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Exploratory study of combining Integrated Product and Services Offerings with Industrial Symbiosis in order to improve Excess Heat utilization

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Abstract

This paper explores the implications of combining an Integrated Product and Services Offering (IPSO) (also known as PSS) with Industrial Symbiosis (IS) in order to facilitate the increased utilization of Excess Heat (EH). To do so, five different EH cases originating from an IS perspective have been investigated. Based on an IPSO-focused literature review, those five EH cases are analyzed to identify potential pros and cons, if an IPSO perspective is applied, in order to further improve EH utilization.

The results indicate that applying the IPSO concept, in combination with IS, has the potential to facilitate and improve EH utilization. However, also of importance is having a clear and well-formulated business agreement, as well as mutual trust and a well-functioning dialogue between the parties involved in the EH supply collaboration.

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Keywords: Industrial ecology (IE); Inter-Organizational Collaborations; Product Service Systems (PSS); Third Party Access (TPA).

1. Introduction

Even though Sweden is among the world's leaders in utilizing Excess Heat (EH), there is still a large unutilized potential for its capture. It is estimated that approximately 50% of all EH from large energy-intensive industries is utilized, mainly in district heating systems [1]. However, as a result of the most economically profitable areas of district heating already being connected to a grid the continuous expansion of district heating has decreased during the past decade. In broad terms, this means that the district heating sector is now a mature industry and technology with declining market growth.

EH can, however, be used and produced in many other areas than district heating and from large energy-intensive industries. It can therefore be expected that utilization of EH from smaller and perhaps currently overlooked sources will increase in the future. Reasons for this include political goals set by the Swedish Energy Agency. One goal is that all EH above 55 degrees Celsius in southern Sweden should be fully recovered by 2020 [1-2]. Other goals concern technological development leading to new and better technology for low-temperature EH utilization [1-2]. This development opens up new business opportunities for companies delivering products and services that solve energy supply (heat, steam, electricity, etc.) using EH as an energy source; this is also something that makes it likely for new distributed solutions to emerge.

This type of EH utilization has the potential to reduce the use of primary energy. However, it requires collaboration between the company providing the EH and those companies utilizing it. Such collaborations have been studied in the field of Industrial Symbiosis (IS). Previous research within this research field shows that despite the potential financial and environmental benefits [3] and existing technical and physical

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conditions, these types of collaborations do not always occur [4]; the question is why.

Recently, several authors [5-7] have highlighted that one IS weakness is that it only considers factors related to the inputs and outputs of collaboration, and does not take into account the business perspective. It has been pointed out as important to also consider the business model of the collaboration where the actors are involved [5-7]. A proposed and interesting way to add the business model perspective is to combine IS with the Integrated Product and Services Offering (IPSO) concept (also known as Product Service Systems (PSS)).

2. Objective and Research Questions

This paper's objective is to ***explore the implications of combining an IPSO with IS in order to facilitate the increased utilization of EH***. In order to do so, five different EH cases that originated from an IS perspective have been investigated. Based on an IPSO-focused literature review, those five EH cases are analyzed in order to identify potential pros and cons, if an IPSO perspective is applied, in order to further improve EH utilization.

The overall objective has been broken down below into four research questions (RQ), with main focus on the last research question:

- **RQ1 –** Why is there a large unutilized potential for the capture of EH?
- **RQ2 –** What alternative uses for EH exist, other than those found within district heating systems?
- **RQ3 –** What are the opportunities for using district heating systems' infrastructure?
- **RQ4 –** What potential opportunities and challenges exist if an IPSO perspective is applied, in combination with IS, in order to further improve EH utilization?

3. Theoretical framework

3.1. Excess Heat

The district heating sector, along with other large technical systems in this regard, are largely characterized by the specific services they provide society [8-9]. These kinds of systems can be conceptualized and described as socio-technical systems consisting of networks of actors, institutions, material artifacts, and knowledge [10-12]. District heating systems based on industrial EH that would otherwise be wasted are in general considered resource efficient [13]. Actors, such as an industry selling excess heat to a district heating company, can benefit from such heat supply collaboration. In addition to the environmental benefits, this approach can bring financial benefits and improved competitiveness for the companies involved [14], as the industries are paid for heat that they otherwise would have been forced to find ways to cool, yet another expense. Therefore the use of excess heat is also relevant when it comes to industrial development at the regional level. In addition, the district heating companies are often given the opportunity to buy EH at a lower price than the market price of primary energy. As mentioned in the introduction, EH can however be used and produced in many areas other than district heating and from large, energy-intensive industries. In order to gain an understanding of the necessary organizational conditions required for these types of inter-organizational collaborations the investigated cases have been studied from an IS perspective, as discussed in the next section.

3.2. Industrial Symbiosis

IS has been developed as a subset of Industrial Ecology (IE), and can be described as a cluster of operational agreements between normally unrelated industrial companies or other organisations that lead to resource efficiency [15]. The agreements, for example, can involve reuse of one company's by-products as raw material for another company, as well as the sharing of manufacturing capacity, power, water and steam supplies, logistics and expertise between companies [15]. Utilization of EH builds and relies on collaboration between the company providing the EH and the company utilizing the heat. Similar collaborations have been studied in the field of IS. Despite the potential financial and environmental benefits [3] along with existing technical and physical conditions, IS research shows that these types of collaborations do not always occur [4]. Furthermore, organizational conditions play an important role in these types of inter-organizational collaborations [3-4]. For successful collaborations, all actors must feel that they have something to gain and that there are common goals and interests. This is something that requires collaboration and co-ordination [16]. Uzzi [17] highlights three important organizational pre-conditions: (1) trust, (2) fine-grained information transfer, and (3) joint problem solving. All together, these allow companies to adapt more quickly and to be more flexible to environments characterized by continuous change and complexity.

3.3. Integrated Product Service Offerings

From an IPSO perspective, these EH supply solutions should be seen as services rather than products [18]. Instead of obtaining products, IPSO strives to reduce the consumption of products through alternative scenarios of product use while increasing a company's competitiveness and profitability [18]. Shifting focus from product sales to selling a function is positive from an environmental point of view since it encourages prolonged durable design of the product [19-21]. The focus of dematerialization is in line with the cornerstones of industrial ecology [8]. Dematerialization is also an important aspect of competitiveness [22]. By integrating different components in new ways, the IPSO provider has the possibility to increase the value of the service for its customers [23]. This is also something that serves as a driver for the development of new technologies [24]. This approach provides a competitive opportunity for many companies striving to reduce their energy consumption, as IPSO alters how products are used by providing services [24-25]. In this way, the IPSO can be described as an instrument that fosters sustainability while enhancing competitiveness [18].

4. Methodology

The research presented in this paper has a qualitative approach, and the aim is of an exploratory nature. This is because it provides fundamental knowledge and understanding about an area of interest, as well as input to better the research for further investigation [26]. Little has been published before in the area of IPSOs for EH. RQ1-3 are questions asking "why" and "what", typically used for exploratory studies [26]. RQ4 has explanatory features asking "how" IPSOs can facilitate the design and dissemination of EH offerings, and "how" questions are used for explaining operational links [26-27].

To answer RQ1-3, this paper is based on interviews with respondents from five different cases, which are all active within different areas as seen in Table 1. RQ4 is of a more general nature and pertains to generic discussions not directly connected to the interview questions. In order to answer RQ4, literature and previous research within the area has been used. The first case is an existing example of *EH supply collaboration* between a pulp mill and an energy company. In this specific case, there is also a nearby greenhouse which is provided with heat from the mill. The second case is an *oil refinery* with a large unutilized excess of heat. Case number three is an energy company which fairly recently started a project called *Open District Heating*. The project is based on the idea that the energy company offers anyone the opportunity to sell and deliver heat on its district heating grid. The fourth case is based on ongoing studies and preliminary results of a research project which aims to explore increased use of *low-grade heat for food production*. The last respondent comes from the fifth case, consisting of the Swedish branch organization *Swedish District Heating Association,* which represents the district heating sector when dealing with the government, parliament and authorities, for example in investigations and consolation responses.

Table 1. Type and number of respondents from each case.

Respondent	Case	Type of respondent	Number
R1	C1	Energy company: Business area manager	1
R2	C1	Energy company: Market manage	1
R3	C1	Pulp mill: Energy coordinator	1
R4	C1	Pulp mill: Site manager	1
R5	C1	Greenhouse: CEO and owner	1
R6	C2	Site manager	1
R7	C3	Project manager "Open District Heating"	1
R8	C4	Program leader	1
R9	C5	Communicator	1
		Total	**9**

The study builds on the first case of the ongoing EH supply collaboration. The four other cases represent areas which all correlate to the first case in different ways. The information gathered from the different cases has been necessary for increased understanding of the complexity behind the emergence of inter-organizational collaboration on EH supply. Table 1 shows the type and number of respondents from each case.

The interviews, conducted during the fall of 2014, were semi-structured. As a semi-structured interview is based on open-ended interview questions that allow respondents to speak freely on specific themes, it allows for follow-up questions that encourage the interviewees to expand on their responses [27]. However, interview guides with basic questions were formulated in advance. The interview guides were formulated to complement each other and to provide a comprehensive overview of the objective of this paper. Table 2 shows the character of the interview questions asked for in each specific case.

Table 2. Type of interview questions for each case

Case	Interview questions
C1	• How did the collaboration start? • What are the key success factors behind the collaboration?
C2	• Why is the EH not utilized? • What do you think would be required for an EH collaboration to occur?
C3	• How does the concept of open district heating work in practice? • What are the key success factors behind the project?
C4	• Who are the typical actors within these heat collaborations? • What types of business agreements would occur?
C5	• What is the desirable development for the Swedish district heating sector? • What is required for the increased use of EH?

The interviews were recorded, transcribed and approved by the respondents. Except for inaudible sounds, repetitions, and other words or sounds from the respondents, the interviews were transcribed word for word. A transcribed interview can be seen as a way to make the information more manageable [27].

As described in Section 3, the empirical data were analyzed from an IS and IPSO perspective. Previous findings about the emergence and development of industrial collaborations within the research field of IS are used to identify necessary factors behind the emergence of inter-organizational EH supply collaborations (RQ1-3), while the IPSO perspective is applied to discuss if the IPSO concept has the potential to facilitate the design and dissemination of EH offerings (RQ4).

5. Reasons why there is a large unutilized potential for the capture of EH

Taking all of the respondents' different opinions into account, a quite consistent picture of the main reasons why they believe there is such a large unutilized potential for the capture of EH emerges. One important reason for this is the fact that these types of heat collaborations require inter-organizational collaboration across the individual business boundaries. Even though there are a lot of potential gains, both financial and environmental, for the companies involved in the collaboration [4], inter-organizational collaborations are often difficult to initiate [4]. The respondents (R1-4) from the energy company and the pulp mill in C1 describe trust, shared visions on common goals and transparency behind a clear and well-formulated business agreement as important factors behind the success of their EH supply collaboration. These features have also been identified as important factors behind the emergence of well-functioning and sustainable inter-organizational collaborations [17,28].

A previous study of similar cases consisting of collaborations between energy companies and industrial firms indicates that one of the main difficulties encountered with these types of collaborations is caused by the lack knowledge and understanding of each others' different activities [29]. This is described as being a direct cause of a lack of communication and trust between the parties involved. Another thing that emerged from the same study is that there is often reluctance from the industry's side to enter heat collaboration, since heat does not belong to the industry's core business. The reluctance has proved to consist of a fear of possible production disruptions of the companies' main activity as a consequence [29].

The results from the interviews with the site manager (R6) at the oil refinery from C2, as well as with the two respondents (R3-4) from the pulp mill in C1, show that they all previously experienced resistance from different energy companies to enter collaboration on EH. These are examples of where energy companies have chosen to build their own boilers for heat production instead of facilitating existing high-grade heat from nearby industries into the district heating grids. Strategic and farsighted comprehensive planning with the mandate to regulate energy issues concerning planning would be desirable in order to avoid the use of primary energy where there already are existing sources of EH.

6. Alternative uses of EH

The program leader of the ongoing studies on low-grade heat for food production (R8) from C4 states that the increased use of EH for food production in close proximity to existing sources of EH is desirable. The same respondent is also supported by the owner of the greenhouse from C1, as they both state that it is also possible to use even lower temperatures, i.e. below 55 degrees, for this purpose. This makes other heat sources, rather than just the traditional large energy-intensive industries, interesting. Potentially new alternative sources of EH could for example include data centers with large servers or other types of refrigeration equipment and cooling systems from grocery stores, among other businesses that generate EH.

The owner and CEO of the greenhouse (R5), along with the respondents (R1-2) from the energy company from C1 and the program leader of the ongoing studies on low-grade heat for food production (R8) from C4, have all experienced problems with deliveries of heat via traditional district heating systems to greenhouses. This is because greenhouses are troublesome customers for energy companies as their rapid fluctuations (the heat demand is drastically affected by sunshine, clouds or rain) of the large quantities of heat they demand affect the entire district heating system.

7. Opportunities for using district heating systems' infrastructure

The conditions for using existing systems of district heating to distribute EH are good from a technical point of view. The program leader for the project on low-grade heat for food production (R8) from C4, however, believes that this requires a Third Party Access (TPA) to the district heating systems.

Currently, the Swedish district heating sector has a monopoly position in the heating market [30]. This is because district heating is one of several options on the local heat markets, where competition at times is fierce. The business associated with district heating involves heavy investments, which makes it feasible to build two competing networks next to each other. This, combined with the fact that it often requires a large investment to replace the existing heating system, makes the customer's position weak. TPA would by definition imply third-party access of the district heating business to a third party, in addition to the district heating supplier and the customer. This third party would have access to the district heating grid and would in one way or another get financial return for the heat it delivers into the system [31].

The project "Open district heating" from C3 can be seen as a modification of a third-party access. The assignment is based on an open business model where the supplier delivers the heat according to a fixed price list. The project manager behind the project (R7) describes the background of the project as stemming from a growing need to find alternatives to the traditional way of conducting business around district heating. Usually, the heart of the district heating companies' business is heat production. Yet, "Open district heating" shifts the focus from the production of heat to the ability to move and distribute heat. For places with the right conditions, such as dense developments like cities where there are always both excesses of heat as well as demand for heat, these kinds of projects have the ability to be successful.

The respondent (R8) from C4, however, states that less densely built areas outside city centers with a combination of a low demand for heat and large unutilized heat sources associated with, for example, industrial activities, may not be suitable for distribution solutions similar to "Open district heating". The respondent (R8) from C4 further states that examples like these are well-suited for large-scale food production in the form of greenhouse crops, and that this could also be an example of when separate solutions, not connected to existing district heating infrastructure for distribution, are preferable. The main reason for this is because for these examples there is typically no existing district heating systems to exploit. However, these solutions also require strategic and farsighted comprehensive planning concerning energy issues. For the increased use of this type of otherwise inaccessible EH, the same respondent stated that areas of land in close proximity to the heat source should be earmarked for food production, for example. Yet an important aspect of this is competitiveness, which is something that is closely related for example to the location of the greenhouse. It is not just an important aspect from a heat source perspective; the transport possibilities are important and dependent on efficient transport routes as well. A demand for the output is another important aspect concerning competitiveness.

8. Potential of the application of an IPSO in order to further improve EH utilization

8.1. Potential Opportunities

As mentioned in the introduction, the IS theory lacks a business perspective [5-7]; an interesting way to address this perspective could be to apply an IPSO perspective. Such a perspective has the potential to improve efficiency, which often leads to positive environmental and financial effects for both industry and society at large [32]. An IPSO provider with the knowledge and responsibility for the distribution of heat could facilitate the increased use of EH by providing the heat integrated with a service offering [24]. Broadly, these heat-related services would consist of offerings facilitating the heat transaction for both the supplier and the recipient of the heat. The IPSO would however differ, depending on whether it is addressed to the supplier or the recipient of the heat. It would also differ depending on the prevailing conditions. For example, the IPSO would differ between urban areas, with constant supply and demand of heat from multiple stakeholders (as in C3) and from more sparsely populated areas (like C4), in which both the supply and the demand for heat is less.

Yet, an important condition that is equally independent of the prevailing technical conditions and circumstances is the knowledge about the product (which is the EH), the service (consisting of the distribution of the heat), and how to integrate them to increase the value of the service for the costumers [23]. The district heating companies have the experience, knowledge and infrastructure required to distribute EH from suppliers to recipients. The project "Open district heating" within C3 can be seen as an example where a district heating company acts as a kind of IPSO provider. To simplify, an IPSO regarding EH could be divided into two different explanatory case types, Type 1 and Type 2. Prospective cases similar to "Open district heating" can be categorized as Type 1. Type 1 cases are those where there are a number of suppliers and recipients, as well as a district heating company with the knowledge and existing infrastructure system required for distributing heat. For these cases the district heating company becomes the undisputed IPSO provider. For prospective cases outside urbanized areas, categorized as Type 2 cases with other prevailing conditions similar to C4, the IPSO provider is no longer that obvious.

When it comes to prospective cases on for example food production it is likely that there is only one supplier, and one or maybe two receivers of the EH. If the heat source, consisting of some sort of industrial activity, is in addition located outside an urbanized area, it is not certain that there is any existing distribution system for the EH. For cases like these, where district heating companies are not a natural actor, an IPSO provider with the necessary knowledge about the product and the service offering regarding the product is especially important. For these cases, however, the IPSO provider's role is somewhat different. The IPSO provider serves as a third-party initiator of the collaboration as it enters from the outside to create a service offering based on the suppliers' and the recipients' needs. Following this, an infrastructure system to distribute the heat is built up by the IPSO provider. This kind of innovative solution could be seen as a result of the increased value that an IPSO has the ability to provide [23], as the IPSO often servers as a driver for the development of new technologies [24].

8.2. Potential Challenges

However, there are difficulties identified with both types of cases. One difficulty, which is the same for both types of cases, is the strong tradition of heat production that prevails among district heating companies. C1-3 show, as previously described, examples of the problems associated with this. According to the respondent from the Swedish District Heating Association there are no routines on whether or how EH is taken into account in the planning and construction of new thermal generating plants. Yet, the approach of IPSOs has the ability to create a competitive opportunity [18].

For the Type 2 cases there is an additional problem associated with planning. As previously mentioned, for sufficiently efficient utilization of the EH, strategic and foresighted comprehensive planning are important. However, despite the importance of planning, this must be communicated to the potential IPSO provider [16]. The organizational preconditions - trust, fine-grained information transfer and joint problem solving described by Uzzi [17] – are important factors to consider. However, an overall planning function that takes both district heating and existing sources of EH into account within the comprehensive planning would also be desirable.

Yet another challenge is related to the adoption of a business model, which is central when successfully implementing an IPSO [32]. The business model should be framed individually for different companies in order to fit the specific company's strategy and operations. Still, a common problem is that companies have problems providing IPSOs because of their internal inability to successfully design and implement IPSO business models [33]. Reim *et al.* [33] argue that there are five influential tactics identified for successfully applying an IPSO: *Contracts* (incorporation of the relationship between a provider and a customer), *Marketing* (communication of the PSS offer's value to the customers), *Networks* (relationship with external actors), *Product/service design* (the usability of a product's requirements) and *Sustainability* (capturing the full environmental and social value). All five tactics are equally important when implementing an IPSO business model. As mentioned above, however, since all companies have different and unique business models, the five tactics should be adopted in a customized way to enlarge the result [33]. This is supported by the results from the interviews, which show that there are no ready-made templates on how to formulate the business agreement between the actors involved in these kinds of inter-organizational collaborations. What has emerged through the interview study is that an important aspect in the design of the business agreement is the relation between potential risks and profits. For example, a district heating company that funded the majority of the necessary investments should be able to buy the excess heat at a lower price than if the costs of the investments would have been divided more equally.

9. Final Remarks

The key to the increased utilization of EH is to find a number of new sources and applications for use. Furthermore, the results also indicate that applying the IPSO concept, in combination with IS, has the potential to facilitate and improve EH utilization. This is because applying an IPSO approach when developing customized business offerings could help shift focus from the product EH to the service of heating, as a way to fulfill a user's initial need and thereby make it more attractive within a wide area of operations. This requires customized service offerings where the risks reflect the potential profits. However, since organizational factors play an important role when it comes to the sustainability of these collaborations, it seems that a combination of the IS and IPSO perspectives is most likely preferable when it comes to inter-organizational collaborations on EH supply.

Henceforth, through further research it would be interesting to examine how this could be done in practice. It would also be valuable to verify if the combined concept of IPSO and IS is applicable for areas other than EH supply collaborations.

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