste hierarchy as an approach for their waste management and they have a waste management plan, which is connected to the EU waste management law. They also want to recycle more of their waste, and to increase the reuse of materials.

5.3.2 If they are going to stay in the area

Fortum believes that they will be in HIA for a long time, as long as there is waste that we recycle the material of. SITA will also stay in the area, due to the good location. EcoTopic will stay in the area, and build 1-3 biochar plants. Vantör would like to stay where they are, but their organisation is limited due to the lack of space.

5.3.3 Where the decision making is taking place

SITA is a national corporation, which is included into an international corporate group, but the decisions concerning the plant in HIA are made locally. As long as the plant makes a profit they have large influence over the local matters. Fortum strives towards that the decisions should be made by those affected. This is true for some kinds of decisions like security measures on site or if there is a stoppage in the production, but when it comes to big investments the decision is made by the board. Stockholm Vatten is the main owner of the biochar project, and the decisions are made there. If the investment decision exceeds a certain amount of money, the CEO of Stockholm Vatten makes the decision or if the amount is very large the board of Stockholm Vatten, consisting of politicians, makes the decision. Vantör can make their own decisions if they stay inside the budget.

6. Analysis

In this part of the report all the factors that were identified for a successful EIP development are compared with the result from the interview study, in order to know in which state HIA is. The analysis is therefore only based on the actors interviewed and does not cover the all of companies active in HIA. In each chapter of the success and limiting factors knowledge gaps, potential areas and areas of improvement will be identified. In chapter 6.3 the two analysing methods, pinch and network analysis, are applied lightly on HIA.

A general view of HIA from the interview study is that there are a few resource exchanges that benefits all involved actors, from this it can be argued that HIA is in Stage 1, but not far in. In the following analysis HIA will be assumed to be in Stage 1 of the development into an EIP.

6.1 The success and limiting factors

The success and limiting factors have been evaluated together with the interview study. Five different stages of the factors have been defined;

fulfilled , partly fulfilled, not fulfilled, unknown and unknown and relevant. The unknown factors that are relevant now in Stage 1 are categorized as ”Unknown and relevant”, and the unknown factors relevant in later stages of the development to make HIA an EIP are categorised as “Unknown”.

6.1.1 Symbiotic Business relationships

Many of the success factors in Table 11 are partly fulfilled, one is fulfilled and one is unknown and relevant. Many are partly fulfilled due to that there is some cooperation between the different actors in the area, but there is also some friction. There are also some lacking actors such as NGOs or national government agencies. The factors that are fulfilled are that because there are existing social networks in HIA. The factor that is unknown and relevant has that status because it is assumed to relevant in Stage 1, but there is a lack of knowledge about how the different actors interests are balanced relative to each other.

Of limiting factors in Table 12, two are unknown and one is partly fulfilled. The two unknown factors are determined not to be relevant in the current development stage. The partly fulfilled factors have that status because Cleantech Högdalen does have the purpose to reduce environmental impact, but not to create an EIP.

Table 11. Symbiotic Business Relationships - Success factors

Success factors	Status	Reason
The importance of the presence of a champion	Partly fulfilled	There are actors that are driving the development of HIA, but not towards a common goal.
Issues of trust, good personal relationships and cooperation between companies	Partly fulfilled	There is a good cooperation will in the area and good relations between some companies but not all.
Existing social networks between companies	Fulfilled	Cleantech Högdalen and Högdalsgruppen are social networks in HIA.
Relationships needs to evolve over time with the engagement of a champion[1]	Partly fulfilled	The relationship between the different companies in HIA has improved the last two or three years with the engagement of the chairman of Högdalsgruppen.
Active participation of stakeholders such as: local, regional and national government agencies, business associations, labour unions, educational and research institutions, multi-	Partly fulfilled	Local government, business associations, KTH and private companies are participating in the projects in HIA.

disciplinary expert and NGOs		
A healthy balance between the different stakeholders interests	Unknown and relevant	Not enough information.

Table 12. Symbiotic Business Relationships - Limiting factors

Limiting factors	Status	Reason
Lack of company interest in EIP development	Unknown	No enough information.
The EIP project are initiated from the local or regional government as a way to improve the local economy	Partly fulfilled	Cleantech Högdalen initiates project with the focus on reducing the resource use and environmental impact in the area, but not with the aim to create an EIP.
Thinking that physical by-product exchange is the most important part of an EIP	Unknown	Not enough information.

6.1.2 Economic Value added

Of the four success factors in Table 13 under the category economic value added, one is unknown and relevant, one is unknown and two are not fulfilled. The reason why one factor is unknown and relevant is because it is unclear if all the actors that cooperate can gains benefits and how large those are. This is considered to be relevant in Stage 1 because that stage is market driven. The unknown factor that is determined not to be relevant in Stage 1 because the EIP concepts needs to have been uncovered, which is during Stage 2. The two unfulfilled factors have that status because the financial contribution of Cleantech Högdalen is not aiming to develop HIA into an EIP.

In Table 14, three of the factors are partly fulfilled, one is not fulfilled and one is unknown and relevant. The partly fulfilled factors are connected to uncertainty or lack of finance. The factor that is not fulfilled is that because Cleantech is not funding the whole development of the EIP, for obvious reasons. The unknown and relevant factor is relevant in Stage 2 because it a condition for forming bilateral exchanges, but there is a lack of data about if the actors thinks that the benefits of forming IS is too small to start cooperating.

Table 13. Economic Value Added - Success factors

Success factors	Status	Reason
All the firms in a	Unknown and	In the relationship between Fortum and

cooperation needs to gain benefits such as reduced cost/expenses and/or profit increase	relevant	SITA this factor is fulfilled, but all cooperate are not identified.
A willingness to invest money, resources and time to develop an EIP among the stakeholders	Unknown	A shortage of time delimits cooperation, but for the willingness to invest money and resources there is a lack of knowledge.
Government funding have the purpose to help companies to examine the economic benefits of an EIP	Not fulfilled	Cleantech Högdalen is not funding with this purpose.
Government funding were used to draw private investment and scale-up the IS projects	Not fulfilled	Cleantech Högdalen is not funding with this purpose.

Table 14. Economic Value Added - Limiting factors

Limiting factors	Status	Reason
Companies could find the investment in collaboration with other companies financially risky or unsound	Partly fulfilled	One actor experiences that larger companies are more reluctant to corporate than smaller companies.
The benefits could not be enough reason to form a symbiotic relationship	Unknown and relevant	Not enough information.
Lack of finance of projects	Partly fulfilled	Cleantech Högdalen and Högdalsgruppen experience a lack of finance.
The government finance the whole cost of planning the EIP	Not fulfilled	The government funds environmental technology projects, but not to develop an EIP:
The government funds the cooperation projects in the area to realize industrial symbiosis	Partly fulfilled	Cleantech Högdalen have initiated and invested in some projects in HIA, but the cooperation between the companies is self-organized.

6.1.3 Awareness and information sharing

As shown in Table 15 and Table 16 the general view of awareness and information sharing is unclear. Many of the success factors in Table 15 are unknown. The first one about effective structures to guide companies are hard to determine if it is relevant for Stage 1 or the later stages. But to start with a high profit and low cost project and have a transparent and efficient information exchange system are considered to be relevant for Stage 1. The first one is important because the private benefit needs to be higher than the private cost in order to sustain the bilateral exchanges. The second one because it could reduce the cost for finding possible business partners. The factor in Table 16 that are fulfilled have the status due to that most actors are unaware about the EIP concept, because HIA is still in Stage 1.

Table 15. Awareness and information sharing - Success factors

Success factors	Status	Reason
Important that the champion, in an early stage, educate the community in the EIP principles and present successful case-studies	Not fulfilled	The potential champion has no knowledge in EIP principles.
Networking and organizing workshops and conferences with key organizations and individuals	Fulfilled	There are two networks, Högdalsgruppen and the Cleantech Högdalen cluster.
Launch information websites	Fulfilled	Högdalsgruppen and Cleantech Högdalen both have websites.
Involve universities	Fulfilled	KTH is involved in Cleantech Högdalen.
Effective structures for continuous technical assistance to guide small and midsize companies so that they find the right information and technology	Unknown	Not enough information.
A coordinative function to support the management of inter-company information flows, to find recycling opportunities and provides assistance and coordination	Not fulfilled	No such function is identified.
Start with focusing on establishing projects with low costs and high benefits	Unknown and relevant	There have been several projects in the area, but there is a lack of knowledge of the benefits and costs of them.
An efficient and transparent system for information exchange	Unknown and relevant	Högdalsgruppen and Cleantech Högdalen are networks for information exchange but the efficiency and transparency is unknown.
Made a model case to	Unknown	Not enough information.

convince other of the benefits of the EIP concept		

Table 16. Awareness and information sharing - Limiting factors

Limiting factors	Status	Reason
Companies that are unaware of EIP principles and benefits or not engaged in the EIP project	Fulfilled	Because of the lack of knowledge of the EIP concept. This factor is not relevant until later stages in the development of an EIP.

6.1.4 Policy and Regulatory

This category of factors has not been analysed, because all the factors are depending on the national law of Sweden, and is assumed of being hard to influence in order to fulfil the factors.

6.1.5 Organizational and Institutional Setups

The outcome from the factors within organizational and institutional setups shown in Table 17 and Table 18 are difficult to draw a united conclusion from. The fulfilled success factors show that there are existing material exchanges and existing collaboration between companies in HIA, but also that the companies are subsidiary companies that have well established environmental policies. There is a lack of infrastructure within and outside the organizations in the area. The unknown factor in Table 17 is not relevant in Stage 1 because the IS concept has not been uncovered. The unknown limiting factor in Table 18 about behaviour barriers is relevant in Stage 1 because the stage is about market-driven cooperation between actors, this factor could possible show obstacles to move forward in the development into an EIP.

Table 17. Organizational and Institutional Setups - Success factors

Success factors	Status	Reason
Each involved firm should include the planned bilateral exchanges into the organizational structure of the company and also in the overall management of the park	Not Fulfilled	This has not been identified.
There is an infrastructure and ICT that makes information exchange and collaboration easier	Not fulfilled	This has not been identified

Already existing cooperation between firms, as a base for IS[1]	Fulfilled	There is cooperation between some companies in HIA.
If the company in the community is a subsidiary-company and the headquarter company has a well established environmental management system or social responsibility system or if the subsidiary company has independent decision-making power	Fulfilled	All the companies that have been interviewed are part of a bigger organization; with headquarters outside of HIA but many of them has many of independence and well-established environmental systems.
At the organizational level: the workload, eagerness and attitude of the managers and the culture of the company needs to be positive for IS	Unknown	Not enough information but the general attitude to cooperation is positive.

Table 18. Organizational and Institutional Setups - Limiting factors

Limiting factors	Status	Reason
Competitive relationships among the companies in the community	Not fulfilled	No competitive attitude has been identified in HIA.
Behaviour barriers that causes low level of inter-company cooperation[1]	Unknown and relevant	Not enough information.

6.1.6 Technology

The factors about technology show great potential within the existing material, waste and energy exchanges as shown in Table 19, because of the already existing cooperation in the area. This cooperation and material exchange can hopefully provide a base for future cooperation in HIA.
The unknown factor in Table 20 is hard to determine whether it is relevant in Stage 1 since the development in this stage is spontaneous and this factor presumes knowledge in the IS and EIP concepts.

Table 19. Technology - Success factors

Success factors	Status	Reason
Already existing material, waste and energy exchange among some companies in the area	Fulfilled	There do exist material exchange within HIA, mainly the cooperation between SITA and Fortum.

Table 20. Technology - Limiting factors

Limiting factors	Status	Reason
There is a missing international standard to define EIP	Fulfilled	This does not exist.
Lack of technical know-how to identify and evaluate IS opportunities	Unknown	Not enough information.

6.1.7 Summary

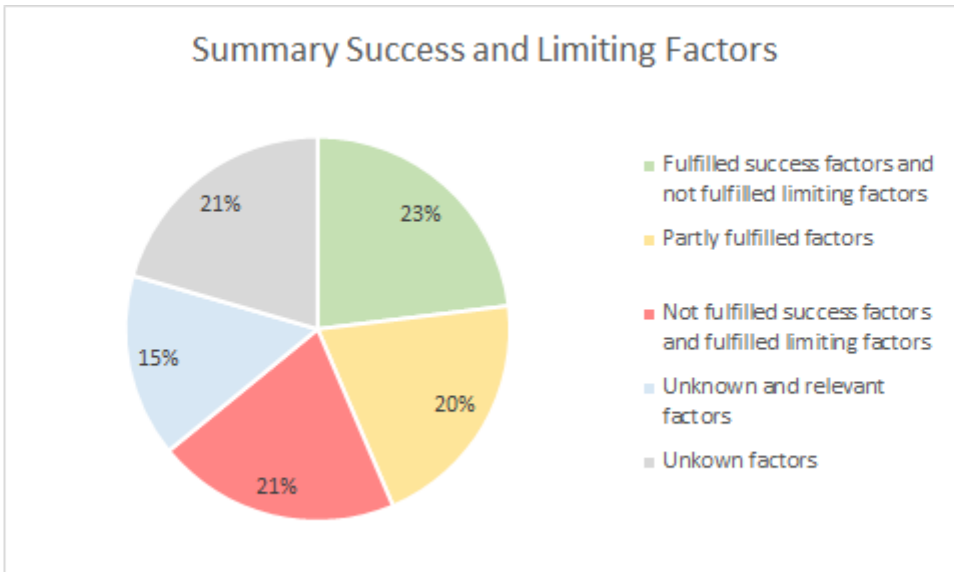

Figure 3. A summary of the analysis of the result.

As seen in Figure 3 just under a quarter of the success and limiting factors are deemed as good, a fifth of them are not deemed as good and another fifth are partly fulfilled and could tilt either way. Just over a third of all the factors are unknown, but not all of them are relevant in Stage 1, which is the assumed stage of development.

6.2 Analysis of the energy and material flows

The largest material and energy flows that have been identified in this study are connected with Fortum. The total material flow input for Fortum is 750 000 tons and 4,5 times larger than the input for SITA, 22,5 times larger than Vantör's input and 57,7 times larger than EcoTopic's. Due to that three of the actors in this study are connected to waste management, the material flows that have been identified consist of many different kinds of materials. The output flows are different than the input, SITA has the largest output flows of all the actors. SITA's output is 170 850 ton and 5 times larger than Vantör's, 15,5 times larger than Fortum's and 570 times larger than EcoTopic's.

Fortum is the only producer of energy, with a production of 3 327 GWh of energy. The energy consumption has been harder to determine, and there is a lack of data for the energy consumption of Fortum and SITA. This makes it hard to make any analysis over the energy input flows.

6.3 Applied analysis methods

In Chapter 4 network and pinch analysis were presented, these analysis methods will be applied on HIA briefly to determine whether they are suitable for future work in the case of HIA and also what data this study could contribute with.

6.3.1 Network Analysis

According to network analysis, actors can be seen as nodes, of the six actors interviewed in this study four of them are nodes in the system with different degree of centrality. Fortum is a node with a high degree of centrality because of its large energy and material flows while the other actors probably have a lower degree of centrality. The social networks in HIA have a higher level of betweenness centrality than the other nodes because they influence the information flow between actors and initiates cooperation between nodes.

6.3.2 Pinch Analysis

Pinch can be applied on HIA, due to the diversity of large, midsize and small companies as shown in Chapter 4. Pinch analysis can be applied with the purpose of matching energy flows and perhaps also material flows within the area to create more inter-company corporations. According to the methodology presented in Chapter 4 application of pinch analysis would need identification of relevant energy integration possibilities along with cost for heat exchangers and piping systems, the system can then be optimized and potential savings can be calculated. However the data collection and identification of relevant energy processes is the first step in the methodology, in this study a few energy processes have been identified and can be seen as a beginning of the data collection needed to apply pinch analysis in HIA.

7. Discussion

An EIP is a community of businesses that collaborate in order to gain greater economical, environmental and social benefits than if they acted alone. In this study several success and limiting factors for developing an eco-industrial park successfully have been identified, and applied on HIA. HIA is an industrial area in Högdalen where Fortum, SITA, Vantör, Högdalsgruppen, Stockholm Vatten and Cleantech Högdalen were identified as key actors, and were interviewed. The interview study showed that there were generally good relationships among the actors, and some bilateral exchanges were already existing.

Data of energy and material flows has also been collected from the different actors. Fortum has the largest input of material compared to SITA, Vantör and eventually EcoTopic. Fortum also has the largest output of energy because Fortum's primary purpose is to produce energy. SITA has the largest output flow, because they are the larger recycling plant of SITA and Vantör and they don not accumulate any of the waste from their input flow.

This study aims to prepare for future studies and to find out whether the future potential to make HIA an EIP exists. This study shows that there is a great potential in HIA because of the existing collaboration, the social networks and the general will of collaboration. To fulfil this potential we have identified a few focus areas for future studies.

7.1 Interest of the different actors

The results points out a few conflicts of interest between stakeholders in the area, these conflicts of interests are examples of when the potential collaboration does not directly give the desired benefits for each involved company. This affects the will from companies to invest time and resources into the projects. The existing collaboration within the area provide good examples of common interests. Fortum and SITA both gain benefits from their cooperation by material exchanges, this is a cooperation that we think can serve as a good start and make a good example of how collaborations can gain all involved actors.

Several different wills have been identified in HIA. Högdalsgruppen is working to improve the nearby environment by area care and by working to improve the possibilities for parking in HIA. CleanTech Hödalen has a totally different focus where they want to encourage and initiate technical environmental projects to develop the area. These two networks cooperate but have completely diverged focus areas that in a way is not necessarily a bad thing. Though the local social network has a great potential to develop into a network that can increase physical cooperation with energy and material, this is also something that is expressed by the chairman of the local social network. This would then mean that the two existing networks moved towards each other, and the reasons to cooperate with each other would increase.

7.2 Other important factors

The focus of this report has been on social and organizational factors and energy and material flows. One identified category of factors has not been considered: policy and regulatory factors. One topic for future research is to analyse the national policy and law of Sweden with these factors in mind, in order to get an idea of how status of these factors are. This category is different from the others, because in order to fulfil these factors there may be a need of legislative changes. This fact does not mean that is less relevant for the development for an EIP in Högdalen, but that it is harder to address.

In order to manage this, the benefits of the EIP concepts need to be demonstrated for the parliament and Swedish government but this demands a new level of work. The category of technical factors is not so exhaustive. A diverse industrial system will have more resilience (Chopra & Khanna, 2014), which could be an important factor to take into consideration. If there are many different kinds of industries one can argue also that the possible connections would increase and the chance for symbiosis to occur would increase with it.

7.3 Important lessons

The projects made so far by Cleantech Högdalen can teach some important lessons. There were projects involving different actors that did not succeed, which could be because the benefits of for the actors where large or obvious enough for them to follow the project through. Maybe the actors were not involved in the design of the project, which did not make the actors to feel ownership for the project. In the future the benefits for all the involved actors must be larger than the costs, and all the actors should be included from the start.

7.4 Areas to advance in and future research

This section discusses how the development of HIA into and EIP chould move forward. There are three different categories; areas of potential, methods to manage unknown and relevant factors and methods to determine resource efficiency.

7.4.1 Areas of potential

The relationship between the actors that were interviewed is good and the cooperation will are perceived as good, with some exceptions as described in section 5.2. There are also two social networks for the companies and actors in the area; Cleantech Högdalen and Högdalsgruppen. This is identified as a potential for future projects in the area. The relationships should be strengthened and more actors should be encouraged to get engaged in the already existing networks in order to develop more cooperation among the companies.

If Cleantech Högdalen changed focus to fund projects with the aim of uncovering what the private economic and environmental benefits are for the companies if HIA was retrofitted into an EIP, several factors could improve. This has shown to be a successful way for the government to fund the development of an EIP. This is identified as an area of potential, because it would raise awareness of the EIP concept in HIA and therefore also begin the transcendence intro Stage 2 of the EIP development.

There are existing social networks, websites and cooperation with a university, but there is limited knowledge of EIP in the area overall. If the awareness of the EIP project were raised by educating the actors by for example KTH, the possibility to improve several factors in awareness and information exchange could increase. This would also trigger the process towards the next stage of the development, to the uncovering. This has been identified as an area of potential.

There are some material and energy exchanges in the area, which could be used as a base for IS, but it would probably need to be developed further so that the companies have bilateral material and energy exchanges planned into their organization structure from start. This base for IS is identified as an area of potential, to study and build further on.

There are also several actors still to be identified, and there are some that are identified as more interesting in the earlier stages than others. SL could be a key actor in the area, due to the large use of HIA for the metro depot. There are also a number of larger industries, compared to the other companies in HIA, that could be interesting and especially the industrial company with between 50 and 99 employees. To map the energy and material flows of these actors could add valuable information to the retrofitting process of HIA and are identified as an area of potential to study further.

Another area for future research is on how the development of the institution, that should drive the expansion of the network in the embeddedness and institutionalization stage, should be developed. There is already an institution among the actors that has been interviewed in this study, Cleantech Högdalen, that could become this institution but it has today another focus. This institution could also function as the champion, which would also be an interesting a necessary aspect to look into where this champion could merge.

7.4.2 Methods to manage unknown and relevant factors

There is several unknown factors that are relevant for Stage one, the "Unknown and relevant" factors. There is one of these factors under the symbiotic business relationship category: "A healthy balance between the different stakeholders interests". We believe that we lack sufficient knowledge to suggest a method to gain knowledge about this factor. The suggestion is that someone with the expertise of relationship between business and organization theory suggest a method to move forward in this case.

The first unknown and relevant factor within economic value added "All the firms in a cooperation needs to gain benefit such as reduced cost/expenses and/or profit increase" can be identified through expanded studies of HIA to identify all corporations within the area. A method that can be used to do this is interview studies with more of the actors in the area. The second unknown and relevant factor is "The benefits should not be enough reason to form a symbiotic relationship". In order to gain knowledge about this factor, more interviews should be conducted among the stakeholders, which could include questions about if they do not think that the benefits is enough and if that is the case, which reason that lay behind.

The awareness and information-sharing category has two unknown and relevant factors. The first reads as: "start with focusing on establishing projects with low cost and high benefits". In order to gain knowledge about these factors, all the projects conducted by Cleantech Högdalen needs to be more exhaustive evaluated with the purpose to uncover the costs and benefits of the actors in HIA. "An efficient and transparent system for information exchange" is the second unknown and relevant factor that can be identified through further research and studies of the information systems within Cleantech Högdalen and Högdalsgruppen in HIA. There is one unknown and relevant factor under the category for Organizational and institutional setup, which states: "Behaviour barriers that cause low level of inter-company cooperation". In order to gain knowledge about this factors further interview studies should be made and maybe other expertise about organizational theory should participate in the configuration of these studies.

7.4.3 Methods to determine possible resource efficiency

To evaluate possible resource efficiency and possible environmental impact, more data of material and energy flows needs to be sampled from the different actors. This data can then be analysed by both network and pinch analysis. Network analysis can be applied to determine the current performance of the system in HIA, while pinch analysis can be used to find the optimized energy usage, and possibly also material usage in the area. This optimized energy usage can be seen as a goal to strive towards, an investigation process to identify what changes can be done in the system must be done to realize this model.

7.5 The possible HIA EIP compared to other EIPs

If HIA is compared to other EIPs around the world, there are two major differences. Firstly, in Kalundborg for example the IS is revolves around a coal power plant and an oil refinery, which from a sustainable development perspective could be problematic. The potential IS in HIA could revolve around recycling plants and a combined heat and power plant, which is much less problematic from the same perspective. If the EcoTopic's great ambition comes true about binding a great amount of carbon back into the soil, the HIA EIP could have a negative net output of carbon dioxide.

The second is that there is often much more companies than the ones in HIA, which makes the systems more diverse than in HIA. One way to increase the numbers of industries in HIA is to widen the system boundary, and include other industrial areas in Stockholm, more like they have done in Kalundborg. This would make the HIA EIP into a category 4 IS, where the firms are not collocated, instead of a category 3 IS. It could also be possible to expand the system boundary to include also some living areas of Högdalen, to see if there are possible connections that could be made there.

7.6 Limitations of the study

There are several limitations of this study. Only a few actors in HIA were interviewed and the interviews could be more thorough than what was achieved in this study. All the interviewees represented larger companies in HIA together with the social networks. The views of the smaller companies have therefore not been shown in the same way and their view can possibly differ from the one presented in this report.

Other limitations with this study is that the mapping of the energy and material flows are incomplete and do not say much about the possible connections in the area, and needs to be extended before a more certain conclusion can be made. Also the literature study of the factors has two main sources on which the entire study supports on, which is a weakness of the conclusions of this study. Another limitation of this study is that the concept of EIP was chosen beforehand as a method to minimize the resource use and the emissions from the area. There could be other approaches to do this, which has not been studied and compared with the EIP concept.

7.6.1 The energy and material flow data

The data of the energy and material flows that has been used in this study is not public data and have been collected by the companies themselves. This makes it difficult to verify the correctness of the data. and is something that has to be taken into consideration if the data is supposed to be used in further analysis. It is in the companies' interest however, to have correct data over the input and output flows as they are material and energy recycling companies.

8. Conclusion

There is a potential to apply the EIP concept on HIA because many of the identified factors have good prospects. However, there are some knowledge gaps that need to be filled out in order to complete the picture, and one example of this is the knowledge of the quantitative minimization of resource usage and environmental impact.

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