"Uncovering Industrial Symbiosis in Sweden" -exploring a possible approach

Sofia Persson [1,*], Jenny Ivner[1]

Linköping University, Linköping, Sweden
** Corresponding author: Sofia Persson. Tel: +46 13285613, Fax: +46 13149403, E-mail: sofia.persson@liu.se*

Abstract: Industrial Ecology (IE) is a relatively new field that is based on the ideology of nature. IE uses nature as a "reference" to study resource productivity and environmental burdens of industrial and consumer products and their production and consumption systems.

Industrial Symbiosis (IS) is a subset of Industrial Ecology with a particular focus on cyclical flows of resources through networks of businesses. One definition is that IS "engages traditionally separate businesses in a collective approach to competitive advantage involving physical exchange of materials, energy, water and/or byproducts. "The keys to IS are collaboration and the synergistic possibilities offered by geographic proximity" [1].

This paper presents a methodology that aims at developing a method for uncovering IS in the Swedish energy sector. The method is exemplified by district heating and consists of data collection of the occurring resource and energy flows to and from district heating plants in three different Swedish regions. The results show that the method presented in this article can be used in future and more comprehensive "uncovering" studies. The material from a broader, nationwide study is expected to make it possible to develop tools to facilitate the conditions for IS to be developed.

Keywords: *Industrial Symbiosis, Methodology, Uncovering*

1. Introduction

Industrial symbiosis (IS) has been defined as "engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products"[1]. IS emerge as a self-organizing business strategy among firms that are willing to cooperate to improve their economic and environmental performance [2]. According to Chertow [1] "The keys to IS are collaboration and the synergistic possibilities offered by geographic proximity". Businesses that are collocated can, in accordance to IS, reach environmental benefits and competitive advantages by physical exchange of resources with each other or with residential areas [3]. In Sweden, the occurring identified cases of IS show fruitful collaboration and integration from the companies´ point of view as well as increased environmental performance [4, 5]. However, there is a gap of knowledge when it comes to an overview of the occurring IS in Sweden. It is currently not known how common these kinds of mutual exchanges and collaborations are.

In the United States Chertow [6] conducted an uncovering study that investigated IS in a broader perspective. In Sweden there have previously been single case studies of IS. Therefore there is both a knowledge gap about the occurrence of IS in Sweden and also when it comes to methodologies to systematically gather data in order to analyze whether IS occur or not.

1.1. Aim and research questions

This article presents a method for uncovering Industrial Symbiosis and how this method can be applied to the Swedish energy sector. The method is exemplified by district heating. The aim is to illustrate and explain a method used to conduct an uncovering study of IS in Sweden and to discuss how the method can be used to create more in-depth knowledge about IS in Sweden when it comes to the extent of collaboration and mutual exchanges. The discussions are based on a pre-study where the method is tested on three Swedish regions.

2. Background

Efforts to understand and replicate Industrial Symbiosis in the form of inter-firm resource sharing like what was largely self-organizing in Kalundborg, Denmark have since 1989 followed many paths. The success has varied, some of the efforts have been very successful and some have not [6]. Chertow [6] describes the year of 1989 as "an inspirational year for industry and environment". The main reason behind the success is described as two key events following the Bruntland Commission report in 1987. The first was a seminal article in Scientific American illustrating "industrial ecosystems" in which "the consumption of energy and materials is optimized and the effluents of one process serve as the raw material for another process." The article was written by Frosch and Gallopoulos [7]. That same year the Industrial Symbiosis in Kalundborg was discovered as a concrete realization of the theory described by Frosch and Gallopoulos [7]. The cluster of intensively resource sharing companies from different industries in Kalundborg, Denmark was uncovered unexpectedly [6].

Previous research shows many, both public and private, benefits of IS as a result of "spontaneously co-location" of different businesses in industrial areas. Duranaton and Puga [8] describe these benefits as labor availability, access to capital, technological innovation and infrastructure efficiency. Key rationales for advancing IS projects as a way of trying to recreate the same types of collaboration and mutual exchanges include economic development, remediation of pollution associated with heavy industry, water and land savings, and greenhouse gas reductions [9]. Another reason for collaboration around energy savings and greenhouse gas reduction is the construction of shared visions and goal, which also makes projects less vulnerable [10].

Examples from previous research from Sweden and the Swedish forest industry show that there are several occurring cases of IS and that the conditions for implementing IS varies [5]. Also, these studies indicate that IS can have advantages both from an economic and environmental perspective [4]. Mapping these existing cases of symbiotic activity makes it possible to use the knowledge in the IS field to study and develop the partnerships further.

3. Method

As mentioned above, this article presents an approach to uncover industrial symbiosis in Sweden. The overall approach to these uncovering activities is data collection from several sources to obtain triangulation of data for each found case. This is an approach that strengthens the validity and to facilitate deeper analyses [11].

Yin [11] recommends four methods of analysis: Explanation–Building, Pattern–Matching, Time–Series Analysis and Program Logic Models. For this type of study, with large amounts of data, it is of great importance to have a fully functional database. In this case the database is designed to show the different flows that occur, as well as between which actors the flows occur. This gives a good overview and understanding of the situation within the studied regions.

Explanation–Building can mean two things: according to Yin [11] it primarily means building an explanatory narrative, which shows the causal relationship, it also can be about creating a coherent and credible overall picture of a phenomenon [12].

Pattern-Matching means that patterns that can be observed are compared to patterns that have been predicted or known from other cases. To analyse the cooperation and mutual exchanges between the studied district heating plants and related, nearby industries and companies within a specific cluster, comparison with previously known cases of similar character as an ideal type is a form of Pattern-Matching.

In the next step the various actors involved in the symbiosis cluster is studied deeper to understand the sequence in which the development of the cooperation and exchanges develop. Time–Series Analysis means clarifying the order in which events or actions occur, with what intensity they vary over time or how far they are in time.

As a last step the Program Logic Models is used to analyse the assumptions about the connections. In this case, the previous knowledge will enhance the understanding and of the elementary conditions for IS.

4. Methodology

To be able to map ongoing cases of IS empirical data about occurring collaboration and mutual exchanges needed to be collected. In order to test if the chosen approach to uncover IS is appropriate a diversity of empirical material is needed. Therefore three geographically diverse regions with different types of industrial conditions were selected for this study; one region with dominating forest industry, one with a dominating agricultural sector, and one with a diverse industrial sector including food industry, manufacturing as well as pulp and paper industry.

Investigating every single industry in these regions was not feasible for this pre-study, therefore district heating industry was chosen as the main actor to start empirical research from. The motive to choose district heating plants in order to uncover IS was that district heating occur in more or less all Swedish municipalities. In addition, activities from the business of district heating generate large flows of material and energy which are important prerequisites for IS.

The first step in process is to collect data of the occurring resource and energy flows to and from the different district heating plants within the three different regions. All of the district heating plants are also studied more in detail, one plant at a time, based on information from websites and additional interviews. All interviews were conducted via telephone and in semi-structured format, which means that the same question guide was used for all interviews, but the interviewer had the opportunity to ask supplementary questions. This type of interview is recommended since it helps structuring the interview [13]. However, this interview method also allows new and unforeseen issues to arise during the interview and hence is an effective tool for gathering information that is difficult to obtain otherwise [14].This method is expected to provide data that will show which of the studied district heating plants who has some kind of collaboration or mutual exchanges with other nearby business or industries.

To be able to identify and classify occurring cases of IS there is a need of a consequent definition with clear criterions. This study will use the same criterions as the previous study

"Uncovering Industrial Symbioses" made by Chertow [6]. Chertow defines the minimum criterion of IS as "3–2 heuristic". This means that at least three different entities must be involved in exchanging at least two different resources. An example of a 3–2 heuristic relationship within this study is industry 1 providing industry 2 with a flow of resource and industry 2, in turn, provides industry 3 with another flow of resource, figure 1.

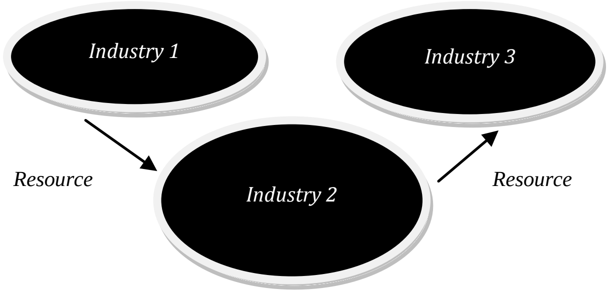

Figure 1. Example of a "3-2 heuristic" relationship. Inspired by Chertow [6].

4.1. Structuring the empirical data

The results from this study are stored in a database designed to address the collected data and to demonstrate the flows of different resources that occur between the actors involved in the detected clusters of symbiotic activity. The structure of the database is built on a model that makes it possible to link "plants" with different "flows" of resources in several steps. The database is also designed to be able to store specific information about the different flows of resources as well as the different plants involved. The information of the plants regards what type of plant it is, the size of the plant, the occurring ownership and the location of the plant. When it comes to the flows, the additional information regards what type of resource it is and of what amount, origin- and destination pant and if the specific resource is used as resource in the industrial process or functions as a utility, see figure 2. It is also possible to specify whether the resource originates as a main product (on which production the industry is based) or a byproduct (waste) from the industry. This information about each resource flow opens up for analyses about for example which kinds of exchanges are more common in relation to different kinds of plants. Martin [15] mean, for instance that by-product synergies are the most abundant type of synergies and that utility synergies in the form of shared use of energy and utilities are not as common.

The implementation of the data is done by two different formulas created in the database. The first formula manages data for each "plant" and the second formula manages data for each "flow" of a specific resource. The formulas are based on the tables within the database where the data is stored and they are created to facilitate the implementation of the collected data. Figure 2 shows the model and how the different data are related.

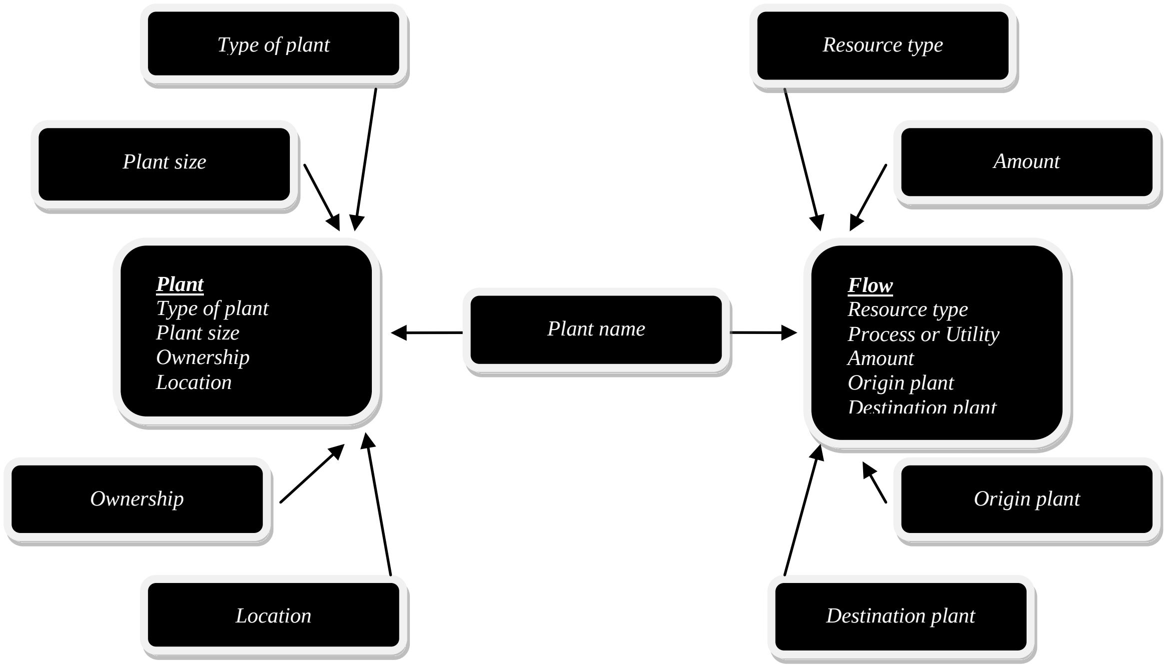

Figure 2. A model of an extract from the database demonstrating how the different data in the database are related.

5. Expected results

The collected data from the three different regions indicate that there is occurring cases of IS within these regions. The most common forms of collaboration is in the form of "3-2 heuristic" relationships, especially in the smaller municipalities. In some of the larger medium size municipalities, where the conditions of collaborations are better, the results show more complex ongoing cases of IS. One example is a forest industry and energy plant co-location, Figure 3. In this (fictional) case it is possible to define five different flows: wood, wood chips, sawdust, process steam and nutrients (ashes). Forestry, the sawmill and the district heating plants all pose as both origin and destination plants, depending on which resource flow is described. It is also possible to define both main products and by-products: wood is a main product from forest industry and ashes are by-products from incineration plants. Furthermore there are resources that pose as both process input and utilities to the destinations plants: sawdust goes into the main process at the main pellet producer and process stem is used as a utility. It is however too soon to draw general conclusions about the data material.

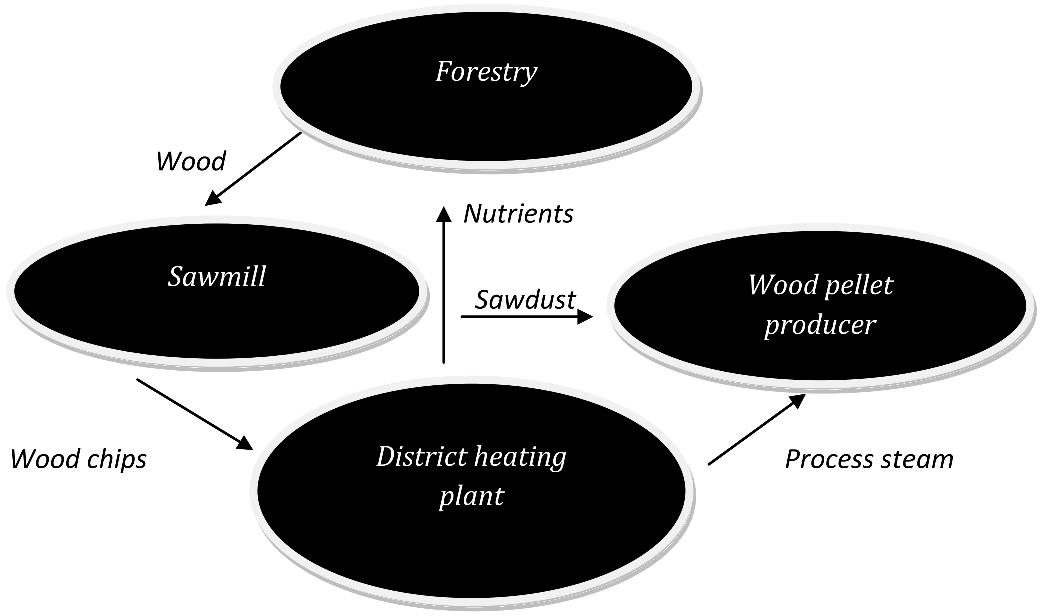

Figure 3. Example of resource flows that can be mapped in the described approach to uncovering industrial symbiosis.

The four methods of analysis described in the methods section can be used to analyze the collected data. This way of arranging the data creates a coherent and credible overall picture of the flows connecting the plants. When mapping the relationships between resource flows and plants is made for a whole region, it will be possible to analyze patterns of occurring collaborations. Thereafter observed patters can be compared to previous research but also to other regions or businesses. In this sense this will function in accordance to the Pattern-Matching as described by Yin [11]. As a continuation of the analysis, Time-Series Analysis can be used to clarify the order in which the different steps in the Symbiotic process occur, to understand the sequence in which the development of the cooperation an exchanges develop. This kind of analysis would however need additional empirical data.

When a deeper understanding of the development of discovered symbiotic activity has been created, it may be used to develop proposals on measures to improve the conditions and the facilitation of the implementation of IS in the future analogous to Yin's [11]the Program Logic Models.

6. Concluding discussion

This article has presented a method for uncovering Industrial Symbiosis and how it can be applied to the Swedish energy sector. Experiences so far have shown that the method for collecting data an organizing them in a database functions well. This method is probably suitable for uncovering IS, however it may be too demanding if it comes to cover large areas, for example the whole of Sweden. A broader, nation wide, study like that with more and broader data would probably need a less personnel intense method than semi-structured interviews with all actors. It is therefore a need to further develop the methods for uncovering industrial symbiosis to be able to expand the studies.

According to Chertow [6] the "Uncovering" of existing kernels of symbiotic exchanges has led to more sustainable development and designing of eco industrial parks. Knowledge about the occurring and ongoing cases of IS in Sweden is expected to provide the basis for more in-depth knowledge of how these collaborations and mutual exchange evolved and what the important elements for them to arise and function are. Therefore it would be of great interest to develop the methods for uncovering industrial symbiosis in Sweden. This would help to create more in-depth knowledge about IS in Sweden when it comes to the extent of collaboration and mutual exchanges and subsequently the prerequisites for such collaboration. Such knowledge in turn can contribute to develop more efficient, environmentally adapted and prosperous business.

References

[1] Chertow, M.R., Industrial Symbiosis: Literature and Taxonomy, Annual Review of Energy & the Environment 25(1), 2000, pp. 313.

[2] Costa, I., G. Massard, and A. Agarwal, Waste Management Policies for Industrial Symbiosis Development: Case Studies in European Countries, Journal of Cleaner Production 18(8), 2010, pp. 815-822.

[3] Van Berkel, R., et al., Industrial and Urban Symbiosis in Japan: Analysis of the Eco-Town Program 1997â€“2006, Journal of Environmental Management 90(3), 2009, pp. 1544-1556.

[4] Wolf, A., Industrial Symbiosis in the Swedish Forest Industry. 2007, Linköping University: Linköping.

[5] Wolf, A., M. Eklund, and M. Söderström, Developing Integration in a Local Industrial Ecosystem - an Explorative Approach, Business Strategy and the Environment 16, 2005, pp. 442-455.

[6] Chertow, M., Uncovering Industrial Symbiosis, in School of forestry and environmental studies. 2007, Yale University.

[7] Frosch, R.A. and N.E. Gallopoulos, Strategies for Manufacturing, Scientific American 261(3), 1989, pp. 144.

[8] Duranton, G.a.P., D. Micro-Foundations of Urban Agglomeration Economics National Bureau of Econimic Research Working Paper. 2003

[9] Chertow, M.R. and D.R. Lombardi, Quantifying Economic and Environmental Benefits of Co-Located Firms, Environmental Science & Technology 39(17), 2005, pp. 6535-6541.

[10] Ling, E., K. Mårtensson, and K. Westerberg, Mot Ett Hållbart Energisystem. Fyra Förändringsmodeller. 2002, Malmö Högskola: Malmö.

[11] Yin, R.K., Case Study Research. Design and Methods. Second edition ed. Applied Social Research Methods Series. Vol. 5. 1994, Thousand Oaks: Sage.

[12] Stake, R., Case Studies, in Strategies of Qualitative Inquiry, N. Denzin and Y. Lincoln, Editors., Sage Publications1998.

[13] Bryman, A., Samhällsvetenskapliga Metoder. 2002, Malmö: Liber Ekonomi.

[14] Krag Jacobsen, J., Intervju. Konsten Att Lyssna Och Fråga. 1993, Lund: Studentlitteratur.

[15] Martin, M. (2010) Industrial Symbiosis for the Development of Biofuel Production. Licentiate Thesis. LIU-TEK-LIC-2010:12.