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MASTER'S THESIS

Implementing the Industrial Symbiosis Concept in Practice in the Forest Industry

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ABSTRACT

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Industrial symbiosis is a part of industrial ecology which engages traditionally separate industries in a collective approach to gain competitive advantage through the physical exchange of wastes and by-products, other materials, water and energy. The objective of this thesis is to evaluate from the strategic and economic perspective how to implement the concept of industrial symbiosis in practice in the industrial area of Kaukas in Lappeenranta. The major success factors and challenges (limiting factors) of industrial symbioses have been identified from the published research literature. It was found out that the success factors and challenges are in conflict with each other, and therefore solutions to these conflicts between the success factors and challenges have been proposed. By examining the temporal development of the industrial symbiosis in Kalundborg it was found out that symbiosis networks reach a state of development where the increase of their number of exchange relationships and participants slows down significantly and even stops. Through the statistical analysis of 31 active eco-industrial parks it was estimated that on the average symbiosis networks involve 16-23 exchange relationships and 9-14 member companies. The process models for the management of symbiosis networks and their external business environment have been examined and summarized into a single model. A series of interviews was conducted with the representatives of the parties who will take part in the development of the Kaukas symbiosis. The interview answers were used to identify how the aforementioned success factors and process model can be specifically implemented and challenges solved in the case of the industrial symbiosis in Kaukas.

TIIVISTELMÄ

Tekijä: Tuomas Lankinen **Työn nimi:** Teollisen symbioosin mallin käytännön soveltaminen metsäteollisuudessa
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Diplomityö. Lappeenrannan teknillinen yliopisto, tuotantotalous. 128 sivua, 6 taulukkoa, 11 kuvaa ja 5 liitettä Tarkastajat: professori Vesa Harmaakorpi ja tutkijaopettaja Eeva Jernström
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Teollinen symbioosi on teollisen ekologian osa-alue, jossa perinteisesti toisistaan erillään toimineet teollisuudenalat tavoittelevat yhdessä kilpailuetua vaihtamalla keskenään jätteitä ja sivutuotteita, muita raaka-aineita, vettä sekä energiaa. Tämän diplomityön tavoitteena on arvioida strategisesta ja taloudellisesta näkökulmasta teollisen symbioosin mallin käytännön toteutustapoja Kaukaan teollisuusalueella Lappeenrannassa. Julkaistun tutkimuskirjallisuuden pohjalta on tunnistettu teollisten symbioosien keskeiset menestystekijät ja haasteet (rajoittavat tekijät). Menestystekijöiden ja haasteiden tunnistettiin olevan ristiriidassa keskenään ja näin ollen työssä esitetään ratkaisuja näiden tekijöiden välisiin ristiriitoihin. Kalundborgissa toimivan teollisen symbioosin ajallista kehitystä tutkimalla saatiin selville, että symbioosiverkostot saavuttavat kehitysasteen, jossa niiden vaihdantasuhteiden ja jäsenten määrän kasvu merkittävästi hidastuu ja jopa pysähtyy. Tekemällä tilastollinen analyysi 31:stä toiminnassa olevasta ekoteollisesta puistosta arvioitiin, että symbioosiverkostot käsittävät keskimäärin 16-23 vaihdantasuhdetta ja 9-14 jäsenyritystä. Symbioosiverkostojen ja niiden ulkopuolisen ympäristön johtamisen prosessimalleja on tarkasteltu ja eri mallit on yhdistetty yhdeksi uudeksi malliksi. Kaukaan symbioosin kehittämiseen osallistuvien osapuolten edustajia haastateltiin. Haastatteluvastausten pohjalta määritettiin ne toimintatavat, joiden avulla Kaukaan teollisen symbioosin tapauksessa voidaan käytännössä soveltaa edellä kuvattuja menestystekijöitä ja prosessimallia sekä ratkaista symbioosiin liittyvät haasteet.

FOREWORD

During doing research for and writing my master's thesis I learned several new things which I hadn't come up against in my earlier studies. If some student happens to read this foreword, he/she may benefit from my experiences and apply them in his/her own course works and thesis. The knowledge that I have gained is summarized in the following points:

- To maintain the clarity of your text, limit the number of concepts you use to a reasonable amount and truly understand the meanings of the concepts you use. Different literature sources sometimes use different expressions for a same concept. Journal articles also have tendency to utilize very many concepts and introduce new concepts even when they are not entirely necessary.
- All articles in a same peer-reviewed journal are often not of equally good quality.
- Articles that contain mathematical equations may create the impression of exactitude but are not necessarily as or more valid and reliable than the results expressed completely verbally.
- When comparing and combining the results of different sources in a literature review, pay attention to differences in their theoretical backgrounds. Different results which at first glance look similar may not logically fit together.
- The supplementary materials of research articles can provide useful data for new further analyses that haven't been carried out in original articles.

After these remarks I want to express my gratitude to the people who have contributed to my work. Big thanks to my supervisors Vesa Harmaakorpi and Eeva Jernström who monitored the progression of my master's thesis and gave professional comments that facilitated its completion. I also want to thank the interviewed representatives of UPM-Kymmene Corporation, Green Campus Innovations Ltd. and Nordic Innovation Accelerator Ltd. who answered with careful dedication to the many questions which I had devised. I am also very thankful for the support I have received from my family.

In Lappeenranta, the 13th of October 2016

Tuomas Lankinen

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1 INTRODUCTION

This thesis project has originated from an initiative to implement the concept of industrial symbiosis in the industrial area of Kaukas in Lappeenranta. The core idea of industrial symbiosis is that companies, which operate in a same industrial site or region, exchange wastes and by-products and other utilities, like energy, with each other and use these materials and utilities obtained through the exchange in their production. This way the amount of disposed waste can be reduced and valuable raw materials can be recovered. Lappeenranta University of Technology (LUT) has collaborated with UPM-Kymmene Corporation which is present in the Kaukas industrial area and this thesis is a result of the collaboration. Other parties which have been involved with this initiative are Nordic Innovation Accelerator Ltd. (NIA), which searches technological solutions from Nordic cleantech-companies, and Green Campus Innovations Ltd. (GCI), which invests on sustainable technology firms.

The objective of this thesis is to evaluate from the strategic and economic perspective how to implement the concept of industrial symbiosis in practice in the Kaukas industrial area. The industrial area of the UPM Kaukas is located on the shore of Lake Saimaa in Lappeenranta. UPM produces eco-efficient products, bioenergy and high-tech bio-innovations from wood raw material in the Kaukas industrial area. Kaukas hosts a pulp mill, a paper mill (producing magazine paper), a sawmill (producing sawn timber), UPM's research and development center and a biorefinery which produces UPM BioVerno, the wood-based renewable diesel which is made of a residue of pulp production, crude tall oil. (UPM 2015a) The production process of BioVerno has been developed at the Lappeenranta R&D center (UPM 2015b). The production residues of the pulp mill include biomass based electricity, biochemicals, soap and crude tall oil. The surplus electricity is sold to the national grid as the pulp mill generates more energy than it uses. (UPM 2015a)

The main research questions of the thesis are:

1. Which success factors and challenges affect the development of industrial symbioses?
2. By what means can be the challenges mitigated in order to enjoy the full benefits of the success factors?

3. Do symbiosis networks reach a stage of development, where the increase of their number of exchange relationships and participants slows down significantly and reaches a limit, or are these networks able to grow all the time?
4. According to what kind of process model should be industrial symbioses managed?
5. By what means the aforementioned success factors and process model can be specifically implemented and challenges solved in the industrial symbiosis of Kaukas?

Because currently the research literature on industrial symbiosis isn't extensive, it is quite challenging to apply it to the development of an individual industrial symbiosis in practice. There were two criteria according to which the research questions were defined: First, answering them should provide guidelines how to develop an individual industrial symbiosis in practice. Second, the current research literature should provide enough relevant evidence for answering these research questions. This thesis concentrates and limits to examine the development of a single industrial symbiosis. The emphasis has been on practical measures which can be implemented to promote the success of a symbiosis. Therefore the source literature that contains such theories which may explain symbiosis development but which, at least currently, cannot be used for the recommendation of practical measures, have not been included.

At the beginning of the development of research questions, literature was searched from the scientific databases with the term industrial symbiosis. When found articles and other literature sources contained new terms which were clearly similar with or closely connected to industrial symbiosis, more literature sources were searched with these new terms. The terms which have been used to search literature include industrial symbiosis, eco-industrial park, eco-industrial network, industrial ecosystem, industrial synergy, by-product synergy and integrative chain management. In addition to obtaining source material through searches from databases, literature sources which had been mentioned in obtained sources (like articles) were acquired in the case where it seemed that the text of the original article would contain significantly more relevant information than the shorter reference. The literature search was ended when new articles didn't bring new information anymore or didn't include new relevant terms or references which would have justified further literature searches.

The research questions of the thesis were defined after about 30 scientific articles which were considered relevant for the practical development of an industrial symbiosis were found. This way it was ensured that it is possible to answer the research questions on the basis of the current literature on industrial symbiosis. The research questions were further refined as new literature sources provided additional information. The perspective of the success factors and challenges in industrial symbiosis development was selected as the first research question because success factors and challenges (limiting factors) were the most recurring themes in the literature on industrial symbioses. Understanding the success factors and challenges is also very relevant in the development of industrial symbioses (as in any other areas of business). Because much literature is available on the success factors and challenges of industrial symbiosis there are many different sources available which improves the reliability of the results. It was found out that the major success factors and challenges of industrial symbiosis are related to each other through their common themes and this inspired to form the second research question. Because process models tell how to systemize the management of a company and an industrial symbiosis, the literature on industrial symbiosis was reviewed in order to find process models designed for the management of symbioses. The fourth research question aims to integrate these found models into a single new model.

The third research question was partly answered through a case study of the industrial symbiosis in Kalundborg, Denmark. The generalizability of a single case of industrial symbiosis is of course questionable, but there were no other ways to examine the temporal development of industrial symbioses. The Kalundborg symbiosis is the most well-known case of industrial symbiosis and therefore the data about the initiation of its exchange relationships is publicly available. Currently there doesn’t seem to be available data about the temporal development of other symbioses. On the other hand, the Kalundborg symbiosis is interesting, because it has received very much publicity after it was discovered. The symbiosis also has a coordinative function which has worked for about 20 years to establish new exchange relationships between companies. Therefore the use of the Kalundborg symbiosis enables to study whether the publicity and coordination are able to increase the number of symbiosis participants significantly. For this reason the use of the Kalundborg symbiosis as the studied case is justified. In addition, a data set of 31 eco-industrial parks (which also includes the Kalundborg symbiosis) was analyzed with the statistical analysis program IBM SPSS Statistics 23 in order to define the average range of the number of exchange relationships and participants in an active industrial symbiosis. The data set was provided as a supplementary material to the article of Layton et al., who had obtained the set by analyzing the case studies of different eco-industrial parks.

In the selection of literature for the further analysis, the priority has been given to the articles which examined industrial symbiosis from some clear point of view that has implications for the practical development of a single industrial symbiosis (for instance, the impacts of company diversity). Therefore for example general case studies on different industrial symbioses were largely excluded. This limitation was imposed in order to restrict the analyzed literature to a reasonable amount and in order to be able to examine the development of a symbiosis from several different points of view. In the selection of source literature more recent publications (from 2010 onwards) have been preferred as they take into account the earlier research results and therefore present up-to-date understanding about industrial symbiosis research. In the writing of the thesis the goal has been to keep the number of used terms as minimal as possible in order to maintain the clarity and understandability of the text. Therefore the original language of the source material has been sometimes simplified in the citations in the text. Less well-known terms have been replaced with more commonly used terms when the more common term is analogous or almost similar to the original term. If the original terms had been retained, the thesis could have very difficult to comprehend because different literature sources often use different terms about a same topic and many of these terms have not yet become generally used in the literature.

Because this thesis concentrates on the development of the industrial symbiosis in the Kaukas industrial area, a case study on the current waste and by-product exchange activities of UPM Kaukas was conducted in order to answer the fifth research question. Also other companies which are members in the symbiosis network of UPM Kaukas could have been examined, but in order to limit the amount of analyzed data, the scope of the study was limited to UPM Kaukas. UPM Kaukas is also the largest and dominant operator in the Kaukas industrial area and therefore its way to manage and develop its waste and by-product exchanges largely defines the development of the symbiosis network of Kaukas.

Whereas the 1.-4. research questions were answered by reviewing the existing literature, the fifth research question was primarily answered by collecting data through interviews. Six representatives of UPM Kaukas were interviewed. These representatives were selected as interviewees because according to the knowledge of this thesis' other supervisor they will likely participate to the development of the Kaukas symbiosis. Because the writer of this thesis didn't have the same kind of understanding about the occupational roles of different UPM representatives, as this supervisor, he couldn't have easily selected the right interviewees himself. However, each interviewee was asked who in UPM will likely develop waste and by-product exchange and utilization in order to find out if there were potential interviewees who hadn't been included to the original set of interviewees. Their answers verified that the initial group of interviewees was very comprehensive because only one new name appeared. However, after the answers of the six original interviewees had been collected, it was assessed that the answers of different UPM representatives had generally been very similar and therefore it wasn't likely that new information would appear in additional interviews. Therefore no more representatives of UPM were interviewed. Also one representative of Green Campus Innovations Ltd. and one representative of Nordic Innovation Accelerator Ltd. were interviewed as it is planned that these companies participate to the development of the Kaukas symbiosis. The goal of these interviews was to find out what these two companies can offer to the development of the Kaukas symbiosis.

Before interviewing the representatives of UPM, NIA and GCI, already existing documents about them were searched in the internet. These documents were supposed to help to answer the fifth research question and construct interview questions. However the found documents hardly helped in answering the fifth question and in the construction of interview questions. Therefore the fifth research question has been somewhat completely answered on the basis of interviews and the theoretical results gained from the review of literature.

Semi-structured interviews with a predefined interview questionnaire were used (KvaliMOTV 2016a). The semi-structured interviews were selected, because the interviewer had to able to clarify the contents of questions to interviewees and ask spontaneous follow-up questions. The interview questions dealt with such specified topics that the interviewees couldn't necessarily answer them without assistance. The interview questions were largely based on the identified success factors and challenges from the literature review. As result of this questions considered very many specific topics which the success factors and challenges had discussed. There was a need to direct the attention of the interviewee clearly to a certain topic and the semi-structured interview served this purpose best. Although interview questions were intended to be as plain language as possible and therefore easy to understand, often it seemed that interviewees had never heard or thought about the topic in question.

Each representative was interviewed separately, no pair or group interviews were held. Before the beginning of the interviews different series of questions were constructed for different interviewees. The idea of this procedure was that interview questions should be posed according to the job description of the interviewee. Initially there also were so many relevant interview questions (several dozens) that it wouldn't have been possible to ask all the questions from one respondent during one interview. For this reason different interview questions were allocated to different interviewees. This way the number of questions in a single interviewee stayed reasonable, and all the original interview questions could be asked during the interview process. All the questions were very important and they had to be asked in order to gain enough information. Because the interviews concentrated on the factual knowledge of professionals, it was generally supposed that what interviewees said was true. Therefore there was generally no need to ask a same question from all the interviewees, if some interviewee had provided the complete answer to some question. During the interviews notes on the interviewee's answers were taken. After each interview a quick analysis was done with the help of these notes. On the basis of this quick analysis it was determined whether it was necessary to modify the original questions for the next interviewee. If an interviewee provided such a complete answer to a certain question, that it provided all the information about a certain topic, the question wasn't asked anymore in the later interviews. The questions which had appeared ambiguous to an interviewee were clarified for further interviews. Sometimes quick analysis provided ideas about new questions which could be asked in the later interviews and these questions were added to the questionnaires. In addition to taking quick notes during the interviews, the interviews were also recorded on tape.

The questionnaire was organized into subsets which each consisted of several questions. Each subset discussed a certain topic. Each subset began with a general and less precise question. As the questions of a subset progressed further they became more and more specialized and precise. This way to organize questions in subsets had two purposes. First, the purpose of the earlier questions was to familiarize an interviewee with the topic of the subset. If more specialized questions had been asked immediately, their context could have been unfamiliar to the interviewee. Second, if the answer to a more general question was very comprehensive there was no need to ask more specialized questions later in a subset as the answer to the general question also covered more specialized questions, and the interview then progressed to the next subset discussing a different topic.

In addition to the quick analysis, the interview questions were analyzed in more detail after all the eight interviews had been completed. The content analysis was used for the analysis of interview questions (KvaliMOTV 2016b) because answering the fifth research question requires finding out the factual knowledge of the interviewees about the development of the Kaukas symbiosis. At the beginning of the detailed analysis the tape recordings were transcribed to text. The answers of the interviewees were transcribed word for word. Because the interview questions were largely based on the identified success factors and challenges of industrial symbiosis, the analysis of the interview answers was based on the classification of success factors and challenges. Thus all the interview questions were clearly related to some theme. Therefore the classification of the success factors and challenges served as an initial framework for the classification of answers.

In the analysis, the answers of different interviewees to a same question were compared with each other and characteristics which appeared in several answers were summarized to one "final answer" which answered the particular question. When the answers of different interviewees to a same question showed disagreement and contradictions, this was most often solved by analyzing what is at least common for these answers on a more general level. Therefore the analysis of this interview question is less precise and the details which showed contradiction were left out from the final answer. It was also examined whether disagreements and contradictions would originate from the different job descriptions of the interviewees. However, this approach didn't create better understanding in most of the contradictions and the approach can also be quite unreliable because there were not very many interviewees. Sometimes an interviewee's answer to a question contained information which clearly answered some other question in the questionnaire. In this case the information was transferred to be included to the final answer of the referred question.

After all the interview questions had been answered separately, different final answers to interview questions, which were associated with each other by being related to a same success factor or challenge, were compared with each other. There were three types of different questions which were connected: the improved version of an earlier question, follow-up questions, and questions which considered a same topic from different points of view. The final answers of questions were combined to form narratives which each discuss certain success factor or challenge. These narratives were joined together to form the subchapters of the chapter 8. Some final answers to interview questions were left out of the narratives when their content was trivial for the development of the symbiosis in Kaukas. An answer was trivial when the answers of the interviewees were too general and didn't contain any special information which could have been used in symbiosis development. After the narratives had been constructed, some of them were used to analyze the presence of symbiosis barriers and enablers in the case of UPM Kaukas by comparing them to the descriptions of the categories in the industrial symbiosis maturity grid. The industrial symbiosis maturity grid is a qualitative evaluation tool which can be used to assess the level of development of an industrial symbiosis. The grid is the only currently known evaluation tool especially designed for industrial symbiosis which can be reliably applied in symbiosis development.

After this introductory chapter, the chapter 2 explains the fundamental concepts and theories for industrial symbiosis which will be applied in this thesis. The chapter 3 thematizes the major success factors for industrial symbiosis. The chapter 4 thematizes the major challenges commonly encountered with industrial symbiosis and proposes solutions to them. The chapter 5 summarizes the success factors and challenges which are interconnected by being in conflict with each other and summarizes the proposed solutions to these conflicts. The chapter 6 examines whether individual industrial symbiosis networks reach some optimal size (measured in the number of companies and exchange relationships) and evaluates the average size of a symbiosis network. The chapter 7 explains different process models for industrial symbiosis development and integrates these models into a single new model. The chapter 8 summarizes and analyzes the answers which the representatives of UPM, NIA and GCI gave in the interviews, which were conducted during this thesis project. The chapter 9 integrates the findings of all the preceding chapters into recommendations about measures which should be taken in the development of the Kaukas symbiosis. The chapter 10 concisely summarizes the main content of this thesis and the answers to the research questions. The correspondence between the research questions and the contents of the chapters in this thesis is presented in the Table 1.

Table 1. The correspondence between the research questions and the chapters of the thesis

Research question	**Answered in the chapters**
1	3 and 4
2	4 and 5
3	6
4	7
5	8 and 9

2 FUNDAMENTAL CONCEPTS AND THEORIES FOR INDUSTRIAL SYMBIOSIS

The term industrial symbiosis originates from the phenomenon of biological symbiotic relationships in nature in which at least two otherwise unrelated species exchange materials, energy or information. Symbiosis is called mutualism when it benefits both species. For example the body of a lichen is formed of both alga and fungus. The fungus provides habitat for the alga and protects it against extreme temperatures and the alga prepares food through photosynthesis and delivers it to the fungus. (Chertow & Ehrenfeld 2012, 15) Industrial symbiosis applies the idea of mutualism to relationships among economic actors (like companies) in order to develop more sustainable industrial production (Chertow & Ehrenfeld 2012, 15; Yu et al. 2013, 280). In sustainable production the efficient use of material resources within businesses leads to economic and social benefits for businesses and their surroundings (Tudor et al. 2007, 199). Industrial symbiosis belongs to the interdiscipline of industrial ecology (Yu et al. 2013, 280). Industrial ecology studies how material and energy can be optimally circulated in industrial and ecological systems so that the flows of these materials generate the least damage in these systems (Jung et al. 2013, 50; Tudor et al. 2007, 200) Cycling material and energy flows throughout an industrial system improves the resource and energy efficiency of the whole system and reduces environmental pollution (Doménech & Davies 2011, 282).

In industrial symbiosis different companies and industries exchange wastes, by-products, water, energy and other materials with each other in order to gain competitive advantage (Lombardi & Laybourn 2012, 29; Yu et al. 2013, 280). This thesis mainly discusses wastes and by-products as they are the outputs on which industrial symbiosis research primarily concentrates. A company which participates in symbiosis gains competitive advantage because it either manages its wastes by supplying them to be utilized in another company or because it sources its inputs by utilizing wastes and by-products which some other company has produced (Liu et al. 2015, 322). These companies and industries collaborate together and are usually located geographically close to each other (Lombardi & Laybourn 2012, 29; Yu et al. 2013, 280). They can also share different utilities together (Jacobsen 2006, 240). There can be two types of waste and by-product exchange relationships: direct connections between companies and mediated connections in which a third firm between the supplier and utilizer of a waste or by-product collects and modifies the by-product or waste to facilitate its use in the production of the utilizer (Liu et al. 2015, 322). Exchange relationships between companies are initiated, for instance, due to economic benefits, resource security, rising waste disposal costs, regulatory pressure and social relationships (Chertow & Ehrenfeld 2012, 19). Industrial symbiosis converts negative environmental externalities that take a form of waste into positive environmental externalities which include decreased pollution and reduced need for raw material imports (Chertow & Ehrenfeld 2012, 15).

Exchange relationships between companies form networks because one company can have exchanges with different companies (Doménech & Davies 2011, 282). These networks can be identified, "uncovered", for instance by interviewing company representatives about the wastes and by-products which their company sources from other companies and utilizes in its production or which the company generates in its own production and delivers to be utilized in other companies (Chertow 2007, 24-25). By collaborating in the symbiosis network participating organizations create a common culture and create and share knowledge which also helps them to improve their business and technical processes (Lombardi & Laybourn 2012, 31-32). In the Figure 1 an imaginary symbiosis network which consists of several companies and exchange relationships has been presented. Dark blue balls represent companies and arrows represent exchanges. The directions of the arrows indicate how wastes and by-products are transported from one company to be utilized in the production of another company.

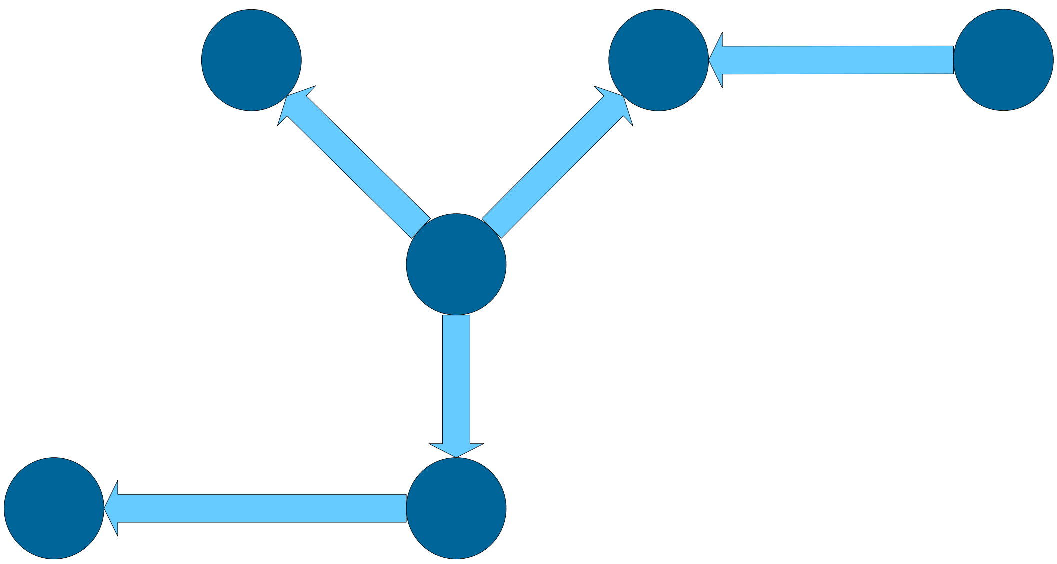

Figure 1. A symbiosis network consisting of several waste and by-product exchanges

The term industrial symbiosis (abbreviated IS) has been used in two different senses: It has been used as a generic name for the branch of industrial ecology that studies the development and operation of resource exchanges between companies. (Chertow & Ehrenfeld 2012, 13) On the other hand, the term has been used as a descriptor for all arrangements where enterprises exchange outputs that, in the absence of a customer, would normally be discharged to the environment and would hence become treated as environmental externalities (Chertow & Ehrenfeld 2012, 13-14). In this thesis the term "industrial symbiosis" is used in the latter sense, because the practical implementation of an individual industrial symbiosis is examined. Also the term "industrial synergy" has been used to describe one waste and by-product exchange relationship of an industrial symbiosis. A group of industrial synergies which takes place within a territory is then an industrial symbiosis (Ghali et al. 2016, 24; Rosa & Beloborodko 2015, 461).

Eco-industrial parks are communities consisting of businesses which have gathered close to each other in a certain geographical area (Jung et al. 2013, 51; Tudor et al. 2007, 200; Yu et al. 2013, 281). In these communities businesses collaborate with each other and with the local community by sharing resources such as information, materials, water, energy and infrastructure and this way they gain economic benefits and operate in a way which promotes environmental sustainability (Jung et al. 2013, 51; Yu et al. 2013, 281). The difference between industrial symbiosis and eco-industrial parks can be summarized by saying that the exchanges of industrial symbiosis are part of eco-industrial parks but eco-industrial parks include also other ways of collaboration to increase the sustainability of its member companies. In this thesis many research articles which discuss eco-industrial parks have been used as a source material about industrial symbiosis as industrial symbiosis is a central element of eco-industrial parks and these articles have concentrated on the symbiotic aspect of eco-industrial parks.

The idea of industrial symbiosis was first described in 1989 in the article by Robert A. Frosch and Nicholas E. Gallopoulos in the magazine Scientific American, although they discussed "industrial ecosystems" instead of symbiosis (Chertow 2007, 12; Frosch & Gallopoulos 1989, 144). In 1989 also the first known example of operational industrial symbiosis was discovered in the municipality of Kalundborg in Denmark (Chertow 2007, 12). A very large number of studies have referred to the Kalundborg symbiosis, which has even been seen as a paradigmatic role model for industrial symbiosis (Jacobsen 2006, 240). In Kalundborg, a number of independent by-product exchanges have gradually evolved into a complex web of symbiotic interactions among five collocated companies and the local municipality. This symbiosis involves a power plant, an oil refinery, a biotech and pharmaceutical company, a producer of plasterboard and a soil remediation company. The material flows among these companies are based either on water, solid waste or energy exchanges. (Jacobsen 2006, 241). Exchange relationships help to optimize the water and energy flows and economic performance at the power plant and they are complemented by utility sharing (Jacobsen 2006, 244). Research on industrial symbiosis has generally been practice-oriented, based on the experience and observation from empirical projects (especially eco-industrial park projects) but over time it has evolved towards more systematic and diverse theory building (Yu et al. 2013, 281, 291). In addition to Kalundborg , an abundance of case studies on industrial symbiosis have been done in China, United States, Finland, Sweden, United Kingdom, Australia and Korea (Yu et al. 2013, 289).

There are different models according to which industrial symbiosis can be developed. Most important distinction between them is their degree of conscious planning. Generally speaking, successful industrial symbioses have tended develop spontaneously, not as a result of deliberate planning (Tudor et al. 2007, 202). In the self-organizing symbiosis model an industrial symbiosis emerges from decisions by private agents who are economically motivated to exchange resources to meet goals such as cost reduction, revenue enhancement or business expansion. If the initial exchanges are successful, more may follow if there is ongoing mutual self-interest, but the system can also remain only as a series of bilateral exchanges. (Chertow & Ehrenfeld 2012, 23)

In the build and recruit model, public or private developers create an industrial park or zone and then seek compatible tenants to whom they can lease or sell the land of the zone. The preparation of the park or zone may require infrastructure development and the application of a variety of marketing techniques. The retrofit industrial park (RIP) model means that existing industrial parks are targeted for conversion to eco-industrial parks after build and recruit has occurred. The planned eco-industrial park (PEIP) model includes a directed effort by the developers to identify companies from different industries with a plan to locate them together which makes it possible for them to share resources across and among themselves.

The tenants will be drawn to the opportunity to use each other's by-products and consciously create environmental public goods simultaneously. The planned eco-industrial park model has been the least successful of the various approaches so far. The technical aspect of symbiosis has been overemphasized which has narrowed the field of possible recruitment targets too much, adding rigidity to a system that needs adaptability in the face of market demands. (Chertow & Ehrenfeld 2012, 23)

One optional approach to reach sustainable production, instead of implementing industrial symbiosis, is cleaner production. While industrial symbiosis is based on exchange relationships between companies, cleaner production seeks opportunities for improvement within the firm boundary (Liu et al. 2015, 324). Cleaner production develops production processes in order to reduce the amount of used input materials and the amount of wastes which are produced (Liu et al. 2015, 319; Sakr et al. 2011, 1168). Another option to reach sustainability is to reuse wastes and by-products within a company, in the case that the company has processes which can utilize them (Liu et al. 2015, 319).

The distinction should be made between the wastes and by-products of industrial production. Both wastes and by-products are not deliberately produced, in other words the production process hasn't been modified in order to create produced material. If the intended use of the material is lawful, the use of the material is certain, the material is ready for use without further processing (other than normal processing as an integral part of the production process) and the material is produced as an integral part of the production process, then the material can be classified as by-product. If any of these aforementioned four criteria doesn't apply, then the material is classified as waste. (Commission of the European Communities 2007, 13) The distinction between wastes and by-products is important because wastes and by-products are treated differently in the environmental legislation of the European Union (Commission of the European Communities 2007, 3). However, in this thesis both terms are often used in the same sense: when the term "waste" is used, also by-products may be considered, and the other way round, as from the strategic and economic perspective of this thesis wastes and by-products are very similar.

3 SUCCESS FACTORS FOR INDUSTRIAL SYMBIOSIS

In the following subchapters the success factors which have occurred several times in different literature sources are summarized. These are the most important success factors for industrial symbiosis identified in the current literature. The literature review (the chapters 3-5) doesn't include success factors and challenges which have been mentioned only once and are also otherwise minor in significance by being very unspecific to industrial symbiosis (in other words, they apply very generally to the development of business networks).

3.1 Uncovering and coordination of existing symbioses

The symbiosis initiatives should come from firms instead of the government (Tudor et al 2007, 203). In some cases, energy and materials exchanges exist in industrial areas without involved companies being aware about the concept of industrial symbiosis (Sakr et al. 2011, 1164). "Uncovering" industrial symbiosis is the process that consists of the explicit recognition by some actor or actors of the positive environmental benefits (externalities) being created by inter-firm waste and by-product exchanges and this is followed by the establishment of an incipient management and coordination of the symbiosis (Chertow & Ehrenfeld 2012, 19, 21). Uncovering typically takes place through the observations of an actor whose perspective is beyond the private transactional network, like an academic institution or business association (Chertow & Ehrenfeld 2012, 19; Sakr et al. 2011, 1164). Compared to attempts to design and build eco-industrial parks only through the conscious planning of physical exchanges, uncovering existing symbiosis has led to more sustainable industrial development (Yu et al. 2013, 283). The parties which assist in the uncovering of waste and by-product exchange relationships (for example, through data collection) include typically public institutions (like government development agencies), private associations (of an industry, business or environment) and universities (Costa & Ferrão 2010, 987).

In a large symbiosis network a function for network coordination can promote the establishment of exchange relationships between member companies and act as matchmaker between waste and by-product flows and resource needs of businesses (Aho et al. 2013, 71; Doménech & Davies 2011, 286; Sakr et al. 2011, 1164). For example a coordinative organization for the development of the Kalundborg symbiosis, the Symbiosis Institute, was established in 1996 and this organization has created new exchanges between companies (Chertow & Ehrenfeld 2012, 21; Costa & Ferrão 2010, 985). During the initiation phase of a symbiosis, when the potential partners do not yet have sufficient information about each other, the role of the coordinative function is especially important in advancing the collaboration among the partners (Ghali et al. 2016, 25). The coordinative function may supplement long-term trust building processes among businesses by providing common rules which coordinate the negotiation and realization of symbiotic exchanges. The coordination can also set up forums where actors, who participate symbiosis development, can interact, solve problems collectively and learn from their experiences. (Boons & Spekkink 2012, 62; Chertow & Ehrenfeld 2012, 24; Doménech & Davies 2011, 294) The coordination doesn't only to improve networking among companies within industrial symbiosis, but it also helps the symbiosis to network with other the stakeholders of symbiosis (for example, national and local government and research organizations) (Chertow & Ehrenfeld 2012, 21; Tudor et al. 2007, 203). In addition to representatives of participating companies, the coordinative function can have members who represent these other stakeholders (Chertow & Ehrenfeld 2012, 21). The coordination could also be carried out through an electronic information system which would facilitate the optimization of resource utilization and include a virtual marketplace for wastes and by-products (Aho et al. 2013, 67).

3.2 Resilient structure of a symbiosis network

The resilience of an industrial symbiosis means the ability of the symbiosis network to maintain its sustainable material and energy flows under disruptions such changes in production levels and technologies and firm closure and relocation (Zhu & Ruth 2013, 74). In order to increase the resilience of a symbiosis, large highly connected firms must reduce their dependency on single suppliers and customers and improve their internal reliability, so that neither can they be easily disrupted, nor can they transfer disruptions further. In general companies should maintain a low dependency level, for example through multiple sourcing, because high dependency diminishes the resilience of the symbiosis network and makes disruptions spread further when the symbiosis expands and incorporates more firms and exchanges. (Zhu & Ruth 2013, 73)

A self-organized symbiosis network has a tendency to grow in a preferential process, in which the probability of each firm to create new waste and by-product exchanges is proportional to the number of its currently existing exchange relationships (Zhu & Ruth 2014, 39, 43). This “rich get richer” feature of self-organized networks is a result from disparities in companies’ capabilities to build symbiotic exchanges. Preferential growth will lead to the symbiosis structure in which few firms are involved in most of the exchange relationships and therefore dominate the whole symbiosis. (Zhu & Ruth 2014, 43) Preferential growth diminishes the resilience of the industrial symbiosis because the whole symbiosis will quickly lose its resource efficiency if the dominant firms are disrupted and stop engaging in symbiosis due to relocation or the change of production processes (Zhu & Ruth 2014, 43-44). Preferential growth may be converted to more homogeneous development by establishing institutional arrangements, such as a function for symbiosis management and coordination. The institutions help disadvantaged firms improve their capabilities to create waste and by-product exchanges and this way diminish the disparities among firms. For example, industrial symbioses which have involved promotional institutions, such as the NISP in the UK and the Eco-Town program in Japan, have developed more rapidly than purely self-organized symbioses. (Zhu & Ruth 2014, 43)

3.3 Adoption of concepts and methods of industrial ecology

In addition to the creation of waste and by-product exchange relationships, the development of industrial symbiosis requires the adoption of symbiosis concept and philosophy (Boons et al. 2011, 907). In order to make industries and other stakeholders fully engaged and active participants, the ideas and concepts of industrial symbioses and eco-industrial parks need to be sold to them (Tudor et al. 2007, 204). Attitudes of different stakeholders towards industrial symbiosis change through the education and awareness of the concepts and benefits of industrial symbioses (Sakr et al. 2011, 1168; Tudor et al. 2007, 205). Standards for the development of industrial symbioses and eco-industrial parks should be created and technical know-how should be provided locally to help industrialists to integrate the concepts and approaches of symbioses and eco-industrial parks with pollution prevention and cleaner production (Sakr et al. 2011, 1168).

Potential symbiosis participants will perceive more opportunities to engage in the development of waste and by-product exchanges if there are one or more key players among them who are willing to take the lead and mobilize others (Boons et al. 2014, 348). "Champions" are agents who believe that symbiotic relationships have value for the world outside the firm in question and who transmit that belief to others in the community and business networks (Chertow & Ehrenfeld 2012, 21; Sakr et al. 2011, 1163). At an early phase of the symbiosis development, champions educate the community to disseminate the basic principles of industrial symbiosis and eco-industrial parks and to present successful case studies (Sakr et al. 2011, 1164). The champions can strengthen the critical role of external institutions that connect network members and build inter-firm exchange relationships (Chertow & Ehrenfeld 2012, 21). The champion(s) may be an individual, a group of individuals or an institution and should live and work in the business community. Champions possess emotional intelligence which enables them to develop humanistic connections instead of just plainly technologically designing waste and by-product exchanges. They are capable to inspire and guide people, resolve conflict and keep people motivated toward a common vision. (Sakr et al. 2011, 1163)

A potential approach to build a symbiosis network would be first to market projects which pose low risk but high benefits for firms as they would encourage participation in further symbiosis developments with greater risk after the environmental and economic rewards of the early projects have been realized (Chertow & Lombardi 2005, 6540; Doménech & Davies 2011, 288; Sakr et al. 2011, 1164). The success of initial waste and by-product exchanges brings a shift in thinking and creates a willingness to consider further exchanges (Chertow & Lombardi 2005, 6540). At the beginning of the building the symbiosis network, the risks which the potential members of the network perceive should be analyzed. The factors which lower the risks in initial projects should be implemented according to the results of the analysis.

3.4 Economic benefits

The major driving factor for the creation of industrial symbioses and eco-industrial parks is to attain economic benefits (Tudor et al. 2007, 202). All parties involved in a symbiosis network need to gain added economic value, for example in the form of increased revenues, improved resource efficiency, reduced costs or taxes, innovative product or process changes or diversified business or managed risk (Sakr et al. 2011, 1168; Lombardi & Laybourn 2012, 30). Direct economic benefits are associated with the value of an exchanged waste or by-product and can be calculated before the initiation of the exchange at least with moderate precision whereas indirect economic benefits are associated with the operation of a company in general and cannot be quantified in detail beforehand (Jacobsen 2006, 252). The National Industrial Symbiosis Programme (NISP) in the UK has often facilitated waste and by-product exchange relationships where the benefit to both the supplier and utilizer is the removal of their respective problems (how to handle a waste and how to source a raw material) with no associated financial transaction among the parties (Lombardi & Laybourn 2012, 28-30). Access to finance and sound financial planning are important factors for the continuity of a symbiosis (Tudor et al. 2007, 203-204). Due to the importance of direct economic benefits they should be quantified as precisely as possible in order to ensure beforehand that waste and by-product exchange relationships bring to potential symbiosis participants economic benefits which are substantial enough to motivate them to take part in the symbiosis.

The waste and by-product exchanges often move from low-value status to high-value status as result of production upgrading or the gradual creation of a market and direct economic benefits. Direct economic benefits are mains reasons for the exchanges of by-products with higher initial value which results, for instance, from the higher energy content or the market value of substances. The recipient of a high value product may be able to focus on its core business instead of running utilities. (Jacobsen 2006, 252) Those eco-industrial park projects which have involved higher value-added products or have required high initial investment, have tended to have high economic performance (Jung et al. 2013, 58). In the development of a nascent industrial symbiosis, possibilities to manufacture high value-added products should be searched and implemented. Even when the initiation of production requires somewhat high initial investment, the high profits enjoyed in the future are likely to pay back the investment.

Industrial symbiosis may also lead to some intangible economic benefits which can be difficult to quantify. These indirect benefits include risk reduction, diversification, asset utilization, achieving a zero waste to landfill policy, improved community and/or government relations (which can for example facilitate permitting processes) and improved firm or brand reputation (because a company’s environmental image improves in the eyes of the public). (Chertow & Lombardi 2005, 6536; Lombardi & Laybourn 2012, 30, 33; Romero & Ruiz 2013, 736) Indirect economic benefits are often the motivation for low-value exchange relationships whereas direct economic benefits, which are related to the value of a by-product itself, are the motivation for high-value exchanges (Jacobsen 2006, 252). In Kalundborg the exchanges of steam and water have been generally based on indirect economic benefits which have been associated with strategic planning to enable increased supply security, operational capability and the expansion of production without the obstacle of water shortages in the long term (Jacobsen 2006, 241, 252). In symbiosis industrial companies don’t only gain their own private economic benefits, but also participate in the creation of public environmental benefits (in other words positive environmental externalities) (Chertow & Ehrenfeld 2012, 18). Public environmental benefits (for example, the decrease of environmental pollution) increase the welfare of the society in which an industrial symbiosis takes place (Chertow & Ehrenfeld 2012, 15). Industrial symbiosis has an important position in a company’ strategy when environmental excellence constitutes a key element in the strategic positioning of the company and has been incorporated to the core principles of the company’s operation and when cooperation on environmental issues brings opportunities for further business cooperation (Doménech & Davies 2011, 294).

3.5 Regional concentration of businesses and other agents

Eco-industrial parks are most efficient when there is an agglomeration or clustering of organizations to utilize waste as a resource. The proximity of businesses generates savings through positive externalities, economies of scale through the reduction of operation costs and encourages innovation through the development of new industries. Businesses gain economic benefits because clustering enables them to get shared access to information, networks, suppliers, distributors, markets, resources and support systems. Waste collection costs can be reduced as a result of decreased wastage and through the recycling of energy, water, materials and emissions. (Tudor et al. 2007, 203) Sustainable site arrangements achieved in symbiosis include more intensive use space, public utilities, joint commercial firm facilities, multimodal transport and high-quality public transport (Tudor et al. 2007, 201). In addition to the material resource exchanges, companies in Kalundborg have also been willing to share other assets for mutual benefits, such as equipment, personnel and information (Chertow & Ehrenfeld 2012, 15). There are two main types of flows in Kalundborg: those with a material component (energy and material flows) and those with immaterial component (information and knowledge flows) (Doménech & Davies 2011, 284). The exchange of knowledge, information and expertise positively influences the physical flows of energy and materials. The members of a symbiosis network gain access to new industry- and firm-specific knowledge and mutual learning. (Lombardi & Laybourn 2012, 32) The flow of information and knowledge helps the symbiosis participants to find value-added ways to utilize wastes and by-products and helps them to improve the efficiency of their own business and technical processes (Lombardi & Laybourn 2012, 32).

3.6 Diversity and complementarity among participants

The symbiosis network should involve a diverse range of firms with complementary materials (Tudor et al. 2007, 203). Studies have found a positive relationship between firm diversity and the activity of symbiotic exchanges (Jensen 2016, 101; Paquin et al. 2014, 276). Also within an industry there exists specialization, as individual firms develop expertise in specific areas of the value chain or materials (Tudor et al. 2007, 204). The increase of participant diversity in symbiosis broadens the knowledge and resource base available to the symbiosis network and fosters innovation and variety in solutions and developments (Boons et al. 2011, 910; Lombardi & Laybourn 2012, 32). Participant diversity increases the possibility of unexpected exchanges between different firms and partnering with firms of different industry also alleviates concerns over sharing sensitive information with potential competitors (Paquin et al. 2014, 276). Companies however likely rely on others in their own industries or supply chains rather than immediately consider cross-industry exchange opportunities even with neighbors (Chertow & Miyata 2011, 278). Research suggests that facilitating organizations may overcome the lack of exchange relationships among diverse firms (Paquin et al. 2014, 276). The diversity of participant companies and the variety of waste and by-product flows are also promoted by accepting longer exchange distances (Romero & Ruiz 2013, 736). However, although diversity in the participant companies' industries and expertise correlates positively with the activity of exchange relationships, this doesn't mean that increasing diversity in general will lead to new waste and by-product exchanges. If we locate some arbitrarily selected group of different firms to an industrial area, they don't necessarily develop new exchange relationships (for instance because their side streams and resource needs are incompatible). Rather the importance of diversity means that firms should search exchange partners in industries and fields of expertise which are clearly different from their own.

3.7 Facilitating symbiosis through information and communications technology

Information and communications technology and information management significantly facilitate collaboration and information exchange between firms (Liu et al. 2015, 326; Sakr et al. 2011, 1166). The use of databases where institutions post information about available wastes and other by-products can reduce search costs sufficiently so that two firms find it financially profitable to enter into an exchange relationship (Chertow & Ehrenfeld 2012, 20). Organizations may connect with each other through social networking in web services and initiate waste and by-product exchange relationships (Ghali et al. 2016, 26, 32). Social networking could also be used for the sharing good practices and experiences on industrial symbiosis (Ghali et al. 2016, 27). The existing ICT tools for industrial symbiosis generally possess the following capabilities and functions:

- standard or geographic information system (GIS) based data storage and processing,
- data publishing and transmission (usually non-public),
- data monitoring and analysis,
- flow matching based on compatibilities between by-products and their potential utilizations and geographic proximity,
- decision support in the form of recommendations based on historical data, best practices and cost estimation (Ghali et al. 2016, 26).

A geographic information system uses information to find resources (mostly wastes and by-products) generally on the basis of geographical proximity (Aho et al. 2013, 67; Ghali et al. 2016, 26). Existing system models (e. g. resource optimization, virtual marketplaces and communication portals) employed in other industries could be possibly replicated and used in designing the optimization and management systems of industrial symbiosis (Aho et al. 2013, 71).

The data on waste and by-product exchanges needs to be organized in taxonomies and catalogues (Cecelja et al. 2015a, 337). Information systems need to be able to communicate two types of knowledge: explicit knowledge (i. e. information) and tacit knowledge (i. e. know-how). Explicit knowledge is easy to communicate, codify and centralize by using tools such as statistics. Tacit knowledge is complex, not codified and is revealed through its application and context. These characteristics make the communication of tacit knowledge between people costly. (Grant et al. 2010, 741) Ontology engineering can be used to communicate various forms of tacit and explicit knowledge (Cecelja et al. 2015a, 337). An ontology model describes tacit knowledge related to waste and by-product streams (materials, energy, water), processing technologies and exchange process (for instance, methods, units of measurements, commercial names and geospatial references) (Cecelja et al. 2015a, 340-341). Explicit knowledge about participating companies is presented in the form of data relevant to symbiosis (Cecelja et al. 2015a, 340).

A third-party user who participates in the symbiosis coordination and management could speed up the formation of exchange relationships between companies by analyzing data about waste and by-product flows and extracting relevant information in order to advise companies about possible new profitable exchange opportunities (Ghali et al. 2016, 30, 34; Romero & Ruiz 2013, 736). An electronic information system could also itself automatically analyze data to find matches between wastes and by-products and their potential utilizations (Ghali et al. 2016, 33). The analyzed information of companies could include indicators representing the compatibility of wastes and by-products and their utilizations (for instance, geographical distance, volume compatibility, similarity with existing exchanges), public information (for example, by-product market price and availability on the market, users' public web sites) and private information (for example, by-product type and availability, contaminants, industrial processes) (Aho et al. 2013, 71; Ghali et al. 2016, 30, 33). Large amounts of data could be automatically sorted and analyzed by data-mining and web-mining techniques. (Ghali et al. 2016, 33) The information system could include optimization tools, which would calculate the optimal configuration of the network of waste and by-product exchange relationships among a group of organizations (Ghali et al. 2016, 34). By using knowledge modelling and ontology engineering, an input/output matching algorithm can be created which automatically connects wastes and by-products and their potential utilizations through a web service (Cecelja et al. 2015b, 265; Trokanas et al. 2014, 259, 262). An algorithm may be generally better to match wastes and by by-products and their utilization technologies than human beings or it may be better in matching some particular types of wastes and by-products and/or technologies.

As an example, based on knowledge modelling using ontologies, Trokanas et al. (2015, 30, 359) have proposed an approach for the calculation of environmental indicators which can be implemented in a web platform. These environmental indicators are calculated from explicit knowledge on properties that characterize the materials, waste streams and processing technologies of companies participating in industrial symbiosis. The outcome of the calculation is used to rank options for waste and by-product utilization by environmental feasibility and hence to make decisions. (Trokanas et al. 2015, 350) The calculated indicators include embodied carbon, saved virgin materials, the amount of waste used instead of landfilling, emissions from transportation and energy consumption (Trokanas et al. 2015, 352-354). This approach for the calculation of environmental indicators and the aforementioned algorithm for automated input/output matching have been both implemented in practice with companies from the municipality of Viotia in Greece (Cecelja et al. 2015b, 262; Trokanas et al. 2015, 350, 359).

3.8 Collaboration at wider regional and societal levels

The successful development of an industrial symbiosis requires broad community support and the active participation of major stakeholders. In addition to representatives from local companies, these stakeholders include local, regional and national government agencies, business associations, labor unions, educational and research institutions, multi-disciplinary experts and consultants and non-governmental organizations. (Boons et al. 2011, 907; Sakr et al. 2011, 1163; Tudor et al. 2007, 203) Government, industries and other institutions should cooperate together to create favorable conditions for the development of industrial symbioses (Costa & Ferrão 2010, 985, 991). Those communities, consisting of stakeholders who represent different interests, which engage in face-to-face, long-term dialogue to address policy issues of common concern are more able to deal with collective problems and thus develop networks of symbiotic exchanges in an industrial region (Boons et al. 2011, 908, 910, Boons et al. 2014, 347). To ensure the willingness of these stakeholders to collaborate, good public relations are essential (Tudor et al. 2007, 203).

Local public institutions should have a central position in the development of waste and by-product exchanges because they are aware of local conditions, can act as a connector between national government and businesses and can develop tailored policies, within the limits of government policies, to support the emergence of exchange relationships (Costa & Ferrão 2010, 991). Local development companies and recycling centers have knowledge about industrial companies and waste streams of a region (Aho et al. 2013, 72). Academic and other research organizations have participated in the development of the innovative technologies which have been central to certain waste and by-product exchange relationships (Lombardi & Laybourn 2012, 29).

Government needs to bring environmental legislation and standards in line with the principles of industrial symbiosis and eco-industrial parks (Sakr et al. 2011, 1165). Stringent environmental legislation, standards and policies are strong driving forces for companies to adopt non-polluting approaches of industrial symbiosis (Romero & Ruiz 2013, 739; Sakr et al. 2011, 1166, 1168; Tudor et al. 2007, 205). When regulation requires companies to reduce various forms of pollution, the companies can start waste and by-product exchange relationships as a measure to avoid the costs created by these regulatory requirements (Chertow & Ehrenfeld 2012, 20). Also tax breaks could be used as an instrument to enable the reutilization of wastes and by-products in different industries (Tudor et al. 2007, 205). In the Kalundborg industrial symbiosis, an incentives-based regulatory framework, which encourages waste and by-product utilization, has been a very significant factor for the successful development of the symbiosis (Sakr et al. 2011, 1165). Outdated legislation also hinders waste and by-product exchanges. For instance in the United States, laws prevent the utilization of many wastes and the application of new technologies. (Gibbs & Deutz 2007, 1693)

4 CHALLENGES COMMONLY ENCOUNTERED WITH INDUSTRIAL SYMBIOSIS

In this chapter challenges, which often take place during the development and operation of industrial symbioses and their waste and by-product exchanges and which prevent their success, have been explained. These challenges have been thematized into subchapters by analyzing several different literary sources where they have been presented. New solutions to the challenges have been proposed in the subchapters. By implementing these solutions in practice in symbiosis development the challenges can be overcome.

4.1 Planning fails to acknowledge business interests and market conditions

According to research literature (for instance Chertow 2007, 21), the "planning" of industrial symbiosis generally means building all the waste and by-product exchanges from scratch (explained in chapter 2) whereas "coordination" is established after the nascent self-organized symbiosis network is uncovered (explained in the subchapter 3.1). Literature states that coordination has facilitated the success of industrial symbioses but that those symbioses which have been planned have often failed. For instance Zhu and Ruth (2014, 43) have stated (as already said in the subchapter 3.2) that symbioses which have involved promotional institutions (equivalent to coordination), such as the NISP in the UK and the Eco-Town program in Japan, have developed more rapidly than purely self-organized symbioses. The deficiency of planning has been confirmed by Chertow and Miyata (2011, 278) and Costa and Ferrão (2010, 985) who state that the most enduring industrial symbiosis networks (like the symbiosis in Kalundborg) have not been planned by a third party, but have been self-organized for economic reasons with the environmental benefits revealed at a later time through the uncovering event of a symbiosis. Because industrial symbioses essentially develop on their own, they are very difficult to intentionally plan, design and manage (Tudor et al. 2007, 205). Significant number of planned symbiosis projects have failed or have been abandoned and they have suffered from poor environmental sustainability (Sakr et al. 2011, 1162; Tudor et al. 2007, 202). For example, a waste exchange system program in Egypt included a database that hosted all system components that covered the management needs for a viable waste exchange, but the program wasn't successful and was discontinued (Sakr et al. 2011, 1162).

The reason for the failure of planned symbioses has been found to be the inability of symbiosis project leaders to consider the motivations and interests of businesses thoroughly enough, which has led to circumstances where only few waste and by-product exchanges have been realized (Costa & Ferrão 2010, 985). When local governments have participated in symbiosis planning their expectations have not necessarily concentrated on environmental improvement. Instead they have emphasized other goals like job creation and the economic regeneration of the localities and may have therefore directed symbiosis planning to concentrate on exchange relationships which are unsustainable in practice. (Gibbs & Deutz 2007, 1690) The planned waste and by-product exchanges have not often been economically profitable (Chertow 2007, 18). In order to restrict the membership of a symbiosis only to those firms that meet the environmental, economic and social aims of symbiosis development, covenants on grey water, landscaping requirements, recycling, employment practices and other conditions have been introduced (especially in the United States) (Gibbs & Deutz 2007, 1687, 1689). These covenants have led to additional costs which have discouraged corporate investments (Aho et al. 2013, 69; Gibbs & Deutz 2007, 1692). The covenants have restricted the member recruitment too much and have therefore often been abandoned subsequently (Gibbs & Deutz 2007, 1689, 1691). When planned eco-industrial parks have failed they have often become conventional industrial parks (Chertow 2007, 18; Gibbs & Deutz 2007, 1687). Planning may also have blocked the communication between the suppliers and utilizers of wastes and by-products so that they haven't been able to form business relationships with each other independently (Gibbs & Deutz 2007, 1692).

The reason why these covenants have failed can possibly be explained if we compare them to government legislation. Covenants put a company into a disadvantaged competitive position as they control only companies that are present in a certain industrial area. Environmental laws, instead, control all the companies in a country or larger area (like the EU) and therefore cause equal disadvantage to all the companies in this country or area. Therefore they don't as often put firms into a more adverse position compared to their competitors. Covenants are also much easier to avoid than environmental laws. To avoid a covenant a company simply decides not to locate in a certain industrial area. To avoid a law company must often relocate its existing operations in another country or continent. As covenants are usually known before the location in an industrial area, potential expensive investments have not yet been made. Laws are often put into effect after expensive investments have been made and therefore these expensive investments prevent the relocation of a company and force it to comply with the laws. From the comparison between covenants and laws, a generalization can be proposed that the wider is the geographical region within which environmental regulation comes into effect, the more effectively the regulation drives companies to sustainable businesses in the subregions, like individual industrial areas.

Also the requirement of relocation to an industrial area has often increased the unprofitability of potential exchanges (Gibbs & Deutz 2007, 1691). Either a company has been completely unwilling to locate to procure low cost secondary materials or the location in a particular industrial area has not generally been logistically best place to operate (Gibbs & Deutz 2007, 1691, 1693). For this reason the demand for agglomeration in a certain location can become a barrier to symbiosis. Although the clustering of businesses creates economic and environmental benefits (as explained in the subchapter 3.5) it shouldn't be interpreted as an absolute condition for symbiosis development but rather as an advantage which should be marketed to potential participant companies of an industrial symbiosis. Lombardi and Laybourn (2012, 31) have stated that geographic proximity is not necessary for industrial symbiosis. No statistical correlation has been found between distance travelled in the physical exchange relationships of the National Industrial Symbiosis Programme and either economic value or tonnage. The transport costs have been substantially smaller than the economic benefit of the studied exchanges. (Lombardi & Laybourn 2012, 31) Therefore symbiosis can also take place within a larger industrial region.

Although the presence of a nascent industrial symbiosis, which is uncovered and institutionalized, distinguishes coordination from planning, it isn't realistic to assume that the same problems which are present in complete planning cannot also affect the coordination of an existing symbiosis. There exists a risk that coordination operates in the same manner as planning which is too strict to adapt market conditions and therefore fails to establish waste and by-product exchange relationships that are economically profitable. As we can suppose that the self-organization of businesses (i. e. companies independently form exchange relationships with each other) doesn't lose its importance in symbiosis network development after the establishment of the coordinative function, there exists a risk that bad coordination can prevent self-organization. The self-organization where the symbiosis emerges from economically motivated decisions of businesses (explained in the chapter 2) and the coordinative function of the symbiosis (explained in the subchapter 3.1) seem to be somewhat in conflict with each other. The self-organization describes a spontaneous evolutionary process where companies freely form exchange relationships with each other. The coordinative function restricts this freedom as it controls symbiosis development by providing rules for the cooperation and by delivering interventions to develop the cooperation. Therefore centralized symbiosis planning has failed when it has controlled the self-organization of symbiosis excessively (too much rules and interventions) or in a wrong way (wrong rules and interventions instead of right ones). “Intervention” here means any coordinative action that is intended to promote the formation of new exchange relationships (for instance, examining waste and by-product flows and resource needs in different companies in order to match the flows and needs). On the other hand there never can be completely free self-organization as there always exists some rules which control the symbiosis development (for example, legislation). Therefore self-organization and the control practiced by the coordinative function must be in balance.

The coordinative function must control the self-organization in the best possible way by providing only those rules and by delivering only those interventions which really can improve the economic and environmental success of a symbiosis. However, the presence of right rules and interventions truly can improve the formation of waste and by-product exchange relationships, for instance by giving all the member companies more equal capabilities to form new exchange relationships (as explained in the subchapter 3.2). The coordinative function should operate according to rules which force the function to continuously take into account the interests and motivations of all the participating businesses and changing market conditions. The coordination should continuously negotiate with all the existing and potential business parties of the symbiosis in order to find out these interests and motivations. The coordination must be a system which by its structure continually monitors the relevant factors and adapts to their changes accordingly. The monitoring of these relevant factors can be a possibly carried out through an information system which automatically collects relevant information. The information system can be a platform on which the self-organization of companies takes place as both the suppliers and utilizers of wastes and by-products can independently find each other through the system. The information system could then also work as an interface between the control of symbiosis coordination and the self-organization of businesses: the coordinative function of the symbiosis provides and maintains the information system and the self-organization of the symbiosis takes at least partially place within this system. However, the good functionality of this information system is very important as a badly designed system which is difficult to use doesn't help the formation of exchange relationships.

4.2 Dependency on other participants can create excessive risks

A key problem in industrial symbiosis is how companies can secure the supply of raw materials (Liu et al. 2015, 323). If a member company suddenly stops supplying wastes or by-products to other companies or if a utilizer doesn't anymore use the supplied waste, the operation of other participants can be hampered (Doménech & Davies 2011, 292). As an example the industrial symbiosis in Jacksonville was discovered to be unstable because its exchange relationships were at risk of demise when a single vendor or participating company became unavailable. The symbiosis was weak because the exchange relationships weren't strongly coordinated and there were no norms that regulated cooperation. (Chertow & Ehrenfeld 2012, 22)

However, these dependency-related risks and their consequences are unlikely to have a major impact on the overall economic performance of companies because wastes and recycling generally represent just a small fraction of the costs of organizations. The disconnection of a network member can disrupt cooperation channels between members but it probably doesn't lead to the collapse of the symbiosis. Until new exchange relationships are established, organizations can use other alternative sources of input materials and treat or recycle their waste streams through other routes. (Doménech & Davies 2011, 292) Plants could possibly be operated as a system whereby if one plant experienced problems then another would compensate (Tudor et al. 2007, 204). However, if companies locate to an industrial area and base their businesses somewhat completely on the utilization of the wastes and by-products of other companies, dependency-related risks can become very significant as when a waste or by-product suddenly becomes unavailable these companies cannot necessarily compensate it by using some other raw material. When a symbiosis network can utilize several alternative suppliers and resources it can likely adapt to changes and recover from disruptions more quickly (Tudor et al. 2007, 204).

The expansion of a network (the increase of the number of exchange relationships and/or participant companies) may increase the dependency among its members and the network's vulnerability in the face of changes that take place either within the network or its external environment (Boons & Spekkink 2012, 68; Doménech & Davies 2011, 292). It can be thought that a large network is more risky because there are more possibilities for dangerous chain reactions which can damage the operation of several companies. This kind situation can take place for instance, when there is a member company (called B) that both utilizes a by-product of another company (called A) and supplies its own waste to be utilized in another company (called C). Now, if the production of the company A stops suddenly, it cannot supply the by-product to the company B anymore and the production of the company B experiences problems. Therefore the company B cannot supply as much waste to the company C and the production of the company C also suffers. The more complex the network of exchange relationships is, the more there are possibilities for this kind of chain reactions. This phenomenon is especially risky if the utilizer companies cannot replace wastes or by-products with other raw materials quickly enough.

A dependency-related risks can possibly be mitigated through the establishment of a joint ventures among the suppliers and utilizers of waste or by-products. For example, in Netherlands Yara, Zeeland Seaports (the regional port authority) and Visser & Smit Hanab (a contractor) created a joint venture in their greenhouse area project. Their project entailed significant economic risks because the establishment of the necessary infrastructure required an investment of 80 million euros, and in order to make the project attractive to greenhouse owners, the involved parties had to guarantee a fixed price for the supply of residual heat and CO_2 for a period of 10 years. (Boons et al. 2014, 347, 352) However, a joint venture doesn't necessarily remove dependency-related risks but rather distributes these risks more evenly between the parties. Also in a joint venture the production of the supplier or utilizer may suffer unexpected problems. On the other hand, if each party has more to lose economically in the case of production problems, they may work harder to ensure that the waste or by-product flow remains stable.

It was stated in the chapter 3.2 that the coordinative function of an industrial symbiosis should facilitate the creation of exchange relationships in the symbiosis network so that each company would have an equal opportunity to easily develop multiple exchange relationships. This way any company doesn't have a too large proportion of the network's exchange relationships and therefore the disconnection of any member shouldn't cause excessive disruptions in the operations of other members. However, as stated before, the increase of the network size increases the complexity of the network, which very likely increases dependency related risks and decreases resilience. When less connected participant companies establish more exchange relationships this may make the network more homogenous in structure but it also increases the size and complexity of the network. A homogenous structure, where each member company has equally many exchanges, can really promote the resilience of a symbiosis, but it may be that as the amount exchange relationships increases, the complexity increases so much that the homogeneity of the network doesn't anymore decrease risks significantly enough. This is illustrated through the following Figure 2 and Figure 3, in which dark blue balls represent companies and light blue arrows represent exchange relationships. In the Figure 2 a small symbiosis network has an uneven structure because the companies α and β have more exchanges than others.

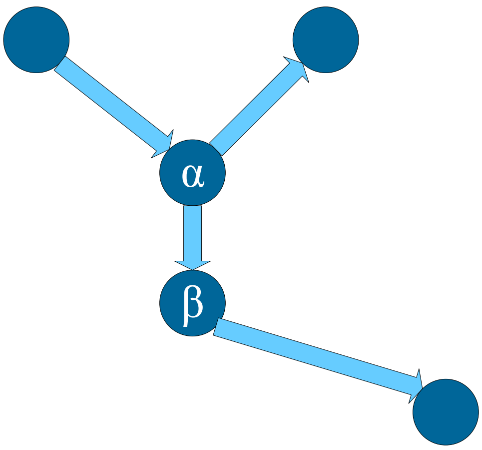

Figure 2. A small, simple and uneven (heterogeneous) network

A development project is started in order to change the network structure more homogenous. As results of this project several new exchange relationships are formed and new companies join the network. The network develops to a state which shown in the Figure 3. This expanded network is homogenous in its structure as each member company has three exchange relationships. However, there are several substructures which can create chain reactions that have been described earlier in this subchapter. As a result of the homogenous structure production problems in any of the network's member companies spread in the network and cause disruptions in very many (and even all) of the network’s member companies. It can be easily suspected that the network in the Figure 3 is much more risky than the network in the Figure 2. This is true especially in the case where most of the member companies base their production primarily on the supply of wastes and by-products from other network members.

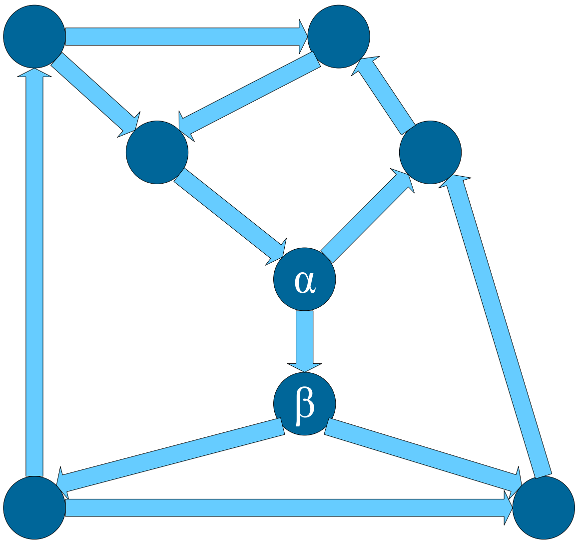

Figure 3. A large, complex and even (homogenous) network

It can be concluded that the structure of a symbiosis network is likely to be most resilient (and have minimal dependency-related risks) when there is a balance between the size (complexity) and the evenness (homogeneity) of the network. Anyway, it may be that when the network grows to involve certain number of members and exchange relationships, the even distribution of exchanges cannot anymore mitigate dependency-related risks. The coordinative function of a symbiosis can possibly mitigate dependencies if it can react quickly to the disconnection of members from the network and find new complementary suppliers or utilizers in a speedy manner.

4.3 Incapability to adopt and implement concepts, methods and technologies

Companies are unable to develop their networks of exchanges because they lack knowledge about the principles of industrial symbiosis (Romero & Ruiz 2013, 735). For example, instead of collaboration in a symbiosis network company representatives regard waste and by-product exchange relationships as bilateral market transactions (Lombardi & Laybourn 2012, 31). Companies also don’t have enough technical know-how to identify and evaluate potential waste and by-product exchanges and to implement sustainable technologies and methods (Sakr et al. 2011, 1166). In the study of Asian eco-industrial parks it was found out that the personnel of these parks had difficulties to adopt principles, methods and technologies of industrial ecology. They didn't clearly understand what industrial symbiosis is about, they couldn't accurately measure the development and operation of their parks and various public bodies had unclear roles in the parks' development and operation. In addition, correct technology and expertise and sufficient management systems and practices were not applied in these Asian eco-industrial parks. (Tudor et al. 2007, 204) The solution to the aforementioned problems could be to come up with concepts, language, methods and technologies which are easier for the potential symbiosis participants to adopt and use in their everyday operations. This means that academic and business discourses should converge so that simpler, more practice-oriented concepts, language, methods and techniques would be developed for building symbiosis. These more practical concepts may not fully reflect the highest ideals of the academics but at least they would be successfully implemented by several companies. As anchor tenants have a particularly significant role in the operation of the symbiotic network, they could transmit concepts and language to other smaller businesses. Therefore, it should be made sure that the anchor tenants first adopt the concepts and methods, so that they are capable to transmit them to other members accurately. Also national and regional governments and other public institutions could engage in actions which encourage the adoption of concepts and methods of industrial ecology and symbiosis, for instance indirectly through legislation, taxation and subsidies.

4.4 Symbiosis inhibits the implementation of cleaner production methods

Solving the problems of waste management though exchange relationships may lock a company into wasteful practices (Boons et al. 2011, 910). The industrial symbiosis complex in Kalundborg in Denmark may also be interpreted as an isolated phenomenon where a number of companies have been coincidentally locked into a web of waste, water, and energy exchanges based on contractual dependency (Jacobsen 2006, 240). Therefore it can be questioned whether the symbiotic downstream solutions have become an obstacle to radical upstream improvements (for instance, more efficient production technologies and processes which require less material inputs and create less wastes and emissions) (Jacobsen 2006, 251). For some industries the most environmentally and economically sound solution is to make changes to the existing process within their plants in order to reduce or eliminate wastes instead of engaging in exchange activities with neighboring companies (Liu et al. 2015, 319, 322, 324). The problem of the ignorance of cleaner production methods can be solved through the careful selection of core companies whose flows are critical to the network stability. When large-sized companies which are central in symbiosis network have strong sustainability and cleaner production orientation and technical knowledge, they are able to develop their production according to the most up-to-date sustainable methods and technologies. There exists a risk that if a supplier company improves its production process, the availability of the utilized waste or by-product may decrease dramatically and therefore the supply of the raw material of another company is suddenly diminished. As a result of this kind of development one or several companies may withdraw from symbiosis. By partnering with those companies whose technological expertise is at a very high level it is more probable that they have already developed their production methods so efficiently that the amounts of wastes which they produce are not likely to decrease very significantly anymore. A company which has developed its production methods less efficiently can more easily improve the resource efficiency of its production. Therefore partnering with companies which have high expertise in sustainable production methods is a way to ensure both the maximum environmental sustainability of industrial symbiosis and the secure supply of utilized wastes and by-products. Those firms who have operated in a highly competitive market for a long time have probably highly optimized production methods because for them the efficient use of raw materials and other resources has been and is a prerequisite for survival in the market.

4.5 Behavioral barriers of participating agents

There are behavioral barriers which so strongly prevent companies to work across organizational borders that even sound economic advantages aren’t sufficient to overcome these barriers (Sakr et al. 2011, 1166). Alongside the network of material and financial flows, there is always a social network connecting individual people in different industries. These social networks more frequently arise spontaneously and often involve such informal channels as family ties or community or civic organizations. (Chertow & Ehrenfeld 2012, 18) For this reason it can be difficult to intentionally establish symbiotic networks through formal channels. If actors have learned in some past interactions that certain courses of action are unfeasible, they are likely to rule those courses of action out in the present (Boons et al. 2014, 348). In the matching of wastes and by-products and their utilizations the practitioners may be biased towards their own expertise or particular industries they wish to serve (Cecelja et al. 2015a, 337). One way to overcome this would be to use a small scale pilot project, as mentioned earlier, to reduce risks perceived by potential symbiosis participants. People promoting and advancing waste and by-product utilization must also have understanding of the mind-set of participating businesses, their perceived risks and ability to connect with them on personal level in order to be capable change their attitudes - in other words they must capable to act as the champions of symbiosis.

4.6 Undersized economic benefit or excessive costs for a company

Companies are mainly motivated by possibilities for profit maximization (Wang et al. 2013, 10). Firms are not generally willing to move to an industrial area if they cannot gain large economic benefits from waste and by-product exchange relationships (Tudor et al. 2007, 204). The costs of carrying out exchanges are not only symbiosis costs for companies. Also the consideration and initiation of potential exchange relationships creates substantial transaction costs which can prevent companies from building symbiosis networks. These transaction costs are created when a company searches information about opportunities for new exchanges, when it negotiates the terms of exchange relationships and when it enforces of the contracts of relationships. (Chertow & Ehrenfeld 2012, 20) The calculation of costs as precisely as possible is one of the most important ways to ensure that participating companies join an industrial symbiosis and remain its members. This way it is ensured that a company doesn’t later find out through cost calculation that participation is unprofitable and withdraw from symbiosis. On the other hand through precise calculation the economic benefits can be illustrated to potential symbiosis partners. Companies could reduce transaction costs if they could use the expertise of a third party which specializes in the aforementioned operations associated with the initiation of waste and by-product exchange relationships.

In the situation where the costs which taking part in symbiosis creates are distributed unequally and unreasonably among member companies, those companies that gain relatively less profit due to higher symbiosis costs may become unmotivated to be members in the symbiosis network anymore (Wang et al. 2013, 10). Therefore they may decide to withdraw from the symbiosis, and this can even lead to the implosion of the network (Wang et al. 2013, 11). In the situation where there is imbalance in the distribution of costs among the member companies, actions to redistribute the costs more equally may be taken. The distribution of costs can be taken into account through negotiation and the establishment of common regulation, for instance for the prices of materials in the symbiosis. For example, those companies which incur symbiosis costs that are relatively higher can increase the price of input materials supplied to those companies which incur less costs from participating the symbiosis. (Wang et al. 2013, 11) It can be supposed that the equal distribution of costs means that the symbiosis cost of company is directly proportional to its economic benefit from the symbiosis (Wang et al. 2013, 10). In other words if the company A gains an economic benefit which his twice the size of the economic benefit of the company B, then the symbiosis cost of the company A should also be twice as high as the cost of the company B.

4.7 Difficulty to gain substantial economic benefit from wastes and by-products

Waste materials are typically nonstandard, difficult to specify and highly variable in composition (Grant et al. 2010, 741). As a result of this waste-flow exchanges require customized, new applications or the use of innovative technologies or approaches and thus the outcomes of their utilization can be uncertain and risky (Doménech & Davies 2011, 288). Additionally, there is no way to economically recycle many industrial wastes (Tudor et al. 2007, 204). The recognition of those wastes which are impossible to utilize can be very important in order to ensure that resources are not wasted to their development. The modelling of waste material and energy streams is challenging as their utilization is based on tacit knowledge that consists of associations, know-how, expertise and engineering intuition (Cecelja et al. 2015a, 337). In can be concluded that in general the high level of expertise in the properties of different wastes, their uses and costs created by their transport and processing is necessary for the successful realization of industrial symbiosis.

Waste management has generally a low priority in company strategies (Doménech & Davies 2011, 294). Relative to the overall cost structure of a company, the costs of waste management are low. Thus cost savings related to waste minimization and reutilization will probably have a limited impact on the costs of an organization and therefore are not strong enough drivers for most companies to relocate close to other symbiosis participants. (Doménech & Davies 2011, 294; Tudor et al. 2007, 204) Also the business opportunities derived from the potential symbiotic exchanges are usually on a limited scale and would rarely act as a localization factor on their own (Doménech & Davies 2011, 294). The companies are willing to relocate to access particular resources only if those resources are the most important inputs for a firm or if materials and energy comprise a large part of the budget (Lombardi & Laybourn 2012, 31). For instance, companies in the US considered the concept of eco-industrial parks to be unrealistic since it entailed relocation to another site close to by-products of minor importance as input materials due to the relatively low procurement costs of those materials (Sakr et al. 2011, 1163-1164). It can be questioned whether environmental savings in terms of substitution or energy cascading in Kalundborg are substantial if they are compared with the total flows of waste material, energy and water of the symbiosis (Jacobsen 2006, 251). When direct economic benefits from the use of exchanged materials and energy are minor, the exchanges must be motivated by some indirect economic arguments (Jacobsen 2006, 252). These include, for instance, asset utilization, diversification, improved community and government relations and improved firm or brand reputation (Chertow & Lombardi 2005, 6536; Lombardi & Laybourn 2012, 30, 33). Although intangible economic benefits may be difficult to quantify precisely, their general scale can potentially be evaluated accurately enough on the basis of intangible economic benefits acquired through earlier business relationships. In the cases where direct economic benefits are quite small, symbiosis network development should concentrate on those exchanges which have highest intangible economic benefits. The public environmental benefits, which an industrial symbiosis creates, should be emphasized in the marketing of the symbiosis as they can influence positive attitudes in the minds of important stakeholders and promote the approval of the symbiosis, and this approval improves the operating conditions of the symbiosis (for example, through more generous funding).

4.8 Diversity may require long distances and lead to conflicts

Secondary flow markets are profitable only within a certain distance range (Aho et al. 2013, 68). The need to import raw materials and export products across regions or countries may cause increased costs and other problems (Tudor et al. 2007, 205). Long distances are infeasible both environmentally and economically due to higher distribution costs (as fuel consumption also causes emissions), latency and the decrease in the quality of some flows, such as energy or steam (Romero & Ruiz 2013, 736; Rosa & Beloborodko 2015, 465). The longer distances also increase the possibility for diverse business partners, which is an example of the common case of the trade-offs between business diversity and the economic feasibility for exchanges (Romero & Ruiz 2013, 736). There should be the calculation of allowable distance ranges for participant companies in an industrial symbiosis, so that these ranges maximize the environmental and economic benefits acquired from participant diversity and minimize the costs and environmental problems due to long distances.

Businesses are essentially separate entities which have different management structures and staff, and therefore their cultures vary and the manner by which staff relate and communicate differs within organizations. Too much diversity among the members of a symbiotic business network can lead to conflicting preferences, interests and wants as well as higher transaction costs in the establishment of relationships. (Tudor et al. 2007, 204) Different governmental units may have their own plans that reflect their management function and responsibilities and therefore their involvement can make the establishment of harmonious symbiosis network difficult (Liu et al. 2015, 326). There could be optimization between network diversity benefits and conflict management costs created by differences between organizations. However these costs are highly abstract and difficult to evaluate quantitatively and therefore their optimization requires experience about conflicts and their management in symbiotic and other business networks. More concrete approach would be to anticipate the conflicts that could arise due to organizational differences and propose potential solutions to them even before these conflicts have taken place. These potential conflicts should be mitigated by the rules through which a symbiosis network is coordinated, and these rules should not only be implemented in the actions of people but also through information systems.

4.9 Waste exchange market large enough involves too many members

The amount of usable wastes and by-products which are available to symbiosis companies is a critical factor, as companies are willing to pay for optimization and management services for symbiotic exchanges only when the volume and turnover of an industrial waste market are so large that it is possible to obtain significant profits (Aho et al. 2013, 68, 72). The creation of a successful knowledge network (like a waste market) requires the establishment of a critical mass of members because the network is valuable only when there are enough participants (Grant et al. 2010, 751). The process of the generation of trust and personal cooperation may constitute an important challenge in the case of a large network, as the size of the network constrains the social mechanisms that allow cooperation and trust to emerge (Doménech & Davies 2011, 283, 293). For example, the National Industrial Symbiosis Programme (NISP) in the UK may not be capable to generate personal co-operational relationships because such aspects as personal, frequent contact, reciprocity or shared vision and goals are difficult to realize in large networks and control mechanisms such as reputation or collective sanctions have lost their impact and relevance (Doménech & Davies 2011, 284, 293). The large size of a network easily leads to greater transaction costs, the slower diffusion of information and the risk of interruption of waste and by-product flows (Doménech & Davies 2011, 286). The expansion of the network may have a very negative effect in the process of building personal cooperation, creating just an 'arm's length' network. The 'arm's length' network resembles the atomistic market condition, where price is the main mechanism determining the transactions. (Doménech & Davies 2011, 292)

In South Korea, eco-industrial parks composed of major chemical industry companies have achieved remarkable economic and environmental outcomes. Compared to these eco-industrial parks composed of large companies, EIPs composed of small companies have exhibited only modest outcomes. (Jung et al. 2013, 58) One explanation for this is that small companies generally produce less wastes and by-products and therefore the cost of building and maintaining waste and by-product exchanges is high compared to the revenue acquired from the exchange of secondary flows, and therefore the profitability is weaker. Compared to large companies which produce substantial amounts of wastes and by-products there needs to be much more complex network for the same amount of wastes and by-products in the case of smaller firms. A complex network also creates more emissions to the environment, for instance due to more frequent transportation. In the case of small companies taking part in the symbiosis network, the presence of "anchor tenants" producing large, relatively constant flows of by-products, for example, in agriculture, energy generation, chemicals, or brewing, can help the success of symbiosis (Chertow & Ehrenfeld 2012, 18). Therefore it can be proposed that business network of an industrial symbiosis should consist of certain proportions of different-sized companies: there should always be big companies which form the core of the network and provide a major volume of waste and by-products flows and thus enable exchange relationships with high revenues and reduce the coordination costs and complexity of the network.

4.10 Manifold and high requirements for industrial symbiosis ICT tools

The systematic utilization of information and communications technology could significantly improve the operation of industrial symbioses, as in eco-industrial parks incomplete or imperfect information often creates difficulties in information dissemination or communication (Tudor et al. 2007, 204). By using ICT systems to construct and store information this problem could be alleviated. Unfortunately, the information and communications technology tools for industrial symbiosis have generally been too complex as they have required a high level of user involvement and systems knowledge (for example, computer and programming skills and a comprehensive knowledge of different industrial organizations) (Ghali et al. 2016, 26; Grant et al. 2010, 750). These tools have not been designed to facilitate actual cooperation between potential business partners but only to allow the identification of potential wastes and by-products or their utilization solutions (Ghali et al. 2016, 26). The tools for industrial symbiosis lack sociability: they don't facilitate the active participation and interaction among companies and other users (Ghali et al. 2016, 26; Grant et al. 2010, 750). The possibility for effective social communication is very important because exchange relationships often form between companies from different industrial sectors that do not have established customer/supplier relationships (Grant et al. 2010, 741). The existing ICT tools have been overwhelmingly targeted for the use of the master designer, planner or broker of a symbiosis instead of individual participant companies (Grant et al. 2010, 750). The taxonomical classifications of resources pose a great challenge to ICT search tools and the usage of non-standardized classifications restricts searchability (Grant et al. 2010, 746, 750). Ontological representations of resources are difficult to establish and maintain, especially due to the semantic annotation process (Ghali et al. 2016, 26). The potential of social media to facilitate industrial symbiosis is questionable as most social networking sites primarily support pre-existing social relationships instead of the establishment of new ones (Ghali et al. 2016, 27). On the basis of the aforementioned aspects it can be proposed that in the development of an ICT system for industrial symbiosis it is very important the design the system's user interface to be so simple and intuitive that the personnel of symbiosis member companies can use it independently and communicate with each other. It must be noted that any of the ICT systems for industrial symbiosis which Grant et al. (2010, 744) have surveyed doesn't seem to be currently publicly available (when searching their titles with a search engine).

The concept of tacit (implicit) knowledge is used to describe knowledge which resides within individuals or companies and which is difficult to express in written or codified forms (Cecelja et al. 2015a, 337; Ghali et al. 2016, 28). For instance, the expertise of an individual professional consists mainly of tacit knowledge (Cecelja et al. 2015a, 337). Tacit knowledge cannot be transferred vertically through a hierarchy or to and from a central authority (Grant et al. 2010, 741). Therefore a single network hub will easily become a bottleneck that inhibits the communication of tacit knowledge (Grant et al. 2010, 748). Compared with traditional commodity exchanges, industrial symbioses are more strongly based on the application of tacit knowledge (Grant et al. 2010, 741). The customized technological solutions of waste exchanges can be realized only through frequent interaction between the supplier and utilizer parties who transmit the necessary tacit knowledge to each other (Doménech & Davies 2011, 288). One reason for the failure of ICT tools for industrial symbiosis is their inability to communicate tacit knowledge. The communication of tacit knowledge takes place in a social relationships or community and therefore tools which don't enable the presence of social communities and communication cannot facilitate the establishment and maintenance of industrial symbioses. (Grant et al. 2010, 741) The matching of wastes and by-products and their utilization solutions usually happens through social communication which involves much tacit knowledge and therefore it is very difficult to codify input-output matching as a computer algorithm (Cecelja et al. 2015a, 337). Instead of designing and introducing completely new ICT tools for industrial symbiosis, the communication for the establishment of new symbiotic relationships and matching of wastes and by-products and their utilizations could be integrated to existing tools for social communication and group work which companies commonly use. When a program and its user interface are already familiar to the potential participants, it is less laborious for them to begin using these tools for symbiosis development. The communication of symbiosis development could be realized, for instance, through a plug-in which is integrated to existing communication tools.

4.11 Symbiosis performance depends on business environment characteristics

An industrial symbiosis is located within a business environment which affects its performance. Several characteristics vary between different environments and there characteristics create differences in the performance of different symbioses. (Romero & Ruiz 2013, 735, 738) Therefore transplanting best practices from location to another should carried out with caution (Boons et al. 2011, 910-911). Between nations there are variations in social, economic, cultural and ecological circumstances and policies and regulations for industrial operation and environmental protection and these specificities make it often difficult to compare different existing symbioses (Sakr et al. 2011, 1168; Tudor et al. 2007, 205). For example, environmental legislation varies between countries (Tudor et al. 2007, 204). Currently there is no internationally accepted standard for the development of industrial symbioses and eco-industrial parks, which would define the methods through which they should be realized and how their performance should be measured so uniformly that ranking and benchmarking between different symbioses and parks is possible (Sakr et al. 2011, 1166). Repeating the success of the industrial symbiosis in Kalundborg has been difficult because in other locations there has been problems with adopting the concept of industrial symbiosis, the high transaction costs of searching suitable wastes and by-products, achieving profits substantial enough and securing the continuous supply of feedstock (Yu et al. 2013, 285).

In order to recognize all the relevant aspects of the business environment which may affect the success of an individual industrial symbiosis, a wide variety of different benchmark cases about industrial symbioses in different countries and localities should be studied. This thesis identifies these important aspects for its part. Those characteristics in the business environment, which are unfavorable to symbiosis development could possibly be mitigated by collaborating with those societal institutions (for example, with public servants and politicians) which have power and capability to implement means that change the national or local business environment to promote industrial symbiosis (for example, by improving legislation and providing subsidies).

5 SUMMARY OF THE SUCCESS FACTORS, THEIR ASSOCIATED CHALLENGES AND SOLUTIONS TO THEIR CONFLICTS

The success factors (from the chapter 3) and their associated challenges (from the chapter 4) can be said to be interconnected by common themes, and therefore they are in conflict with each other. In order to enjoy the full benefits from the success factors and avoid the risks of the challenges, solutions overcoming the conflicts between the success factors and challenges are proposed according to the ideas presented before. The interconnected success factors, challenges and their proposed solutions are presented in the Table 2 below. When a success factor and a challenge have been positioned on the same row, they are interconnected. The solutions have been explained in more detail in the subchapters of the chapter 4.

Table 2. The success factors, related challenges and solutions to their conflicts

Success factor	**Challenges related to the success factor in question**	**Solution resolving the conflicts between success factors and challenges**
Uncovering existing symbioses A function for symbiosis network coordination	Centralized symbiosis planning failing to acknowledge business interests and market conditions	A symbiosis must be adaptively coordinated through the continuous systematic monitoring of participant interests and motivations and market conditions.
The resilient structure of a symbiosis network	Dependency-related risks among network members An oversized network leads to excessive risks	Joint ventures The balance between the size (complexity) and evenness (homogeneity) of the network Coordination finds complementary partners fast when a member disconnects from the network

Table 2. The success factors, related challenges and solutions to their conflicts (continued)

Success factor	**Challenges related to the success factor in question**	**Solution resolving the conflicts between success factors and challenges**
The adoption of concepts and methods of industrial ecology	Incapability to adopt and implement concepts, methods and technologies of industrial ecology Symbiosis inhibits the implementation of cleaner production methods	Academic and business discourses converge in order to develop practical concepts and methodology Anchor tenants disseminate concepts and methods to other partners. The large-sized companies central in the symbiosis network must have strong sustainability and cleaner production orientation and technical knowledge as their flows are critical to the network stability.
The presence of symbiosis champions Reducing risk with a small-scale pilot collaboration	The behavioral barriers of participating agents	People promoting symbiosis must have understanding of the mind-sets of participating businesses, their perceived risks and ability to connect with them on personal level.

Table 2. The success factors, related challenges and solutions to their conflicts (continued)

Success factor	**Challenges related to the success factor in question**	**Solution resolving the conflicts between success factors and challenges**
Quantifiable (direct) economic benefits and financial planning Turning and by-product wastes to products of high added value	Symbiosis creates excessive costs and/or undersized profits for a company The uneven and unacceptable distribution of costs The complex nature of the wastes and by-products of industrial companies	The better the understanding (quantification) of costs and profits, the better risks can be avoided and benefits can be captured. The expertise of a third party can reduce transaction costs. Regulation to ensure even distribution of costs, f. e. negotiating input prices The high level technical expertise on different wastes and by-products
Intangible (indirect) economic benefits	The limited economic and environmental potential of waste and by-product utilization	Concentrating on those exchange relationships which bring most intangible economic benefits Marketing public environmental benefits for the public recognition of the symbiosis

Table 2. The success factors, related challenges and solutions to their conflicts (continued)

Success factor	**Challenges related to the success factor in question**	**Solution resolving the conflicts between success factors and challenges**
The regional concentration (clustering) of businesses (and other agents) The flow of information, knowledge, expertise and technology	Trade-off between short distances and participant diversity	The calculation of an optimal distance range which maximizes environmental and economic benefits
Diversity and complementarity among participants	Excessive diversity among network members leads to conflicts	Optimization between network diversity benefits and conflict management costs Anticipating solutions to potential conflicts between different partners (in coordination and ICT systems)
Anchor tenants	A waste exchange market large enough achieved only through a network of too many members (a large number of small participant companies)	A network consisting of certain proportions of companies of different size (several big companies form the network's core)

Table 2. The success factors, related challenges and solutions to their conflicts (continued)

Success factor	**Challenges related to the success factor in question**	**Solution resolving the conflicts between success factors and challenges**
Facilitating the establishment and maintenance of symbiosis through information and communications technology	Existing ICT symbiosis tools designed for the use of technical experts The development of description language simple and comprehensive enough for tacit knowledge	A simple, intuitive and communication-oriented user interface Implementing symbiosis communication in existing social tools (f. e. through plug-in)
Collaboration at wider regional and societal levels	The performance of a symbiosis depends on business environment characteristics	Identifying relevant business environment characteristics through benchmark cases The improvement of the business environment by collaboration with societal institutions

6 LIMITS OF A SINGLE SYMBIOSIS NETWORK

This chapter concentrates to evaluate whether individual industrial symbiosis networks reach some optimal size (measured in the number of companies and exchange relationships) or whether they can realistically grow forever. Currently there isn't much scientific research about the optimal or average size of symbiotic networks. Scientific research mainly concentrates on large symbiosis networks as they manifest the success of the concept of industrial symbiosis. It is obvious that the sizes of symbiosis networks can vary greatly due to numerous factors (like the specific combination of different industries or the expertise of symbiosis developers). However, averages are significant as they reveal what kind of goals are realistic for the development of a single symbiosis network in general. Most of the symbiosis networks and most of their developers are destined to be somewhat average (instead of exceptionally large or successful). If the case would be otherwise, averages wouldn't exist. By accepting this fact one may in fact obtain some new insight which helps to develop industrial symbiosis networks more successfully.

There are several reasons why the number of participant companies and exchange relationships may reach a limit after which the symbiosis network doesn't grow substantially anymore:

- For a certain combination of different industries and the wastes and by-products which they produce, there is only a certain limited number of exchange relationships which create economic benefit that is high enough to satisfy the demands of potential parties.
- As industrial symbioses take place within a certain geographic area, many too distant companies are not willing to relocate closer to other symbiosis participants or they are not willing to transport their wastes and by-products due to high transportation costs.
- As the number of exchange relationships increases the risks related to dependencies between companies also increase. If a waste or by-product from one company suddenly becomes unavailable, the production of many other member companies of a symbiosis network may decrease or stop. When there are a certain number of exchange relationships in a network, the dependency-related risks have grown so high,

> that new exchange relationships are not initiated although they could create substantial economic benefits in principle. Therefore potential new members decide not to join to the symbiosis network and the existing members don't want any new members who would increase the dependency-related risks even further.

The symbiosis of Kalundborg is used to illustrate that an individual symbiosis network may reach an optimal size after which even publicity or conscious symbiosis development through an institutional structure may not lead to the involvement of new member companies who initiate new exchange relationships. Therefore a more effective approach to develop industrial symbiosis at the societal level is to concentrate on developing several waste and by-product exchange networks and to concentrate on those smaller networks which have more potential for additional development. The average size of a symbiosis network is evaluated from a data set of 31 eco-industrial parks at the end of this chapter.

6.1 Temporal development of the Kalundborg symbiosis

In the following section the development of the symbiosis network of Kalundborg is examined. This examination concentrates on how the symbiosis network has evolved from 1961 onwards. The temporal evaluation allows us to identify whether the pace in which new participants joined the network and the pace in which new exchange relationships were formed has accelerated or slowed down as the time passed. It can be hypothesized that if the network development has slowed down, this is because the symbiosis has reached its maximum number of exchange relationships and participants. In other words, the symbiosis network is fully developed. It also allows us to identify whether the publicity brought by the uncovering of the symbiosis in 1981 and the establishment of the Symbiosis Institute in 1996 really promoted the development of the symbiosis (Chertow 2007, 12, 20). Kalundborg symbiosis was selected for examination for two reasons. Because it is the most well-known industrial symbiosis, there is enough data about the temporal development of its exchange relationships. In addition, exceptional publicity which the symbiosis has received allows us to evaluate the effect of publicity (and marketing communications) to the symbiosis network development.

In the Table 3 the temporal development of the exchange relationships of the Kalundborg symbiosis is presented by listing the exchange relationships according to their years of initiation. Three of these exchange relationships (initiated in 1972, 1992 and 1999 respectively) have stopped. The source material of the table is from the year 2011, but according to the website of the Kalundborg symbiosis, no new exchange relationships have been initiated since 2010 (Kalundborg Symbiosis 2016). Asnaes power station and Inbicon A/S are both regarded as one party (DONG Energy) as they are both owned by DONG Energy group (Inbicon 2016a). The demonstration plant of Inbicon which produces ethanol from biomass was launched in Kalundborg in 2010 (Inbicon 2016b). Novo Nordisk A/S and Novozymes A/S are both considered as one party (Novo) as they are both subsidiaries of Novo A/S (Novo A/S 2016). It wasn't until 1989 when two Danish companies, Novo and Nordisk Gentofte, merged to become Novo Nordisk. In 2000 Novo Nordisk was split into three independent companies: Novo Nordisk A/S, Novozymes A/S and Novo A/S. (Novozymes 2016)

Table 3. The exchange relationships of the Kalundborg symbiosis according to their initiation years (Kalundborg Symbiosis 2011)

Initiation year	**Supplier / utilizer**	**Waste or by-product**
1961	the municipality of Kalundborg / Statoil refinery	surface water
1972 (stopped)	Statoil refinery / Gyproc	gas
1973	the municipality of Kalundborg / DONG Energy	surface water
1976	Novo / farms	biomass / NovoGro
1979	DONG Energy / cement industry	fly ash
1980	DONG Energy / fish farm	heat
1981	DONG Energy / the municipality of Kalundborg	heat
1982	DONG Energy / Statoil refinery	steam
1982	DONG Energy / Novo	steam
1987	Statoil refinery / DONG Energy	cooling water

Table 3. The exchange relationships of the Kalundborg symbiosis according to their initiation years (continued) (Kalundborg Symbiosis 2011)

Initiation year	**Supplier / utilizer**	**Waste or by-product**
1987	the municipality of Kalundborg / Novo	surface water
1989	Novo / pig farms	yeast slurry
1990	Statoil refinery / fertilizer industry	sulphur
1991	Statoil refinery / DONG Energy	technical water
1992 (stopped)	Statoil refinery / DONG Energy	gas
1993	DONG Energy/ Gyproc	gypsum
1995	Statoil refinery / DONG Energy	drain water
1995	Novo / the municipality of Kalundborg	waste water
1998	the municipality of Kalundborg / Soilrem	sludge
1999 (stopped)	DONG Energy / recovery of nickel and vanadium	fly ash
2002	DONG Energy / Statoil refinery	deionized water
2004	the municipality of Kalundborg / Novo	water
2006	Novo / DONG Energy	alcoholic residue
2007	DONG Energy / Statoil refinery	sea water
2009	Novo / the municipality of Kalundborg	condensate
2009	farms / DONG Energy	straw
2010	DONG Energy / Statoil refinery	bioethanol

In the following list the participants of the symbiosis network of Kalundborg are presented in the order in which they joined the symbiosis. Novo and farms are put in the places 7 and 8 (instead of the places 5 and 6) because although the exchange relationship between them has existed since 1976, they didn’t join the main symbiosis network of Kalundborg until 1982 when Novo started the exchange of steam with DONG Energy. When two parties have joined the symbiosis network simultaneously, the supplier has been placed before the utilizer.

1. the municipality of Kalundborg
2. Statoil refinery

3. Gyproc
4. DONG Energy
5. cement industry
6. fish farm
7. Novo
8. farms
9. pig farms
10. fertilizer industry
11. Soilrem
12. recovery of nickel and vanadium

In the Table 4 on the next page the temporal development of exchange relationships is examined separately for each member. The columns of the members have been arranged to the same order in which they joined the Kalundborg symbiosis. Each column presents one member. Therefore the column titled “1.” refers to the municipality of Kalundborg, the column titled “2.” refers to Statoil Refinery and so on. The values of a particular symbiosis member indicate its number of exchange relationships in a particular year. Blank cells mean that companies have not yet joined the symbiosis network. Cells with the value zero mean that the company doesn’t have exchange relationships with symbiosis participants anymore and therefore isn’t anymore a member of the network. There are some exchange relationships which have stopped, and these have been marked by the decrease of values (often to zero). Because all these exchange relationships have already ended in 2011, it is supposed that they ended a year after their initiation. There is no information available when these exchange relationships have ended and their year of ending isn’t significant for the purpose of this study.

Table 4. The temporal development of the exchange relationships of each member company in the Kalundborg symbiosis

Initiation year	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12
1961	1	1										
1972	1	2	1									
1973	2	1	0	1								
1979	2	1	0	2	1							
1980	2	1	0	3	1	1						
1981	3	1	0	4	1	1						
1982	3	2	0	6	1	1	2	1				
1987	4	3	0	7	1	1	3	1				
1989	4	3	0	7	1	1	4	1	1			
1990	4	4	0	7	1	1	4	1	1	1		
1991	4	5	0	8	1	1	4	1	1	1		
1992	4	6	0	9	1	1	4	1	1	1		
1993	4	5	1	9	1	1	4	1	1	1		
1995	5	6	1	10	1	1	5	1	1	1		
1998	6	6	1	10	1	1	5	1	1	1	1	
1999	6	6	1	11	1	1	5	1	1	1	1	1
2002	6	7	1	11	1	1	5	1	1	1	1	0
2004	7	7	1	11	1	1	6	1	1	1	1	0
2006	7	7	1	12	1	1	7	1	1	1	1	0
2007	7	8	1	13	1	1	7	1	1	1	1	0
2009	8	8	1	14	1	1	8	2	1	1	1	0
2010	8	9	1	15	1	1	8	2	1	1	1	0

From the Table 4 we see that most symbiosis participants have formed only one exchange relationship. Four of the participants have formed exceptionally high amount of exchange relationships compared to others. These are the municipality of Kalundborg, Statoil refinery, Dong Energy and Novo. In order to find out whether these four participants have an exceptionally high amount of exchange relationships with each other, the amount of exchange relationships between them is compared to the amount of all the exchange relationships in 2010.

By using the Table 3 it is found that there are 24 exchange relationships and 16 of these are between the municipality of Kalundborg, Statoil refinery, Dong Energy and Novo. There are 11 participants in the symbiosis. From this information we can make a comparison:

$$\frac{16 \text{ exchanges}}{24 \text{ exchanges}} = \frac{2}{3} \gg \frac{4}{11} = \frac{4 \text{ participants}}{11 \text{ participants}}$$

From the equation above we can see that there is an exceptionally high number of exchange relationships between these four participants in comparison to the exchange relationships with other participants. These four participants form the "inner circle" of the symbiosis where they mainly have exchanges with each other. Also the exchanges of the other participants take place with the members of this inner circle, the other participants don't have exchanges with each other.

However, when we examine which wastes and by-products are exchanged between these four parties, we find that clearly dominating exchanges are water (11 relationships) and steam (2 relationships). Other by-products which are exchanged between these parties are heat, alcoholic residue and bioethanol (1 relationship per each). When we examine the other exchange relationships, which these four parties have with the other parties of the symbiosis, we find a much greater variety of wastes and by-products: biomass/NovoGro, fly ash, heat, yeast slurry, sulphur, gypsum, sludge, straw (1 relationship per each). Therefore main reason for the abundance of exchange relationships among the municipality of Kalundborg, Statoil refinery, DONG Energy and Novo is that they benefit highly from the water and steam exchanges. When the three companies can secure the supply of water and steam in their production, the economic success and employment rate in the municipality of Kalundborg are promoted. There are several conclusions which can be drawn from the structure and development of the symbiosis network of Kalundborg. The first one is that public institutions (like, in this case, municipal institutions) can have powerful role in promoting the development of waste and by-product exchange networks. The second conclusion is that one way two build a successful symbiosis network is to concentrate on exchanges of some central commodity (in this case, water and steam). The third one is that without water and steam exchanges the symbiosis network of Kalundborg would have been considerably smaller or would have never come to existence.

In the Figure 4 we see that after the uncovering of the Kalundborg symbiosis three parties have permanently joined the symbiosis network. In addition, Gyproc had earlier a stopped gas exchange, so actually only two partners (fertilizer industry and Soilrem) are completely new. Because the Kalundborg symbiosis is the most well-known case of industrial symbiosis, it has been widely covered in the press and other media. However this publicity for the symbiosis didn't spark off any strong expansion of the symbiosis network. It could have been supposed that as potential participant companies became aware of possibilities for waste and by-product exchanges in the symbiosis they would have eagerly searched partnerships with the current member companies of the symbiosis. The most probable reason why not many new partners joined the symbiosis is that there simply wasn't (and isn't) many new possibilities for exchanges which create enough economic benefit for the parties.

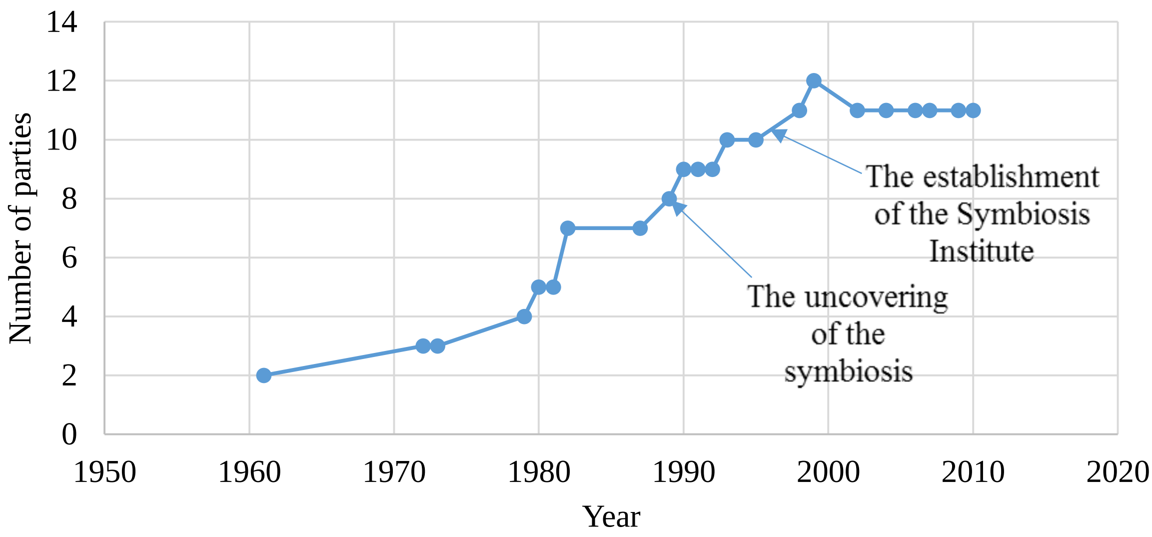

Figure 4. The number of parties in the Kalundborg symbiosis

In the Figure 5 we see that unlike the number of parties, the number of exchange relationships has continued to increase. In other words, the most of recent new exchange relationships take place among the existing parties of the symbiosis. By comparing the Figures 4 and 5, we can conclude that the Symbiosis Institute has rather promoted the establishment of new exchanges among the existing parties than the involvement of new parties. Because the existing parties are already located in Kalundborg it is easier for them to benefit of new exchanges (because they don't need to incur the costs of location). Therefore even the exchanges with somewhat small direct economic benefit can be profitable to them.

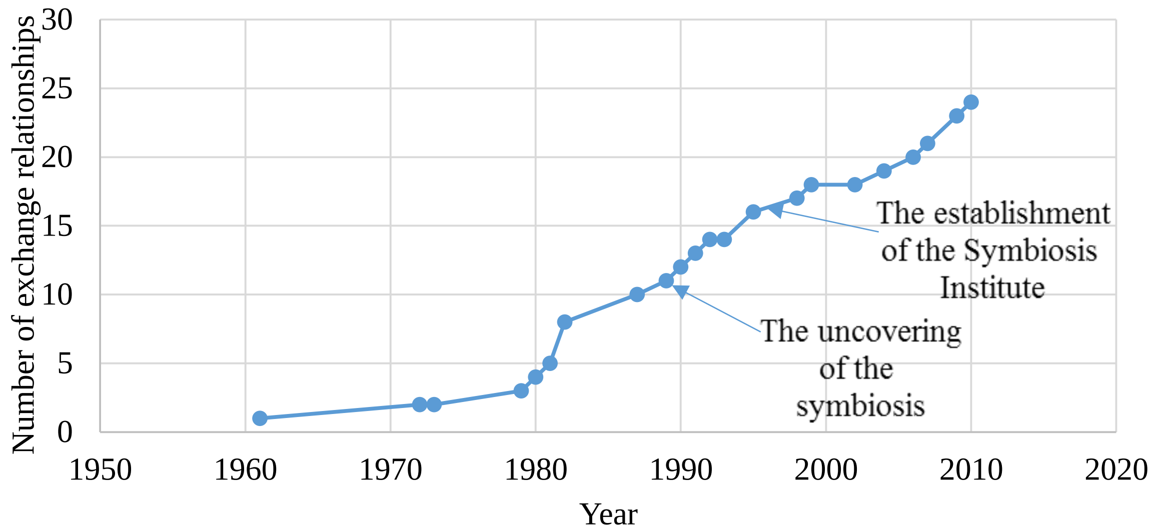

Figure 5. The number of exchange relationships in the Kalundborg symbiosis

The Figure 6 on the next page highlights the earlier results by showing that in general the average number of exchange relationships for one party has increased at an accelerating pace. This is because the number of exchange relationships has increased much faster than the number of parties. The values of the Figure 6 have been calculated with the following equation:

$$\text{Exchanges/party} = \frac{2 \times \text{The number of exchange relationships}}{\text{The number of parties}} \tag{1}$$

The dividend has the coefficient 2 because each exchange relationship has two parties.

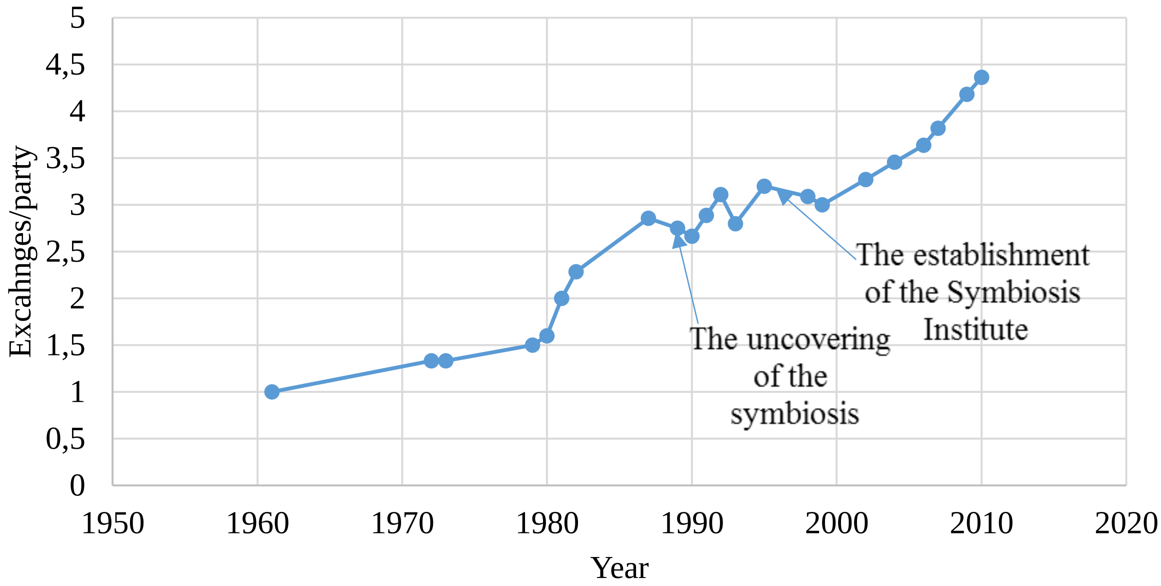

Figure 6. The average number of exchange relationships for one party

The final conclusion of the analysis of Kalundborg isn't that publicity (by the press and other media) and coordination (as exercised by the Symbiosis Institute) are not means to involve new symbiosis member companies. Rather the conclusion is that if the further development of an individual symbiosis network cannot anymore offer high enough additional economic benefits to new participants, publicity and coordination cannot themselves improve the situation. It can be said that an individual symbiosis network has then reached its maximum number of members. The development actions should instead concentrate on other symbiosis networks which have less participants and exchange relationships. Here may lie a societal phenomenon which can hinder the optimal development of symbiotic networks in general. If some symbiosis network is very large, it gets more publicity (because large things are impressive). Therefore development efforts concentrate on these large networks. However, these large networks may not benefit from developmental actions to the same extent as smaller, less developed networks. However, these smaller networks are less likely to be noticed and third parties are not as interested to develop them. Because developmental efforts are targeted to wrong networks, these efforts produce weaker results than in the situation where they are directed towards less developed networks. These less developed networks are also less likely to be found. The most developed symbiosis networks are likely built around very large and well-known companies, and these companies first come to mind (that’s why they are well-known) to the people who uncover networks. Less-developed networks are built around somewhat less well-known companies or companies whose industry isn’t generally associated with waste and by-product utilization.

Another reason for the ignorance of less developed networks is that because there are more companies in a very developed symbiosis network, the probability to “hit” the network is much higher. The mapping of a symbiosis network can be started from any of the member companies and every time the whole symbiosis network can be uncovered (as one exchange relationship leads to another). This means that if there are 9 companies in the symbiosis network A and 3 companies in the symbiosis network B, the symbiosis network A is 9/3=3 times more likely to be uncovered. The only way to direct the developmental efforts to those smaller networks which benefit from extra development is to systematically search new networks, for instance by examining companies in a certain geographic area or in a wide range of different industries. Also a single large corporation may have several distinct symbiosis networks, some of which are less developed than others and which have more potential for further development. If information doesn’t flow effectively between the corporation’s distinct networks, the possibilities for development may not become known when the developmental efforts concentrate on a limited amount of existing networks.

6.2 Average size of symbiosis networks

Because it seems that symbiosis networks reach an optimal developmental stage where their number of exchange relationships and participant companies doesn’t increase significantly anymore, the sizes of currently existing successfully operating industrial symbioses can be possibly used to estimate the average size of a fully developed symbiosis network. In their recent study, Layton et al. (2015) have collected information about the size of 48 eco-industrial parks through literature reviews and internet searches. Their original data has been provided as a supplementary material to their research article. In this thesis the data has been used to determine the average number of symbiosis participants and the average number of exchange relationships. Those eco-industrial parks of the original data set, which have failed or are currently inactive and those parks which have only been proposed (they have not yet been realized in practice) have been removed from the set. This leads to a set of 31 currently existing eco-industrial parks (which includes also the Kalundborg symbiosis).

It was tested with the statistical analysis program IBM SPSS Statistics 23 whether the values of the number of symbiosis participants and the number of exchange relationships followed the normal distribution by using the one-sample Kolmogorov-Smirnov test (Metsämuuronen 2004, 66-69). It was found out that the number of participants didn't follow the normal distribution. However, by using the one-sample Kolmogorov-Smirnov test it was discovered that the distribution of the numbers of participants was significantly different from the uniform distribution. According to the one sample Kolmogorov-Smirnov test the number of exchange relationships followed the normal distribution. Therefore the range of the average number on exchange relationships was defined with the one-sample t-test (Metsämuuronen 2002, 62-64). According to the one-sample t-test the average number of exchange relationships is in the range 16-23. All the statistical tests described above were evaluated at the level of significance of 0.05. Because both variables weren't normally distributed, non-parametric rank correlation coefficients, Spearman's rho and Kendall's tau, were calculated for the number of participants and the number of exchange relationships and their significance was tested (Metsämuuronen 2004, 243-244). It was found out that according to both tests there was a significant positive correlation between the number of participants and the number of exchange relationships (at the level of significance of 0.001).

A linear regression was defined for the two variables (Metsämuuronen 2001, 71-74). Because the number of exchange relationships is zero when there are zero participants, the constant was excluded from the equation. The number of exchange relationships, *ER*, depends on the number of participants, *P*, according to the following equation:

$$ER = 1.702P \tag{2}$$

The coefficients of determination are very good, $R^2 = 0.912$ and adjusted $R^2 = 0.909$, so the equation explains very well the correlation between the variables (Metsämuuronen 2001, 66). The equation is adequate at the level of significance of 0.001. By using the determined range of the average number of exchange relationships we can apply the regression equation the estimate the range of the average number of participants. First the lower bound of the range is calculated:

$$P_l = \frac{ER_l}{1.702} = \frac{16}{1.702} \approx 9.4007 \approx 9$$

The upper bound of the range is the following:

$$P_u = \frac{ER_u}{1.702} = \frac{23}{1.702} \approx 13.5135 \approx 14$$

On the basis of the statistical evaluation, it can be said that on the average symbiosis networks have 9-14 participants (which are usually companies) and on the average these participants have 16-23 exchange relationships. However, the estimated number of exchange relationships is much more likely to be accurate than the estimated number of participants, because only the values of the number of exchange relationships follow the normal distribution. This is consistent with propositions presented at the beginning of this chapter which stated that a symbiosis network can involve only a certain number of economically profitable exchange relationships. Therefore the number of participants is less precise as these exchange relationships can take place among few or very many participants. Although in the case of Kalundborg the number of participants reached its maximum before the number of exchange relationships, this doesn't imply that the number of participants is a real limiting factor for the symbiosis. New partners haven't joined because there aren't potential exchange relationships which are profitable enough. Besides, as stated earlier in the subchapter 6.1., new exchange relationships have not been initiated since 2010, so it seems that the increase of exchange relationships has also slowed down.

There are several reservations which can be presented towards the approach of estimating the potential size of a symbiotic network from the current sizes of existing networks. First, there always exists some average numbers of participants and exchange relationships. It is possible that in the future these averages change. It may be that because waste and by-product exchange networks are still quite in the early phase of their development they haven't yet grown to involve the greatest potential number of participants. Still, the averages tell what is generally possible and can be expected in symbiosis network development. This is important in order to recognize too grandiose and too pessimistic ideas about the possibilities of a single symbiosis network. Another reservation is that on the average the developers of symbiosis networks may not have applied best possible methods (for example, effective coordination and the creation of relationships through information and communications technology) and therefore the symbioses have developed more slowly than could be possible in optimal circumstances. The third reservation is that the studies like the one presented in this chapter could have created negative expectations about the potential size of symbiotic networks and therefore symbiosis developers have been too careful and haven't invested heavily enough to extend their networks. In other words, research results have created "a circle of negativity". When it has been initially found out that symbiosis networks have generally involved only limited number of members, the current members of symbioses have decided not to invest much to the search of new partners. The lack of investment has caused that further studies have confirmed the limited size of exchange networks. These researches have further made symbiosis developers too careful in their actions. This circle between limited results and insufficient investments has continued as further studies have emerged. This kind of phenomenon is very unlikely to take place because currently there isn't many studies about the average size of symbiosis networks. The article by Layton et al. is the only one found in the literature search for this thesis and the results of this subchapter have been gained by analyzing their original dataset, not from the text of their original article.

7 PROCESS MODELS FOR SYMBIOSIS DEVELOPMENT

At the beginning of this chapter three different process models for industrial symbiosis development are explained. These are the only currently existing process models on industrial symbiosis. After the models have been presented, a common structure behind the models is outlined and the three models are integrated into a single model according to this structure.

Liu et al. (2015, 319-320) have proposed the three-level approach that has been implemented in the symbiosis of the Hai Hua Group in China. Their approach combines industrial symbiosis and cleaner production (Liu et al. 2015, 319). The approach involves three phases:

- the training and information gathering which is conducted at the regional level and aims to raise awareness and gather information of the whole region for the approach (including identifying existing symbiotic relationships),
- the cleaner production audit which is executed at the firm level and identifies wastes and by-product and seeks the internal improvement opportunities within individual plants,
- the eco-industry development plan which is prepared at the inter-firm level and regional level and which explores the potential symbiotic links within the industrial symbiosis and the whole region (Liu et al. 2015, 320).

The training and information gathering establishes organizations which ensure that the approach will be successfully implemented, help the people of the local region understand the concept of cleaner production and industrial symbiosis and gather the required information (Liu et al. 2015, 320). The cleaner production audit identifies the potential opportunities to reduce wastes, raw materials and toxic substances, so that individual companies can gain both economic and environmental benefits (Liu et al. 2015, 321). The firms are also encouraged to put forward opportunities for establishing waste and by-product exchange relationships with other firms. Once a waste or by-product is identified, changes can be made to a process to reduce or eliminate the waste or the wastes can be utilized by other company in a manner that benefits both companies and/or the natural environment. (Liu et al. 2015, 322) The regional eco-industry development plan aims to seek and identify potential ways to utilize wastes and by-products both at the inter-firm level and the regional level (Liu et al. 2015, 322).

In the research which implemented the three-level approach, all the companies that carried out the cleaner production audit achieved economic and environmental benefits at the individual firm level. Operating exchange relationships were discovered and potential exchanges were identified at the inter-firm level. (Liu et al. 2015, 326) The problem of this process model is that it has been realized in the centrally planned economy of China where there exists strong regional coordination which enables this sort of approach. This approach cannot possibly be implemented without the presence of strong regional coordination. Therefore the approach should possibly be carried out only at the individual firm and inter-firm levels in other countries.

Costa and Ferrão have proposed a middle-out process for symbiosis development which has been implemented in the municipality of Chamusca in Portugal (Costa & Ferrão 2010, 986). The middle-out process also considers the national level in addition to the regional, inter-firm and individual firm levels of the three level approach. In the middle-out approach different agents (national, regional and local government, industries and other institutions) work together to change the relevant factors (for example legislation) in an industrial symbiosis' external business environment (which Costa and Ferrao call "context") more favorable to the symbiosis' development (Costa & Ferrão 2010, 985, 987, 991). The business environment is developed through right interventions (for example, legislative changes) and the development of favorable environment encourages the initiation of waste and by-product exchanges (Costa & Ferrão 2010, 985, 991-992). After these interventions have been delivered, their effects to the development of industrial symbioses are monitored (for example, in order to find out whether new legislation really helps companies to better establish exchange relationships). On the basis of observations the agents then work to together to define and deliver new improved interventions (for example, new better laws are legislated to correct the deficiencies of former legislation). (Costa & Ferrão 2010, 991-992) In Chamusca, collaboration between the government, industries, university and other institutions at the national and local level during a five year period has resulted the waste and by-product exchanges that have taken place in the municipality (Costa & Ferrão 2010, 991-992). The national government has introduced the policy instruments and the local government has promoted social interaction at the local level through events where agents (for example, industries and the university) have engaged in interaction with each other (Costa & Ferrão 2010, 992). The middle-out process includes the following steps:

- the assessment of the national and local business environment's initial conditions,
- the identification of the principal agents that should be involved,
- the identification of current and expected interventions from the agents (e.g. policy instruments, coordination activities),
- the monitoring of actions and their impacts on the business environment,
- the feedback of information to the agents in order to carry out further interventions (Costa & Ferrão 2010, 992).

The challenge in the middle-out process is how to ensure the balance between the contributions of government and industries. There is a danger that an intended middle-out process ends up becoming a planned eco-industrial park (which has been the least successful model for industrial symbiosis development, as stated in the chapter 2) if the participating businesses don't engage actively enough in the development. It is questionable how the public institutions can engage businesses without at the same time trying to influence and control them. Therefore autonomous, strong will on the side of businesses to develop symbiosis is a prerequisite for a successful middle-out process.

By reviewing the functionality of ICT systems for industrial symbiosis Grant et al. have identified a process model consisting of five primary industrial symbiosis developmental phases. These phases lead to the realization of actual waste and by-product relationships. The phases are:

- opportunity identification,
- opportunity assessment,
- barrier removal,
- commercialization and adaptive management,
- documentation, review, and publication. (Grant et al. 2010, 744)

In the Figure 7 on the next page those actions of the five phases which belong to the economic and strategic perspective of this thesis are highlighted in red rectangles (the not-highlighted actions belong mainly to the technology perspective):

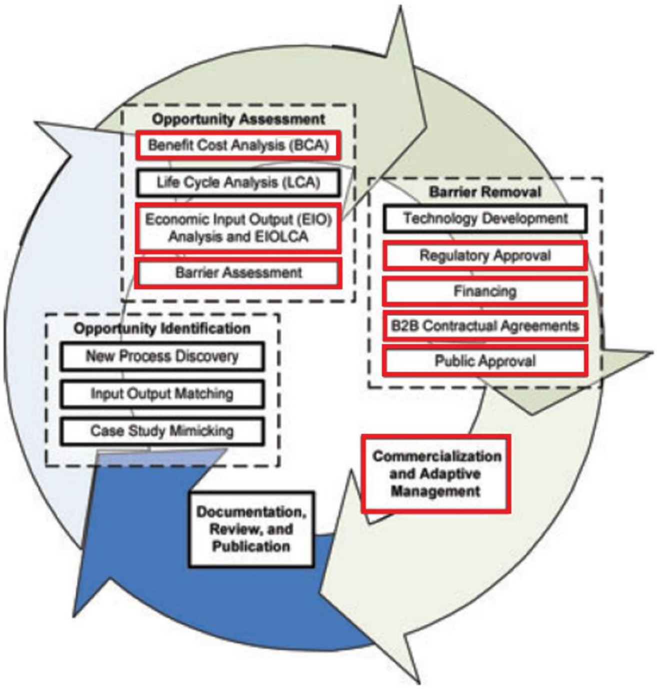

Figure 7. The industrial symbiosis development process model (Grant et al. 2010, 745)

There are three primary means to perform opportunity identification:

- New process discovery: A novel approach is created to transform a waste or by-product into a usable product.
- Input-output matching: It is found out that resource needs of a company can be fulfilled by the utilization of a waste and by-product which some other company produces.
- Relationship mimicking: A successfully operating exchange relationship between two companies is copied by other two similar companies. (Grant et al. 2010, 745)

Opportunity assessment evaluates the outcomes and challenges associated with a new innovation or process. Barrier assessment identifies challenges to the realization of the exchange relationship by assessing feasibility from the market, political, social, environmental, financial, and technical perspectives. Benefit/cost analysis primarily compares monetary outcomes of a decision on the basis of explicit quantifiable information. Process-based life cycle analysis assesses a product's environmental impact from raw material extraction to the end of life. Economic input-output analysis predicts the effects of economic changes in one industry on related industries by utilizing a matrix representation of economic flows between industries. Barrier removal overcomes or eliminates challenges associated with the realization of an exchange relationship. (Grant et al. 2010, 746) Commercialization means full-scale implementation of the by-product-based industrial process, and adaptive management provides a feedback loop for the continuous improvement of a firm's process and strategy based on internal and external assessment. By documentation, review, and publication the success of companies and their waste and by-product exchange relationships is communicated. (Grant et al. 2010, 747)

The basic structure of symbiosis management can be summarized from the three presented process models. This structure contains the common fundamental elements of the models. Different actors which potentially participate in the development of an industrial symbiosis each have a certain role and position in the structure. Environmental influence refers to those actions which aim to change the factors present in the external business environment of symbiosis so that the societal preconditions become more favorable for the operation and development of the symbiosis. The symbiosis network coordination refers to the specific actions which coordinate waste and by-product exchanges between the member companies of a particular industrial symbiosis. Because the size of an individual symbiosis network won't likely grow forever (as was stated in the previous chapter), one function can possibly coordinate several networks. The characteristics of the business environment can have powerful effect on different industrial symbioses as they take place at the wide societal and regionals levels whereas the coordination of a single symbiosis network has usually only a limited influence on the characteristics of environment due to the moderate size of the network. The three presented process models have differentiated between four levels: national, regional, inter-firm and individual firm levels. Environmental influence takes place mainly at the national and regional level whereas symbiosis network coordination takes place mainly at the inter-firm and individual firm levels.

The symbiosis network coordination occurs through information systems and systematic evaluation methods which also analyze developmental needs in the business environment. These identified development needs of the business environment are addressed in the environmental influence process where the main stakeholders, who have power to change the characteristics of the business environment, define and carry out actions to make the environment more favorable to the symbiosis development. These stakeholders include, for example, the representatives of the municipality and state, as they can bring about regulatory changes, representatives of media (f. e. newspapers and television) who can change public attitudes towards symbiosis, research organizations which can provide information necessary to the development of symbioses and the representatives of businesses. The most important business participants of the environmental influence process are anchor tenants as they are responsible for major symbiotic exchanges and the coordination of symbioses and therefore have understanding about the developmental needs of the symbiosis environment. Also management professionals who are central in the development and coordination of a symbiosis network should participate in the environmental influence process. These professionals can be individuals working directly for the symbiosis or representatives of companies which participate in the symbiosis management. The basic structure of industrial symbiosis management is presented in the Figure 8. As the anchor tenants and management professionals participate both in the symbiosis network coordination and environmental influence, the round-cornered boxes representing these actors pass over the sharp-edged boxes of both symbiosis network coordination and environmental influence.

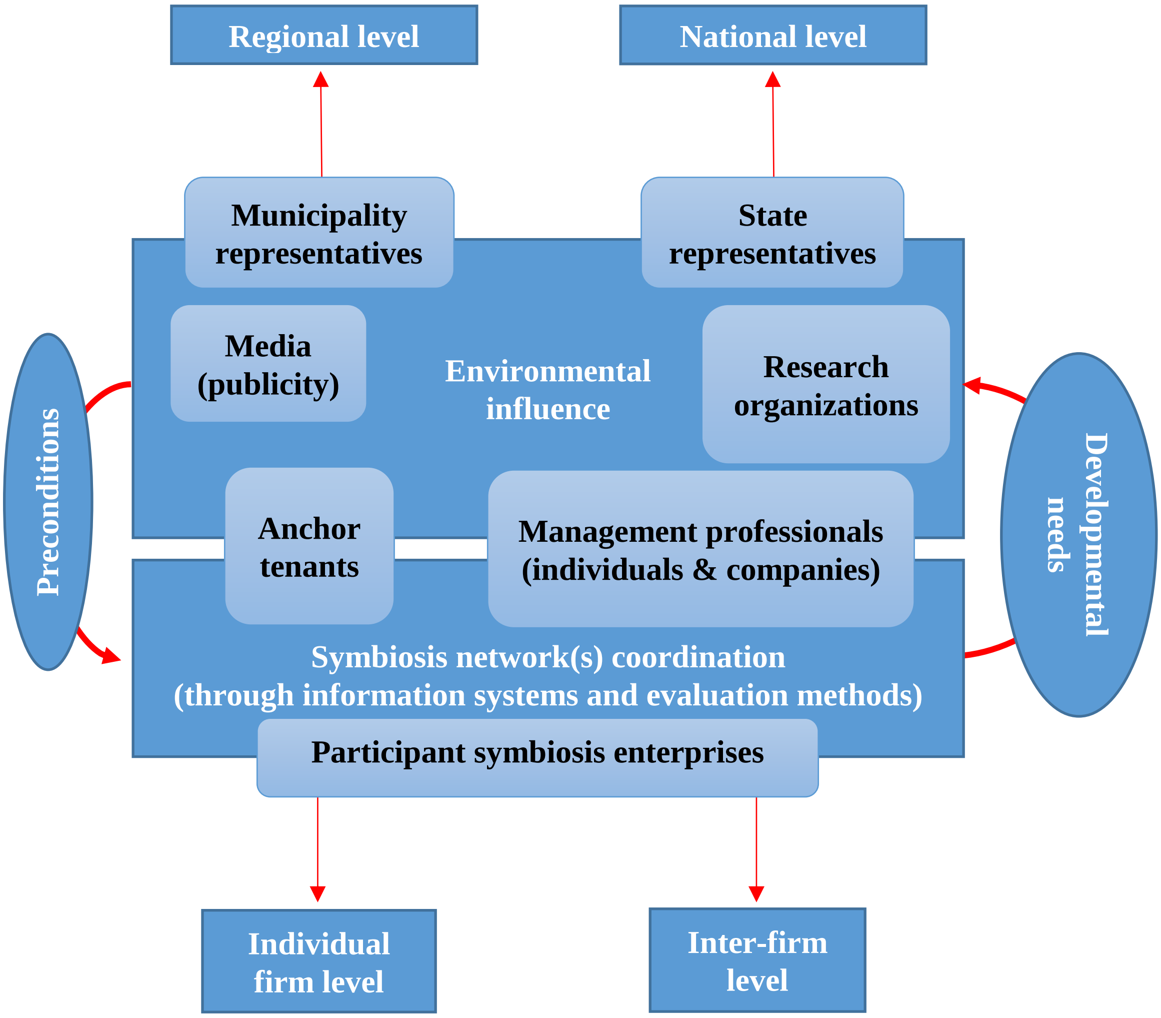

Figure 8. The basic structure of industrial symbiosis management

In the following figure the interrelationships between the three process models (by Costa and Ferrão, Grant et al. and Liu et al.) of symbiosis development are shown against the identified basic structure of symbiosis management. When their interrelationships are identified, their actions can be combined to form one integrated model. The Figure 9 shows only the elements Environmental influence and Symbiosis network coordination of the basic structure in order to maintain the clarity of the figure.

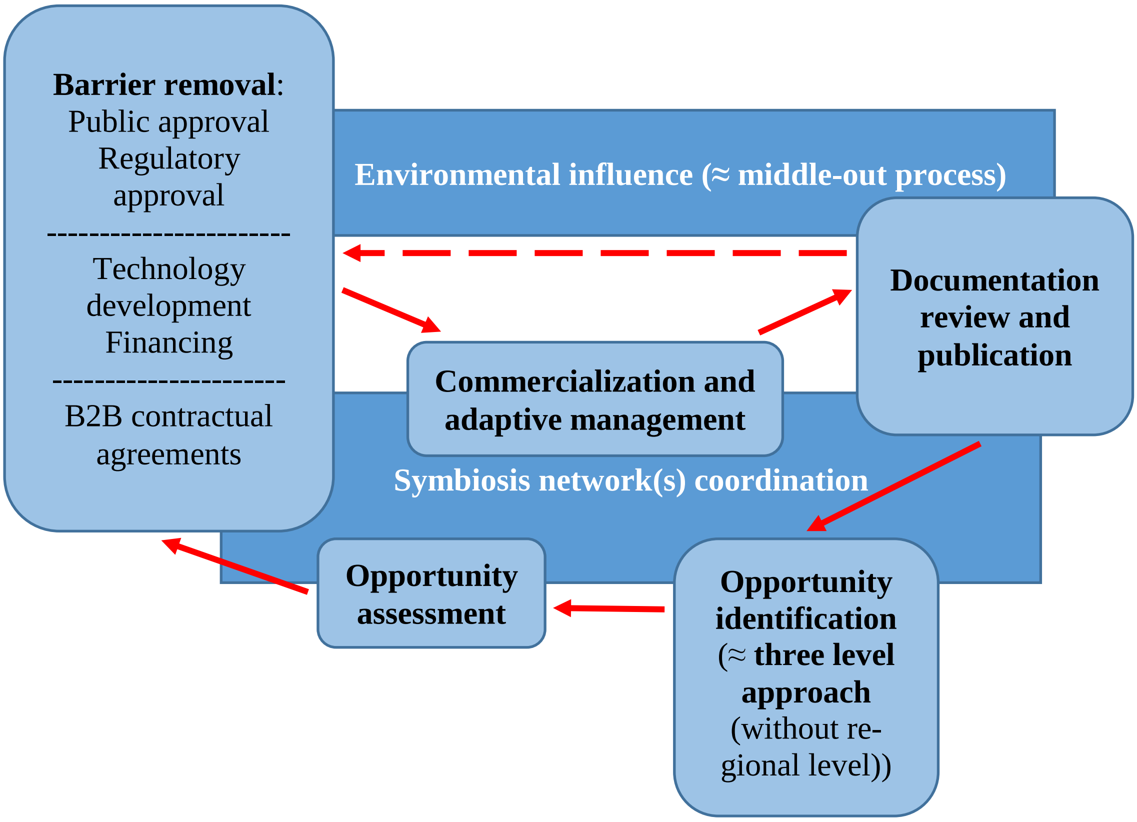

Figure 9. The interrelationships between the three process models

The middle-out process by Costa and Ferrão can be likened to the environmental influence process of the basic structure of symbiosis management. The factors present in the national and regional business environment are monitored by the actors which have capability to influence these factors to become more supportive for the symbiosis. After the analysis of the factors present in the environment, the interventions, which the actors participating in the environmental influence process should carry out, are defined and realized according to the conditions identified to be present in the business environment and according to measures available to actors. After the decided interventions have been carried out, their effects to the development of symbioses are evaluated. This evaluation provides information for the actors for further interventions which develop symbiosis preconditions continuously closer to the optimal state. In practice the environmental influence process can mean that, for instance, in order to change the legislation and public subsidies more favorable to industrial symbiosis, the representatives of a symbiosis systematically communicate with politicians and public servants in such organizations where all these parties are able to cooperate together.

The three level approach by Liu et al. can be applied in different national cultures if the regional level coordination of the approach is ignored, as this coordination originates from the centrally planned economy of China. The phases of three level approach can interpreted to belong to the opportunity identification phase of the model by Grant et al. When combined with the three level approach, opportunity identification begins with training, which teaches the potential members of an industrial symbiosis the central concepts of symbiosis, and information gathering in which existing symbiotic relationships are identified. After this, a cleaner production audit is performed at the individual firm level. The cleaner production audit identifies wastes and by-products and seeks opportunities for companies to reduce these wastes and by-products in a way which can lead to both economic and environmental benefits. Changes can be made to a process to reduce or eliminate the by-products and wastes or these wastes can be utilized by another company. The companies can put forward opportunities for exchange relationships with other firms. Finally, the coordinative function of the symbiosis network creates a development plan which finds and establishes exchange relationships within industrial symbiosis at the inter-firm level. In practice, opportunity identification could be carried out by establishing a program where some institutions would collaborate with the industrial companies that are present in a certain area or region in order to find opportunities for the initiation of the waste and by-product exchanges. Opportunity identification should be carried inside a certain region or area as it requires to study companies through face-to-face communication with them (it cannot be carried out exclusively through electronic information systems). For instance, teaching companies the concept of industrial symbiosis and evaluating technological opportunities for waste and by-product exchanges are best to be carried in face-to-face contact with company representatives.

In the model representing interrelationships between the three different process models the five phases (opportunity identification; opportunity assessment; barrier removal;

commercialization and adaptive management; documentation, review and publication) have the same meaning and content as in the model by Grant et al. Most of the five phases of the model belong completely to the symbiosis network coordination process, but both barrier removal and documentation review and publication belong partly to the environmental influence process. Public approval and regulatory approval belong to the environmental influence process as they are characteristics of the business environment. Technology development and financing can belong both to the symbiosis network coordination and environmental influence as they can take place both within symbiosis and in the business environment outside symbiosis. For example, both public institutions and the member companies of a symbiosis network can develop technology and provide financing for symbiosis development. B2B contractual agreements take place completely within symbiosis and thus belong to the symbiosis network coordination. Documentation, review and publication communicates knowledge about successful waste and by-product exchanges both internally to other symbiosis participants and externally to the wider public. It also promotes barrier removal because the news about successful waste and by-product exchanges can promote positive public opinion towards symbiosis.

It can be said that the operation of the internal coordinative function of a symbiosis network should be generally carried out according to the five phases of the model by Grant et al. Both the symbiosis network coordination (according primarily to the model by Grant et al.) and the environmental influence (according to the model by Costa and Ferrão) are iterative processes, where the outcomes of one cycle are used as informational inputs of the following cycle. In other words experiences gained during the implementation of these processes are used to advance future symbiosis development in these processes. A qualitative evaluation method, the industrial symbiosis maturity grid, which is described in the subchapter 8.13, can applied in the adaptive management phase to find out the stage of development and developmental needs of the symbiosis network. The solutions to the conflicts between the success factors and challenges, which are outlined in the chapters 3-5, can be applied in the barrier removal phase to find ways to mitigate barriers in the realization of industrial symbiosis and exchange relationships identified in the barrier assessment of the opportunity assessment phase.

8 SUMMARY AND ANALYSIS OF INTERVIEW ANSWERS

The preceding chapters have explained success factors, challenges, process models and limits for the development of industrial symbioses on a general level. In order to develop the industrial symbiosis of Kaukas in practice, it must be defined which concrete measures should be taken in order implement the aforementioned results. To define these measures, a series of interviews was conducted with six representatives of UPM Kaukas, one representative of Nordic Innovation Accelerator Ltd. and one representative of Green Campus Innovations Ltd. In the following subchapters those interview answers, which bring forward factors and possible problems that are relevant in the development of the Kaukas industrial symbiosis, are collected together and analyzed. The interview questions were largely based on the identified success factors and challenges of industrial symbioses which have been discussed in the chapters 3 and 4. On the basis of the analysis possible solutions are presented to the future challenges. At the end of this chapter symbiosis barriers and enablers in the case of Kaukas are evaluated according to the industrial symbiosis maturity grid by Golev et al. The appendices include the interview questions which the representatives of UPM (Appendix I), NIA (Appendix II) and GCI (Appendix III) were asked.

8.1 General information about the interviewed parties

Nordic Innovation Accelerator (NIA) will search technological utilization solutions and commercial users for companies' waste and by-product streams. NIA's premise for the selection partners is to look for Nordic cleantech (environmental technology) companies. The search can be also limited to concern a smaller group of potential partner companies. NIA can find exchange partners for wastes and by-products through its network which includes practically all the communities of the cleantech cluster, both in Finland and elsewhere in the world. The Finnish business networks, through which NIA can find exchange partners, include Cleantech Finland, the programs on sustainable development by Tekes, regional development companies (for example BusinessOulu and Ladec), business incubators and different programs (for example Smart Chemistry Park).

GCI will most probably invest in small technology firms, whose technology development is based on university research and whose technology has market demand. GCI can also invest in a larger company if other investors also take part in the investment, because its own investment potential is on a limited scale. Investee companies must develop technological waste and by-product utilization solutions which will be marketed in international markets, because in Finland there is no large enough market for a firm representing cleantech industry. Up to this point GCI has already invested in one technology solution related to the utilization of wastes and by-products. This is a technology, developed by Endev Ltd., which is used to recover phosphorus and heat from community waste. In addition to partner companies, Lappeenranta University of Technology and Saimaa University of Applied Sciences are the main partners of GCI, as they belong to the owners of GCI.

According to GCI, the division of duties in the Kaukas symbiosis development should be that Lappeenranta University of Technology will be responsible for the research related to the symbiosis development, Green Campus Innovations will take responsibility for building new businesses and Nordic Innovation Accelerator will search potential partners to take part in exchange relationships. GCI exploits its Executives in Residence –network, through which experienced process industry professionals participate in building new value chains. Up to this point initiatives for the utilization of wastes and by-products have come solely from UPM Kaukas, but in the future NIA and GCI will search initiatives associated with the Kaukas symbiosis also from other potential partner companies.

At the moment UPM is a member in such business networks in which network members look for the utilization solutions of wastes and by-products. Such networks include Green Energy Showroom in Lappeenranta; the network of Sitra; CLIC Innovation, in which universities, research institutes and companies carry out research programs related to the utilization of side streams, and the BIC-association (Bio-based Industries Consortium), which operates in the EU and through which research programs are executed and funding is channeled into plants which pilot new technologies.

8.2 Understanding and use of the concept of industrial symbiosis

The definitions of industrial symbiosis given by the representatives of UPM, NIA and GCI were very similar with each other. The original definitions, which the interviewees gave, have been provided in the Appendix IV. Below an average definition of industrial symbiosis

has been constructed from the answers given by all the interviewees. This average definition is very similar to every definition obtained in the interviews.
Companies, which operate in a same industrial region or site, exchange wastes and by-products and other utilities, like energy, with each other and use the raw materials and utilities obtained through the exchange in their production.

The obtained definition closely resembles the earlier definitions of industrial symbiosis and summarizes well the basic idea of symbiosis. Therefore it can be concluded that the concept of industrial symbiosis in its basic form is well adopted among the interviewees and that the idea of symbiosis clearly isn't difficult to understand and adopt. If we compare the definitions given by the interviewees to the currently newest definition of industrial symbiosis given by Lombardi and Laybourn in 2012 (summarized in the chapter 2), we however find some elements which didn't come forward in the answers given. Any of the interviewees didn't mention that through cooperation in a network it is possible to create a culture which promotes symbiosis development and through the cooperation create and share knowledge for the development of technical and business processes. This result can be summarized by saying that the definitions given by the interviewees concentrated more on the realization of individual waste and by-product exchange relationships than on the wider perspective of network cooperation. The reasons for this characteristic are probably that the individual exchange relationships are the most easily observable part of industrial symbiosis and that the interviewees don't yet have experiences of the developed cooperation in the Kaukas symbiosis network.

At the moment the concept industrial symbiosis is used to some extent in UPM and Kaukas. The concept is quite new and it has been used in UPM's communication for about a year. At the moment it is used mainly in communication with external stakeholders (for example, the city of Lappeenranta) and very little in the internal communication of the Kaukas mill. In the future, the concept of industrial symbiosis is intended to be present more visibly in UPM's communication. In the case of UPM, we can conclude that at this point the concept of industrial symbiosis is rather a marketing tool which is used to facilitate collaboration with potential partners than a paradigm which has been internalized by the entire personnel. In the future, it should be ensured that industrial symbiosis is not discussed only in communication with business partners, but that the personnel in the companies participating in the

Kaukas symbiosis will internalize the approaches of symbiosis and will apply them in their daily work. The concept of industrial symbiosis has appeared to some extent in the discussions which NIA has had with its customers, but the concept is not used in the company's other communications. GCI states that at the moment it uses the concept of industrial symbiosis frequently in its corporate communications.

At the moment any special methods are not used to ensure that UPM's personnel and external stakeholders will understand and adopt the concept of industrial symbiosis. Currently other related concepts such as circular economy are used more often in UPM's communications instead of industrial symbiosis. At the moment UPM is working on a communication strategy on circular economy, which also includes industrial symbiosis. In the near future training sessions on circular economy and industrial symbiosis will be held for the personnel of the technology function. GCI carries out the dissemination of the concept of industrial symbiosis through the discussions it has with its stakeholders. It can be concluded that the systematic dissemination of the concept of industrial symbiosis with different means of communication is just in the beginning, and that this dissemination work should be carried out more systematically according to a communication strategy especially created for this purpose. The aforementioned perspective of collaboration in the symbiosis network should be emphasized in the communication. The concept of industrial symbiosis could be most effectively disseminated to potential partner companies through initiatives on waste and by-product exchange and utilization. When the companies perceive potential tangible benefit in the adoption of the concept they are more likely to work to understand and adopt it. General presentations, trainings, newsletters and other documents can have some effect but they may also easily be ignored, if potential partners don't have a practical reason to use the concept. Going through a project which finds uses for wastes and by-products illustrates the operation and benefits of industrial symbiosis to partner companies in practice.

At this moment there are lots of different terms used in the communications of companies and other business actors which are closely connected to the same subject area as industrial symbiosis. Such terms are, for example, circular economy and ecosystems. Metsä Group's bio-product factory in Äänekoski practically very much resembles industrial symbiosis in its operation, but still it is called a bio-product factory. For Kaukas, the use of the term industrial symbiosis can be a way to differentiate itself from other players in the field, but on the other hand the new term should be marketed actively in order to make potential partners internalize it and to ensure that the concept doesn’t lose competition to other terms. However, anyone of the interviewees, who was asked for an opinion about the concept of industrial symbiosis, didn’t think that industrial symbiosis is a bad concept for the marketing of the upcoming waste and by-product exchange collaboration in Kaukas and that it should be replaced with some other concept.

8.3 Identification of symbiotic relationships

The currently active waste and by-product exchange relationships of the companies, which are present in the Kaukas industrial area, have been explained in the Table 5. Currently UPM Kaukas, Kaukaan Voima Ltd. and Co-operative Otsina are the only parties of the exchanges that are located in the industrial area of Kaukas. The other exchange parties operate in other locations. The table tells the utilizer of a waste or by-product, the industry in which the waste or by-product is utilized, the supplier of the waste or by-product and the name of the supplied waste or by-product and how the supplier processes it (if necessary) before delivery to the utilizer. In addition to interview answers, online documents were used to clarify the nature of exchange relationships in the case of Kekkilä Group (UPM 2015c), Soilfood Ltd. (Tyynelän tila 2016, Soilfood 2016) and Co-operative Otsina (Otsina 2016).

Table 5. The waste and by-product exchange relationships of the companies in Kaukas

Utilizer	Utilization industry	Supplier	Supplied wastes and by-products
Kekkilä Group	soil-improvement and fertilization	UPM Kaukas	barksand
Soilfood Ltd. (previously called Tyynelän maanparannus Ltd.)	soil improvement and fertilization	UPM Kaukas	lime (slaked), lime mud, sludges (composted)

Table 5. The waste and by-product exchange relationships of the companies in Kaukas (continued)

Utilizer	**Utilization industry**	**Supplier**	**Supplied wastes and by-products**
Kaukaan Voima Ltd.	energy production by combustion	UPM Kaukas	the primary and secondary sludge from the wastewater treatment plant, bark from the mill
Kuljetus Kilpiä Ltd.	land construction	Kaukaan Voima Ltd.	ashes
Kuusakoski Ltd.	recycling	UPM Kaukas	scrap metal
Co-operative Otsina	creative design	UPM Kaukas	sawing waste
UPM Kaukas	land construction (field structure)	Lemminkäinen Group	asphalt residue
UPM Kaukas	biorefining	other forestry companies	tall oil

Currently in Kaukas there is not yet present such symbiosis network, in which UPM's waste and by-product exchange partners would cooperate with each other. UPM Kaukas has individual exchange relationships with different companies, but these partner companies don't network with each other or cooperate, at least not in the context of the Kaukas symbiosis. We can therefore say that at present UPM is the other party in almost all the exchange relationships of the symbiosis (when the relationship between Kaukaan Voima and Kuljetus Kilpiä in excluded). The structure of the current symbiosis network in Kaukas is illustrated in the following Figure 10 on the next page.

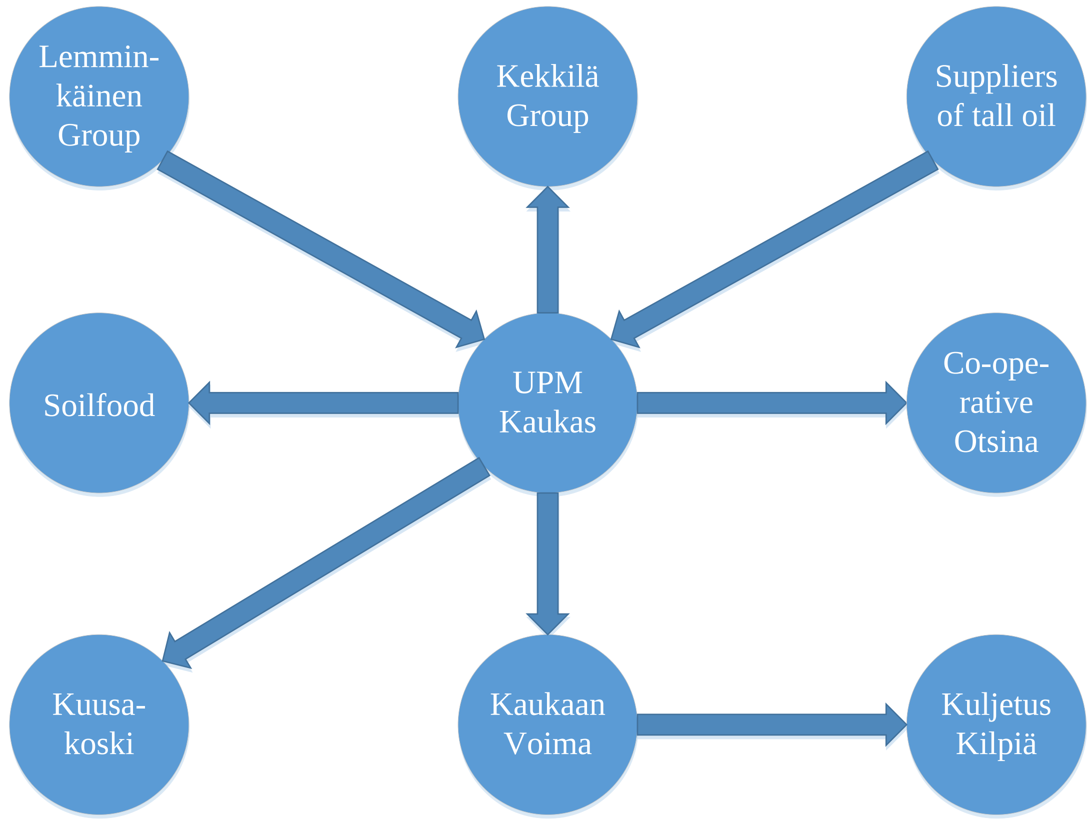

Figure 10. The current structure of the network of exchange relationships of Kaukas

The current symbiosis network of Kaukas is a typical example of the "anchor tenant" type mutualism of industrial symbiosis networks (identified by Zhang et al. 2016, 361) in which the core enterprises deliver by-products and wastes to affiliated downstream enterprises and in which the affiliated enterprises mostly exchange resources with the core members (in other words, they rarely or never exchange resources with each other). This means that if the core enterprises (in this case UPM) change their production processes, they may no longer provide enough by-products or wastes to downstream enterprises making the network unstable because some of the former paths would disappear. It is possible to mitigate the dependency of the affiliated member enterprises on the core members by establishing symbiotic connections among them and this way bring unexpected information and opportunities to them. (Zhang et al. 2016, 361) NIA has planned to supply a web service for the symbiosis, and in the development of this service it is crucial to focus on collaborative communication between the existing and potential member companies of the symbiosis so that companies can independently network with each other and form exchange relationships. Companies should be able to communicate the wastes and by-products or the utilization, solutions which they will supply, to a wide group of potential partners. This web service can be a measure by which the development of the symbiosis network of Kaukas is directed away from the anchor tenant mutualism towards “equality oriented” mutualism where the members of the network have relatively equal roles and the network doesn’t rely excessively on a single node (like UPM Kaukas) (Zhang et al. 2016, 359).

At the moment in Kaukas there exists one case of the basic type of industrial symbiosis identified in research literature, which consists of at least three different entities, not primarily engaged in recycling-oriented businesses, exchanging at least two different resources. The basic type of symbiosis has been defined to distinguish more complex network structures from isolated waste and by-product exchange relationships between two parties. (Chertow 2007, 12) The term “entity” has been interpreted in the case of Kaukas as company. If entities would be different production units of a same company, then it could be much easier to find the basic type of symbiosis. However the exchange relationships within a same company don’t demonstrate the same kind of collaborative capability which is required in the establishment of inter-firm exchange relationships. Because collaboration between companies is required in the future development of the Kaukas symbiosis, the stricter interpretation has been adopted in the identification. UPM Kaukas delivers the primary and secondary sludge from its wastewater treatment plant and bark from its mill to be combusted in the power plant of Kaukaan Voima Ltd. Kaukaan Voima then delivers its ashes to Kuljetus Kilpiä Ltd. for the use in land construction. Their primary businesses, pulp and paper production (UPM), energy production (Kaukaan Voima) and land construction (Kuljetus Kilpiä) are not recycling-oriented. Kaukaan Voima Ltd. is a joint venture of Lappeenrannan Energia Ltd. (which owns 46 % of the shares) and Pohjolan Voima Ltd. (which owns 54 % of the shares) (Pohjolan Voima 2016a). UPM-Kymmene concern owns 43.7 % of the shares of Pohjolan Voima (UPM Kymmene Corporation owns 42.83 % and Myllykoski Corporation, a member of the concern, owns 0.87 %), so UPM is indirectly a party in the joint venture (Pohjolan Voima 2016b). However, joint ventures are not excluded from the definition of the basic type of industrial symbiosis and other partners of the joint venture still own the majority of the shares, (46 % + 54 % * (100 - 43.7) % ≈ 76.4 %). According to research, the existence of a nascent self-organized industrial symbiosis indicates that the symbiosis is much more likely to develop into a highly sustainable network compared to the situation where symbiosis is non-existent and would therefore be planned completely from scratch. This is because the existence of a nascent symbiosis demonstrates that exchange relationships of the current firms of the symbiosis can be profitable and based on solid economic arguments and because the existence of the current exchange relationships shows that the firms have enough expertise to initiate new exchanges. (Chertow 2007, 26; Chertow & Ehrenfeld 2012, 23) Due to the existence of a nascent self-organized symbiosis the current industrial symbiosis of Kaukas has realistic possibilities to develop further into a more profitable and sustainable network. Because the basic type of industrial symbiosis has been found in the exchange relationships of the area of Kaukas, it can said that this thesis has uncovered a nascent industrial symbiosis in Kaukas (according to the chapter 3.1). The structure of the basic type of industrial symbiosis involving a minimum of three different entities exchanging at least two different resources is illustrated in the Figure 11 below. The shapes represent entities (companies) and the arrows represent exchange relationships.

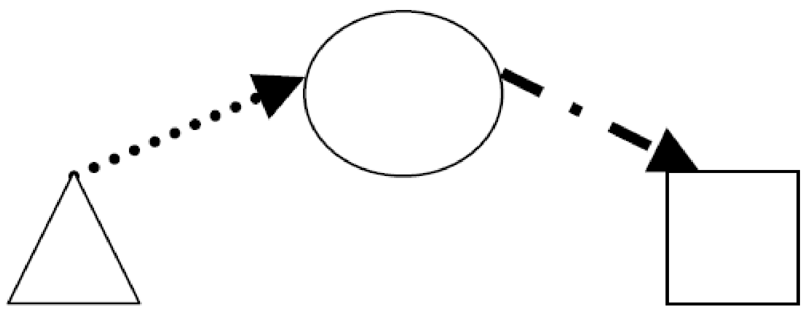

Figure 11. The basic type of industrial symbiosis (Chertow 2007, 13)

The creation of waste and by-product exchange relationships in Kaukas has originated from the need to decrease the amount of waste which is landfilled. This need has resulted from the large opening and closing costs of a landfill, taxation and legislation. UPM Kaukas has considered potential applications for the wastes and by-products, which the company itself doesn't use, and has contacted a potential user it has identified. A potential user has also often independently searched a waste or by-product which it has needed and has contacted Kaukas for this reason. In other words UPM Kaukas has found its current waste and by-product exchange partners solely through direct contacts. On the basis of interviews no third party was found, which would have certainly taken part in the creation of an exchange relationship between UPM and a user or supplier of a waste or by-product. Thus collaboration in a network, which involves a third party that takes responsibility in building exchange relationships, is a completely new kind of situation for UPM and Kaukas.

At the mill level (in this case, in Kaukas) the environmental manager is responsible for the cooperation on the exchange of wastes and by-products with other companies. UPM Research Center in Lappeenranta currently hosts a program, in which applications are searched for waste and by-product streams. Moreover, UPM currently runs a program, which aims to close all the landfills in the mill locations. Also at the concern-level UPM seeks partnerships in order to find technological utilization solutions for wastes and by-products.

8.4 Symbiosis coordination

It is realistic to assume that UPM will very probably be the largest individual member of the Kaukas symbiosis when comparing the size of its revenue to the revenues of the other member companies. Therefore the decisions it makes can very easily define the future development of the businesses of other participating member companies. For this reason the network of exchange relationships between the other member companies of the symbiosis must be strong enough, so that they can also operate together independently from UPM. There can be a risk that if UPM acts as an anchor tenant, it can acquire an overly central position in the collaboration, which can hinder the cooperation between the other participant companies of the Kaukas symbiosis so that these other companies don’t form symbiotic relationships with each other or with new member companies effectively. Therefore the Kaukas symbiosis needs a function for coordination and management, which will take all the participants of the symbiosis into consideration and help them all to form new exchange relationships. Also NIA stated that, instead of UPM, the symbiosis network of Kaukas should be coordinated by a function which is independent of any individual company, so that no single company could affect too much the operation of other participating firms. The current symbiosis network of Kaukas manifests the tendency of preferential growth (which is explained in more detail in the subchapter 3.2) and the coordinative function could implement measures to overcome preferential growth by promoting capabilities of all the symbiosis participants to build exchange relationships.

In the coordination of the symbiosis it is important to carefully define the division of responsibilities between anchor tenants (UPM), GCI and NIA in order to ensure that the Kaukas symbiosis will be led equitably. NIA and GCI have expressed their willingness to take part in the creation and management of the coordinative function of the Kaukas symbiosis. NIA's task would be to supply a web service for the creation of waste and by-product exchange relationships. Many representatives of UPM thought that UPM can act as an anchor tenant of the symbiosis, but this idea was also opposed on the basis that the waste and by-product exchange relationships which come into existence as a result of the symbiosis don't belong to the core businesses of Kaukas at the moment. According to the integrate management, UPM is ready to take a lot of responsibility for the coordination of the symbiosis network only in the case that the company can obtain lots of additional revenue through exchange relationships.

Currently UPM follows the economic profitability and environmental friendliness of its waste and by-product exchange relationships. However, there doesn't exist such a function, which would be independent of any individual firm and which would coordinate the overall economic profitability and environmental friendliness of the Kaukas symbiosis (in other words, the exchanges of wastes and by-products) from a perspective which considers all the symbiosis member companies equally. At the moment any party, which is independent from individual companies (like UPM), doesn't monitor the equality of the division of profits and costs in the businesses which take place between the companies participating in waste and by-product exchange relationships. UPM follows the costs of its own waste and by-product exchange relationships on a monthly basis. Up to this point it has been possible to define the equal division of profits and costs between the parties accurately enough during the contractual phase of UPM's business relationships. The uneven distribution of costs and profits hasn't been a reason for a party to withdraw from an existing relationship in the case of the business relationships of UPM or Kaukas. The division of costs and profits can possibly pose a greater challenge when the symbiosis network in Kaukas grows in size and complexity. In that situation some way for redistributing symbiosis costs (and therefore profits, as they are related to costs) may need to be introduced.

8.5 Legislation affecting the symbiosis

For companies, legislation is the primary external factor which at present hampers the exchange of wastes and by-products. The exchange is constrained by several laws like the Environmental Protection Act and the Fertilizer Act. Legislation doesn’t take into account several potential waste and by-product utilization solutions and prevents their practical implementation. For example, the transportation of wastes across national borders is restricted in the European Union, which hampers the implementation of pilot plants in other countries. The directive on the incineration of waste prevents in certain cases the separation of raw materials from wastes by thermal treatment. The changes of legislation are also slowed down for the reason that they are often decided at the EU-level.

The UPM representatives brought up several developmental needs in the laws which regulate the exchange of wastes and by-products. The laws, which regulate the utilization of wastes and by-products, should be uniform in the member countries of the EU. At present legislation varies between the member countries and, for example, in some countries concentration limits for usable waste are smaller than in other countries. Therefore products manufactured from wastes and by-products can be sold in some countries and in other countries not. Legislation should concentrate on regulating final products instead of regulating by-products and wastes which are used in the production of these final products. Laws should take more into account different new products, which can be manufactured from wastes and by-products, and permit their production in practice. EU legislation should enable the aforementioned transportation of wastes and by-products across national borders in utilization cases. The development of legislation should also be predictable. For example, tax incentives can be disadvantageous in the long run, because they can be suddenly removed, and therefore they can increase business risk.

8.6 Significance of direct and indirect economic benefits in marketing

According to the answers of the representatives of UPM, NIA and GCI indirect economic benefits, which industrial companies can generally achieve through the establishment of symbiosis and the initiation of waste and by-product exchange relationships, include the change of legislation to better enable waste and by-product exchanges and getting funding for the realization of the waste and by-product utilization solutions. Indirect economic benefits (which are explained more thoroughly in the subchapter 3.4) are such economic benefits which cannot be calculated in detail before the initiation of an exchange relationship and which are not allocated clearly to some certain product. This kind of benefits are, for instance, risk reduction, diversification, asset utilization, improved community or government relations and improved firm or brand reputation.

As stated earlier, for companies legislation is the most important external factor, which currently hampers the exchange of wastes and by-products. Exchange relationships can create public environmental benefits which foster the welfare of society. The most likely public environmental benefit, which UPM can achieve in the near future, is zero waste to landfill policy, as it reduces environmental pollution. Other possibly achievable environmental benefits are associated, for instance, with the reduction of greenhouse gas (for example, carbon dioxide) emissions. By marketing public environmental benefits the awareness about the advantages of industrial symbiosis is disseminated through the society and therefore the importance of favorable legislation that promotes the exchange of wastes and by-products is understood among those parties, who influence the development of legislation. The marketing of environmental benefits can also facilitate obtaining funding for the realization of utilization solutions. One UPM representative considered that currently there's a lack of public funding for investments which are related to the utilization of wastes and by-products. At the moment public money is mainly available for research, but not for piloting new technologies. Those parties who manage a symbiosis should continuously collaborate with the parties who can advance the change of legislation to more favorable to waste and by-product exchanges, as for instance with politicians and public servants. However, it can also be very significant to market industrial symbiosis in different media, because it makes the whole society aware of the subject, in which case for example politicians can more visibly make decisions that foster symbiosis, as their voters will understand the importance of these decisions.

According to the answers of the representatives of UPM, NIA and GCI, at the moment industrial companies make their decisions to initiate waste and by-product exchange relationships primarily of the basis on direct economic benefits. In other words a waste or by-product exchange relationship is initiated only because it brings costs savings or revenue growth to the exchanged product, which can be calculated beforehand at least with moderate precision. The initiation of the all current waste and by-product exchange relationships of UPM Kaukas has been based on direct economic benefits. Any of the current existing waste and by-product exchange relationships cannot be said to be based on indirect economic benefits. According to UPM's representatives, the existing exchange relationships can bring indirect economic benefits (for example, the improvement of the company's brand) to some extent, but the decisions to initiate and maintain these relationships have been based only on direct economic benefits. Indirect economic benefits are even often considered important at a general level, but still they very probably won't be an effective cause to initiate waste and by-product exchange relationships in the near future. Some representatives of UPM mentioned the reasons related to the company's brand as an important factors, but still the decision to initiate any current exchange relationship hasn't been based on the improvement of the company's brand. The brand improvement is rather a recognized possible benefit, which is associated with exchange relationships, than an argument of decision making. Restrictions imposed by legislation and direct economic benefits (virtually cost savings) can be said to be only real reasons for UPM to initiate waste and by-product exchange relationships at the moment. According to NIA and GCI, currently indirect economic benefits don't affect the decisions of companies to initiate waste and by-product exchange relationships, but they think that in the future indirect economic benefits may become factors which affect decision making, if stakeholders of companies start to demand that industrial companies take into account environmental protection more actively.

The small importance of indirect economic benefits in the decision making may originate either from a circumstance where indirect economic benefits haven't been substantial in the earlier exchange relationships or other business relationships or from a circumstance where indirect economic benefits haven't been examined carefully enough, so that their effect on the profitability of exchange relationships could be estimated accurately. A representative of UPM stated that the low significance of indirect economic benefits originates from the first option, so that on the basis of the experiences, which have been gained up to this point, the initiation of new exchange relationships isn't predicted to bring indirect economic benefits substantial enough. The current primacy of direct economic benefits may seem surprising, but it isn't in any way a bad premise for symbiosis development as Chertow and Miyata (2011, 278) have stated that the most enduring industrial symbioses have been originally pursued for economic reasons instead of environmental sustainability. The environmental benefits of economically motivated exchanges have been revealed only later through the uncovering of a symbiosis (Chertow and Miyata 2011, 278). Although calculable revenue growth and cost savings are extremely important for companies, the symbiotic exchanges which bring these growth and savings will additionally create environmental benefits through the recovery of materials.

Because of the importance of direct economic benefits in the decisions to initiate exchange relationships waste and by-product exchanges should be marketed to the future parties of a potential exchange relationship by bringing forward the cost savings and revenue growth in detail. A third party, who takes part in the building of a symbiosis network, should communicate these direct benefits to the future parties of relationships through economic calculation. By careful calculation and communication of costs and profits it can be ensured that companies will remain in the Kaukas symbiosis in the long term. GCI has told that it will calculate and communicate these economic benefits in its investing. The current significance of direct and indirect economic benefits can be summarized by saying that direct economic benefits should be used to market industrial symbiosis and exchange relationships to companies, but indirect economics benefits can be achieved by marketing the environmental benefits of symbioses and exchange relationships to public entities, because favorable legislation and financing improve the operating conditions of exchange relationships. Because only three parties (UPM, NIA and GCI) have been interviewed, this result shouldn’t be interpreted as a too strict rule. There can indeed be industrial companies which sometimes base their decisions to initiate exchange relationships on indirect economic benefits. However, the results indicate that direct economic benefits are *generally* very important for industrial companies in the decision-making on the initiation of waste and by-product exchange relationships.

8.7 Definition of direct economic benefits and costs

According to UPM representatives, the calculation of direct costs and direct economic benefits of waste and by-product exchanges contains some special characteristics which differentiate this calculation from other business-related economic quantification. Compared to other products, the pricing of wastes and by-products can be more difficult because it is often challenging to clearly identify the market, in which their prices will be defined. Because there already exists working solutions for the treatment of wastes and by-products in the mills, the threshold of initiating a new exchange relationship can be high. In this case the economic benefits brought by the initiation of an exchange relationship must be large enough so that they overcome the risks associated with the initiation of a new business relationship. Additionally, the amounts of wastes and by-products are large and their applications may use only a small fraction of generated wastes and by-products. The separation of a certain part of a waste or by-product and the delivery of this part to a downstream user may create only additional costs for the supplier.

Those representatives of UPM, whose job description is associated mainly with the existing production, told that by now their company has been able evaluate the direct economic benefits and costs of a new business relationship accurately enough at the beginning of relationship. However, those representatives of UPM, whose job description is mainly associated with the development of new technology, told that by now their company hasn't often been able to quantitatively evaluate the direct economic benefits and costs of a new business relationship so accurately that a later examination wouldn't have changed the understanding about the size of the costs and economic benefits of the relationship. From this we can possibly propose a generalization that it is more difficult to beforehand economically evaluate utilization solutions which implement new technologies than it is to evaluate technologies which are already in use. A reason for this can be the lack of knowledge about the cost of developing an industrial solution and the operation cost of the solution. However, anyone of the interviewees couldn't give an example of a situation where more accurate knowledge about costs or benefits would have changed the decision about taking part in a business relationship. If the waste and by-product utilization solutions of the Kaukas symbiosis implement highly new technologies, the evaluation of their direct economic benefits and costs can pose a significant challenge and hinder the willingness of the parties to begin relationships. Therefore, at the initial stages of the Kaukas symbiosis it may be reasonable to implement technologies which have been piloted to some extent on the industrial scale. Otherwise too risky relationships may decrease the motivation of the parties to engage in the symbiosis. After the symbiosis network has grown in size, the benefits of symbiosis have been demonstrated and the companies may be more willing to take risks.

According to representatives of UPM and GCI, true advancement in the emergence of Kaukas symbiosis requires additional effort especially to the search of potential waste and by-product utilizer companies, as there are sidestreams to which it is difficult to find any utilizer. Of all the tasks which precede the beginning of the actual exchange, the search of new partners and the economic and technical evaluation of potential utilization solutions of wastes and by-products are the ones which cause most costs. However, the costs of negotiating the terms of the exchange and the costs of enforcing the contract are not significant in size. Therefore the common management and coordination function of the Kaukas symbiosis should specifically advance and execute the search of partners and the economic and technical evaluation of solutions. If a single common function can carry out the work which different members would otherwise do separately, all the participating companies can obtain cost reductions. The centralized function can develop further in its expertise than separate individual actors, because it works continuously to optimize the network of waste and by-product exchanges as a whole.

8.8 Economic risks

In the interviews the following economic risks, which prevent the initiation of waste and by-product exchange relationships, were identified. The risks can be classified into three categories:

Dependency-related risks:

- The availability of the used waste or by-product may decrease or end suddenly (for example, when production stops).
- A party doesn't commit to a relationship in the long term, (a risk especially in a situation where the relationship is very important to the other party, in other words, the dependency is one-sided).
    - A small company is more prone to go bankrupt unexpectedly.

Regulation-related risks:

- Legislation (limits on the concentration of harmful substances in different countries) forbids an exchange in practice.
- Getting the environmental permit for a new product may take a long time and the final decision can be negative or disadvantageous for the exchange.
- Legislation may change suddenly.

Technology and novelty -related risks:

- Because there doesn’t necessarily exist a clear market for a new product, the demand cannot necessarily be predicted accurately enough.
- Variation in the composition of wastes can hinder or prevent the utilization of the wastes in the production (only waste which has a certain composition can be used).
- The functionality of a new technology on industrial scale cannot be ensured beforehand.
- The technological solution of a future partner may finally use only a small part of a waste or by-product.
- Getting financing for a new technology can be very challenging, as banks don’t finance technologies, which haven’t been strongly proven to be functional on industrial scale through several practical examples (a technology must be “bankable”).

Ways to mitigate the dependency-related risks have been discussed in the subchapters 3.2 and 4.2. Also the decision to develop multiple separate symbiosis networks (instead of one very large network) is a way to avoid excessive dependency, because a greater number of exchange relationships and member companies in a network can increase dependency-related risks (as was proposed in the chapters 4.2 and 6). Solutions to regulation-related risks have been discussed in the chapters 3.8 and 7. However there are no clear solutions to the technology and novelty related risks. Only the piloting of a new technology or of manufacturing a new product can increase knowledge about the technology or the product and therefore mitigate these risks.

Some of these business risks have caused real problems, which could also appear in the Kaukas symbiosis. Due to a legislative amendment, ashes from Kaukaan Voima couldn’t be used anymore in forest fertilization because the cadmium concentration of the ashes is too large. In its business relationships NIA has experienced a situation, where the company which has supplied a technological solution has been small and its economic situation has been prone to fluctuations. This has caused uncertainty about the continuity of the relationship for a large company which been the other party.

Changes in legislation were the only factor in the market environment of UPM which the representatives of the company recognized to be able to cause unexpected powerful fluctuations in the demand of wastes and by-products and the products which are manufactured from them. Certain uses which are related to building and earthworks, like road bases, are dependent on the time of year and therefore their demand varies cyclically. However, these changes in demand can be anticipated unlike changes in legislation.

In a situation where the utilizer of a waste or by-product ends the relationship suddenly, it might be easier to find new uses to some wastes and by-products compared to some others. For example, there are lots of external demand for the ashes of Kaukas, but only little demand for sludges (Kaukaan Voima is the primary user of sludges). If Kaukas begins to supply a larger part of its wastes and by-products to other companies, the possibility that a utilizer company may go bankrupt suddenly can become a significant business risk. In the situation, where an exchange relationship ends suddenly, UPM Kaukas would probably return, if possible, to the independent treatment and incineration of waste. According to the representatives of UPM, the risk of the user of a waste or by-product ending the exchange relationship suddenly is existent in the current relationships but not especially probable. It can be said that currently the risks related to the excessive dependency on exchange partners are not especially strong or dangerous for UPM Kaukas and that it isn’t necessary to restructure the symbiotic network of UPM Kaukas in order to reduce its dependency. The dependency on UPM Kaukas rather creates risks for its exchange partners. In the situation where a utilizer of a waste or by-product ends the relationship, NIA can open a new search for partners. However, NIA states that it is more helpful to look for another utilization option already during the first search, so that the supplier of a waste or by-product can move into this option if the first relationship comes to an end.

At the moment UPM Kaukas hardly uses other companies’ wastes or by-products (the biorefinery uses some tall oil which others have produced). Therefore a dependency-related risk that the supplier of a waste or by-product would end the relationship so suddenly that UPM Kaukas cannot obtain the raw material from somewhere else fast enough, doesn’t currently pose a significant risk to the production of Kaukas. In addition, currently used raw materials are available so abundantly through different suppliers that their availability isn’t a problem.

8.9 Preconceptions

Most interviewed representatives of UPM didn’t recognize problems, which would have occurred in business cooperation due to the prejudices and attitudes of other parties and which could probably take place also in the symbiosis cooperation of Kaukas. In the interviews the UPM representatives brought forward a situation where they had proposed to the city of Lappeenranta that UPM could deliver ash and mineral wastes to the city to be used in road construction. The representatives of the city had refused the cooperation and the interviewed UPM representatives believed that the reason for the negative answer was prejudices present in the public administration. Same kind of wastes have been utilized in road construction in other localities and this fact was brought up in the proposition, but even this argument didn’t increase the willingness of the city representatives to negotiate the cooperation. One representative of UPM also mentioned that in Kaukas there may be resistance towards the change that more actors come to the mill site as a result of symbiosis. One reason for this resistance may be that new actors increase the complexity of the mill site operation, for example from the perspective of safety management. One way to solve this problem could be to take the increase of complexity into account during the evaluation and selection of waste and by-product exchange relationships.

At the moment there hardly exists companies, with which Kaukas isn’t ready to collaborate on symbiosis development. Due to limitations posed by competition legislation, UPM cannot cooperate with direct competitors, i. e. other forest industry companies. Such companies, which already cooperate with UPM’s competitors, are challenging partners. There exists a risk that a company, which cooperates with UPM’s competitor, may hand over UPM’s information further to this competitor. This challenge may be very relevant in the case of industrial symbiosis as some utilizer of a waste or by-product may probably want to cooperate on wastes and by-products with several forest industry companies. Symbiosis collaboration with companies, which cooperate with UPM’s competitors, is possible but it must be considered very carefully. For instance, the confidentiality of information that must be given to the partner in the exchange relationship affects the decision.

8.10 Expertise from different industries and differences in corporate cultures

A UPM representative stated that the role of future partner companies is to be subsequent actors in UPM's value chain, which have special expertise that benefits UPM and Kaukas and which can manufacture final products that are successful on the market. According to the UPM’s representatives, the waste and by-product utilization solutions of its potential symbiosis partners will most likely be associated with the production of biogas, the utilization of digestate, fertilizers, separation technology, the manufacturing of composites, construction materials, biomaterials, mineral materials, the processing of minerals, the processing and end use of ash, energy production and energy-intensive applications. Completely new possible applications for wastes and by-products are, for instance, utilization in the manufacturing of composites (like asphalt, rubbers, plastics) and the utilization of ashes in somewhere else than road construction. NIA has stated that its network includes companies, which offer solutions in industries mentioned by the UPM representatives. In addition, GCI has mentioned the utilization of carbon dioxide, medicine, control systems engineering and digital solutions (for example based on an Internet of Things (IoT) –model) as potential special fields of waste and by-product utilization solutions.

The UPM representatives acknowledged that it is possible to get both technical and business expertise from another company through waste and by-product exchange relationships. However, it wasn’t confirmed or explained in more detail in the interviews that expertise, which have been acquired this way, exists by now. From this we can conclude that the expertise obtained from another firm isn’t a very important factor for the development of the waste and by-product exchanges or other businesses of Kaukas at the moment. This lack of transferred business and technical expertise indicates the underdevelopment of the current symbiosis network in Kaukas as the transfer of knowledge and expertise is an important element of symbiosis (as explained in the subchapter 3.5).

In the symbiosis collaboration of Kaukas, there can possibly appear cooperation problems which are related to the corporate culture of a large company. The slow decision-making of large firms is a problem from the point of view of small companies. Making one decision may easily take half a year. This can be a problem especially because the economic situation of small companies is more likely to be prone to powerful fluctuations. Even large concerns can accelerate decisions, if the schedule of decision-making is negotiated beforehand. The representatives of UPM didn't recognize the special characteristics in the corporate culture of small companies. GCI has stated that cultural differences can appear, if the suppliers of technical solutions of the symbiosis come from outside Finland (especially if companies come from somewhere else than Europe or the United States).

8.11 Technological capability

The UPM representatives generally thought that the personnel of Kaukas can estimate in every situation in question whether it is more efficient to decrease wastes and by-products in the production stage through technology development or to deliver the produced wastes and by-products to be used in another company. Decreasing wastes in the production stage is at the moment considered to be the most cost efficient way for UPM instead of delivering wastes to another company. This reveals that at the moment wastes and by-products are not yet generally considered valuable raw materials and that it is difficult to find such uses for wastes and by-products, which could be probably turned into profitable businesses. This answer also emphasizes the fact that at present UPM doesn't recognize the utilization of the side streams of pulp and paper production as its core business. We can propose that in the case that truly profitable utilizations are found for wastes and by-products, they can be seen to possess independent value as raw materials. It is likely so that at present UPM doesn't network with potential utilizers of wastes and by-products effectively enough, which leads to a situation where it cannot find uses for wastes and by-products easily enough. In the situation where the cooperation in networks is effective, supplying wastes to another company may be more profitable for UPM than the improving its own production.

The representatives of UPM considered that the utilization of Kaukas' wastes and by-products in production doesn't generally require any less well-known special expertise. There can be exceptions which include some wastes and by-products, like tall oil, and certain areas of waste treatment like the removal of heavy metals. On the other hand, special expertise may be needed in the development of some completely new high value-added products from wastes and by-products. Those representatives of UPM, who worked on technology development, recognized the need for special expertise somewhat better than those representatives, whose job description was more associated with the existing production. From this we can possibly conclude that challenges are not mostly related to the characteristics of a particular waste or by-product itself but to the technology which allows to turn this waste or by-product into a certain final product.

UPM doesn’t want to invest much of its own resources to the development of the technical solutions of exchange relationships, but rather expects external actors, which participate in the Kaukas symbiosis, to develop ready applicable technical solutions for the utilization of wastes and by-products for UPM. For this reason it is especially important that some third party will foster the collaboration between the suppliers (primarily UPM) and utilizers of wastes and by-products so that technical solutions, which work in practice, are created through effective cooperation. In the interviews GCI and NIA have expressed their willingness to play a role of this third party. The development of these technical solutions could be possibly carried out for example through a program of Tekes or some other actor.

8.12 Electronic information system

UPM representatives didn’t know anything about electronic ontology models (explained in the subchapter 3.7), which can be used to communicate explicit and tacit knowledge in the exchange of wastes and by-products. At present, UPM doesn’t have any information system which could be used to electronically describe wastes and by-products in their exchange. There exists information about the by-products of Kaukas in some electronic systems, but these existent systems cannot be used in the exchange with other companies. UPM has a concern-level database for wastes and by-products, which is used only by the concern and from which information is also given to partners. At present UPM’s waste and by-product database is used only by the personnel of the environmental function and the environmental managers of the mill sites. The database is not generally well-known among the other personnel.

All the interviewees agreed that for the exchange of wastes and by-products in Kaukas there should be an information system, which could be used to communicate information on wastes and by-products to the existent and potential partners. However, this information system should not be UPM’s own system, but a general national system to which each symbiosis member enters its information. The lack of the information system wasn’t experienced to be a barrier to the development of waste and by-product exchange at the moment, but the introduction of the information system was believed to accelerate the development.

NIA's current web service can be used to do searches in which potential partner companies are looked for and the properties of an exchanged waste or by-product can be generally described in these searches. In order to make NIA's current web service applicable to the development of the Kaukas symbiosis, a possibility to social communication should be first added to it. At present companies find each other through the web service, but they don't discuss with each other through the service. NIA is willing to make an electronic modeling of the Kaukas symbiosis, which would depict waste and by-product streams even in real time. NIA has some experience in the modeling from one customer case and some demonstrations on the modeling have been already done for UPM. The web service for waste and by-product exchange, which NIA will design, will probably be ordered by one or several anchor tenants of the symbiosis (for example, UPM, Lappeenrannan Energia, Veolia). After the anchor tenants, other actors would be searched and invited to use the web service. According to the results of the chapter 6, a single symbiosis network likely involves only a limited number of member companies. Therefore the communication and networking features of the information system are probably able to attract a lot of new partners only if the premise is that the information system will be used in the development of several different symbiosis networks. It is very important define the initial scope of the system's users before starting the development of the system. This scope could be symbiosis networks in the whole of Finland or the most of UPM's sites internationally.

A central property, which must be communicated to the utilizer through the symbiosis web service, is the composition of a waste and by-product (for example, the concentrations of harmful substances) and how it is related to the limits set by legislation. The continuous communication of variation in the composition (i.e. quality) of the different batches of wastes can create challenges for the exchange (for instance, the exchange of ashes). These variations of composition cannot be communicated with NIA's current web service, and also for this reason a new information system is very probably needed for the Kaukas symbiosis. Up to this point the communication of waste and by-product properties hasn't yet caused difficulties in UPM's business relationships.

8.13 Presence of symbiosis barriers and enablers in the case of Kaukas

Golev et al. (2014, 141) have developed an industrial symbiosis maturity grid which is utilized to monitor and assess the level of regional industrial collaboration and find out a needs and possibilities for further improvements and development in an industrial region, depending on where the region currently lies on the grid. For over twenty years, maturity grids have been successfully applied in the fields of quality management, product development, communication, data security and risk management to assess strategic and operative capabilities in an organization (Golev et al. 2014, 142). The industrial symbiosis maturity grid consists of seven categories of symbiosis barriers and enablers (commitment to sustainable development, information, cooperation, technical, regulatory, community, economic). The strength of the presence of enablers (and the absence of barriers) is evaluated on a scale from 1 to 5 (1 is the weakest and 5 is the strongest) in each category. (Golev et al. 2014, 142-143) The validity of different ratings of the seven categories has been tested with case studies (Golev et al. 2014, 142). Where an industrial region lies on the grid is determined from interviews with industry representatives and different stakeholders, like for example government bodies, interindustry organizations, and community environmental groups, and from the analysis of additional supporting and clarifying information and data (Golev et al. 2014, 143). The respondents can also directly asked to choose the most appropriate positions on the grid according to the every category of barriers and enablers (Golev et al. 2014, 144-146). When examining the industrial symbiosis in Gladstone, Australia, Golev et al. (2014, 146) decided to interview site environmental managers, chief executive officers (CEOs) and operation managers for small- and medium-sized enterprises (SME) and/or new and emerging industries in the area.

The grid measures the level of development of societal practices and attitudes and mental models and practices within companies and in collaboration between companies. The presented enablers and barriers cover same subject areas as the success factors and their related challenges which have been presented in the chapters 3-5. The presented enablers can be said to be comparable to success factors for industrial symbiosis. The general correspondence between the categories of enablers and subchapters explaining success factors is the following: commitment to sustainable development: 3.3; information: 3.7; cooperation: 3.5-3.6; technical: 3.3; regulation: 3.8; community: 3.1, 3.8 and economic: 3.4. Hence in order to find which success factors are not yet present in an industrial symbiosis, it is reasonable to apply the industrial symbiosis maturity grid.

The categories which are distinguished in the industrial symbiosis maturity grid have been evaluated on the basis of the interview answers. In the Table 6 on the next page the different categories of the grid have been distributed according to their current stages of development. In the following explanatory paragraphs the categories have been organized according to their ratings from the strongest to the weakest. The descriptions of different ratings are provided in the Appendix V. The rating of a category is followed by an explanation for the decided rating by comparison to the rating descriptions in the industrial symbiosis maturity grid by Golev. et al. The categories have been evaluated by only examining UPM Kaukas, and the companies which are its exchange partners have been excluded due to the lack of required information. However, UPM is the dominant operator in the Kaukas industrial area and therefore its capabilities to build and maintain symbiosis generally describe the developmental stage of the whole industrial area of Kaukas.

On the basis of the industrial symbiosis maturity grid of symbiosis barriers and enablers, UPM Kaukas is most developed in the technical capability and after this at the next best level are UPM's capabilities to independently coordinate economically and environmentally its exchange relationships. The capabilities which reveal strongest needs for development are exactly those which are associated with communicating, negotiating and collaborating in the symbiosis network. Because UPM hasn't developed these capabilities, the symbiosis network of Kaukas is currently underdeveloped. According to the correspondence between the enablers of the industrial symbiosis maturity grid and the success factors of symbiosis, the following ways to improve the missing capabilities and the worst two ratings (cooperation and community) can proposed through the implementation of success factors. The cooperation-related capabilities could be improved through the coordinative function of the symbiosis and the information system which both would facilitate the formation of waste and by-product exchange relationships (as explained in the subchapter 3.1). This facilitated establishment of exchange relationships could also increase the diversity of firms involved in these relationships and thus also the general activity of waste and by-product exchange (as explained in 3.6) It would also enable the flow of information and knowledge which would accelerate the development of waste and by-product exchanges (as presented in 3.5).

The presence of symbiosis champions would also be a way to improve cooperation-related capabilities. Some person or group of persons from UPM Kaukas (or other member organizations participating the symbiosis) should clearly assume the position as the champion of the Kaukas symbiosis who communicates the benefits of the symbiosis and exchange relationships to potential participant companies (as explained in 3.3). In order to improve the community-related capabilities the function for the coordination and management of the Kaukas symbiosis should negotiate with different stakeholders (for example industries, government and research institutions) in order to change the external characteristics of the business environment (like environmental regulation) more favorable to industrial symbiosis (according to the subchapters 3.1 and 3.8).

Table 6. The distribution of the categories of the industrial symbiosis maturity grid according to the stage of development

Stage 2	**Stage 3**	**Stage 4**
Cooperation Community	Commitment to SD Information Regulation Economic	Technology

Enablers related to technology are at the stage 4 (proactive). At the moment possibilities to utilize the wastes and by-products of Kaukas in the production of other companies in different industries are studied at UPM's Research Center in Lappeenranta. However, in the interviews it was brought forward that UPM wants the partner companies, which participate in the Kaukas symbiosis, to develop for UPM ready technical solutions, which will work in practice and produce economically profitable products. This means that UPM strives to identify the possibilities for the utilization of its own wastes and by-products, but wants an external company to develop final solutions for UPM. UPM is not willing to develop its expertise in identifying possibilities to utilize the wastes and by-products of other companies in its own production, because at the moment there is no need or willingness in Kaukas to use others' side streams. Through the symbiosis UPM rather tries to deliver its own wastes and by-products to be utilized by other companies.

Representatives of UPM knew some methods, which can be used to manufacture products of high added value from the wastes and by-products generated in Kaukas. Such methods are, for example, the production of biogas, the improvement of the building properties of ash and the anaerobic digestion of sludge. However, on the basis of current knowledge these methods won't likely be economically viable, mainly because the demand of the manufactured high added-value product is probably too small compared to the high investment costs which starting the production would require. The industrial manufacturing of high value-added products usually requires large investments, which have payback times of several years. Representatives of UPM also knew some methods by which UPM Kaukas can manufacture new products of high value added from wastes and by-products generated by other companies. This kind of method is, for example, the gasification of bark. Also in this case, the practical implementation of these methods in hindered by the facts that the demand of the high value-added product will probably be too small and that the investment costs of starting the production will likely be too big. It can concluded that such waste and by-product exchanges which can be carried out without considerable investments and economic risks have already been realized. The rating of the category isn't the best possible one (in other words 5) because UPM isn't easily ready to carry out considerable investments and pilot new technologies on waste and by-product utilization.

Enablers related to commitment to sustainable development (SD) are at the stage 3 (active). At the moment UPM uses only one indicator for the evaluation of the exchange relationships, the by-product and waste recycling rate (as a percentage). This indicator defines the share of a produced waste or by-product, which is recovered or utilized. UPM Kaukas measures the waste and by-product recycling rate, because it is a measure which is used in the EMAS reporting. Because currently there are not very many exchange relationships, there hasn't yet been any considerable need for more developed indicators. By now there hasn't also been any special investment to the selection of indicators for the exchange relationships in Kaukas. The rating of the category isn't the best possible one because there doesn't yet exist a system of indicators, which would be used to ensure that sustainable development is carried out effectively at every level of the company.

Enablers related to information are at the stage 3 (active). At present UPM Kaukas annually publishes an environmental report, which is compiled according to an environmental management system called EMAS (the EU Eco-Management and Audit Scheme). It tells all the waste and by-product emissions quantitatively (in tons). The rating of the category isn’t as good as possible because there doesn’t yet exist a coordination mechanism or body for the environmental data sharing and analysis or a public database on waste streams in the Kaukas area.

Enablers related to regulation are at the stage 3 (active). Current legislation largely takes into account best-known waste reuse practices. It can be said that taxation generally supports the exchange of wastes and by-products, as clear shortcomings in taxation weren’t mentioned in the interviews. For instance, the voluminous taxation of landfilled waste directs to utilize the waste. However, the rating of this category isn’t as good as possible because legislation doesn’t take into account several potential waste and by-product utilization solutions and prevents their practical implementation. In addition, taxation doesn’t necessarily equally support the exchange of all waste and by-product fractions. Tax incentives could be possibly directed to encourage the manufacturing of a certain product from a certain waste or by-product.

Enablers related to economic factors are at the stage 3 (active). The waste treatment costs are hundreds thousands euros per year and therefore they affect significantly the decisions taken. Legislation (for example, the prohibition of organic waste disposal by landfilling) affects significantly the treatment costs and decisions made. At present the economic benefits which UPM Kaukas gets from the waste and by-product exchange relationships are costs reductions. In other words, the waste and by-product exchange relationships only generate costs for Kaukas, but these costs are smaller compared to the situation, in which the treatment of wastes and by-products would be carried out without these exchanges. Other companies are either paid for the utilization of wastes and by-products or they are given for free. At the moment, the first goal of UPM is to acquire savings to waste and by-product treatment costs through exchange relationships. In the future the goal will be to create profitable businesses through the utilization of wastes and by-products, in other words, change the treatment of wastes and by-products from a cost to a source of revenue. Therefore, it can be said that the personnel of UPM Kaukas generally recognize that wastes and by-products may be a valuable resource.

Those representatives of UPM, whose job description was associated with the existing production, thought that at the moment the company invests enough money to the development of waste and by-product exchanges. Certain representatives of UPM, whose job description was associated with the development of new technology, though that at present the company doesn't invest enough money to utilization applications of side streams which require piloting and implementation of new technology. The payback time of the potential investments related to the utilization of side streams is usually between three and five years, which is currently a too long payback time for UPM, so that it would decide to carry out the investment. According to a representative of UPM, the length of the required payback period likely depends on whether the question is about a strategic investment, which brings growth, or about an investment which brings costs savings. Shorter payback periods are usually required for the investments, which bring cost savings, than for the strategic investments.

All the interviewed representatives of UPM said that the long-term profitability (compared to the short-term profitability) is a priority for them in the development of exchange relationships. However, if an exchange relationship seems unprofitable at the beginning, it will be difficult to get an approval for the investment, which the relationship requires, in UPM's decision making process. In this kind of situation it must be very probable on the basis of valid arguments that the relationship will become profitable within a certain time. An executed investment is often unprofitable at the moment of the start-up, but after this point it will soon become profitable. The main reason why the rating of the economic category is not the best possible one is because on the whole it can be said that short-term profitability is currently very important for UPM in the consideration of investment decisions. The current exchange relationships with external firms only bring cost savings and not additional revenue to UPM and therefore they are "unprofitable" in a certain sense, but on the other hand they haven't required large investments on the part of UPM, and therefore there doesn't exist equal risk as in an investment situation. By now UPM hasn't carried out waste and by-product exchanges which wouldn't haven't been feasible from a short-term perspective. The representatives of NIA and GCI state that potential waste and by-product utilization solutions are unprofitable at the initial stage. This is told to originate from a circumstance that at the beginning the exchanged and produced amounts are small and only after some time these amounts reach a profitable level.

The representatives of UPM and Kaukas told that searching new applications for UPM's own wastes and by-products is one continuous development area of the company, although working on this theme doesn't necessarily take place every day. The representatives of Kaukas made different estimates of how often a new waste and by-product exchange relationship is considered. However, from their answers it can be estimated that a new exchange relationship is considered once a year on the average. At the concern-level, UPM has meetings related to the exchange of wastes and by-products weekly. On the whole it can be concluded that there is somewhat continuous investigation for new waste and by-product exchange opportunities, which complies with the description of the rating 4 of the economic category. However this is the only point of the rating 4 which is currently true about the case of Kaukas, so the correct rating for the economic category is still 3.

Enablers related to cooperation are at the stage 2 (initial efforts). At the moment changes in legislation are one the main reasons which have driven industries to collaborate on the initiation of waste and by-product exchange relationships. For example, the prohibition of landfilling organic waste came into effect at the beginning of this year (2016). This prohibition states that waste, which has the concentration of organic material higher than 10 percent, cannot be anymore deposited in a landfill of ordinary waste (Ympäristöministeriö 2013). In other words, collaboration between the industries has largely originated from serious challenges created by changes in the legislation. In Kaukas, the environmental manager currently takes care of the exchanges of wastes and by-products with other companies. The rating of this category isn't as good as possible because at this point initiatives on waste and by-product exchange are not generally furthered at the top management level. There also isn't yet company-wide interest and trust for symbiosis cooperation with other companies.

Enablers related to community are at the stage 2 (initial efforts). At this point the external stakeholders with which UPM Kaukas collaborates for the development of the exchange of wastes and by-products comprise mainly other companies. Currently Kaukas cooperates with the local community through the cooperation with public organizations. The partners of Kaukas in the public sector include Lappeenrannan Energia Ltd., owned by the city of

Lappeenranta, and the business company of the Lappeenranta region, Wirma Lappeenranta Ltd. Kaukas is also a member in the Green Energy Showroom –network, which operates in Lappeenranta and whose operation is based on environmentally friendly energy production. Lappeenranta University of Technology is a research organization with which Kaukas collaborates on industrial symbiosis. Up to this point UPM hasn't communicated very widely in the media aimed at the general public. The rating of the community category isn't the best possible one for the reason that there hasn't yet been established any system for communication with the local community nor any official community body which would negotiate with industries and government about the Kaukas symbiosis.

9 CONCLUSIONS

In this chapter the findings of all the preceding chapters are integrated into recommendations about measures which should be implemented in the development of the industrial symbiosis in Kaukas and industrial symbioses in general. The numbers inside the parentheses refer to those chapters and subchapters in this thesis in which the topic of the sentence in question is explained in more detail. The remainder of this chapter discusses the current absence of special quantitative indicators for symbiosis.

9.1 Recommendations for the development of the Kaukas symbiosis

The concept of industrial symbiosis in its basic form is well adopted among the representatives of UPM, NIA and GCI, but their understanding currently concentrates excessively on individual waste exchanges instead of cooperation in a network to create culture that promotes symbiosis development and creating and sharing knowledge for the development of technical and business processes (8.2). The operating conditions of the whole symbiosis network should be developed instead of concentrating only on individual separate waste and by-product exchanges. These currently non-recognized important aspects of industrial symbiosis should be emphasized in the internal and external communication of the symbiosis network so that the existent and potential symbiosis participants internalize them. It is important that some representatives of participating companies or other parties of the symbiosis act as champions who take an initiative to disseminate the concept of industrial symbiosis to potential partners of the symbiosis network (3.3). In UPM Kaukas, the concept of industrial symbiosis is currently used mainly in communication with business partners, but in the future it should be ensured that the personnel in the companies participating in the Kaukas symbiosis will internalize the approaches of industrial symbiosis and apply them in their daily work. The concept of industrial symbiosis could be most effectively disseminated to potential partner companies through initiatives on waste and by-product exchange and utilization. When the companies perceive potential tangible benefit in the adoption of the concept they are more likely to work to understand and adopt it. Going through a project which finds uses for wastes and by-products illustrates the operation and benefits of industrial symbiosis to partner companies in practice.

At present UPM is the other party in almost all the exchange relationships of the symbiosis (8.3). In order that the other member companies of the symbiosis are also able to operate together independently from UPM, these exchange partners of UPM should also develop exchange relationships with each other and other companies which don't yet belong to the symbiosis network. Too strong dependency on UPM makes the symbiosis network vulnerable in the face of changes, like when a waste or by-product becomes unavailable (3.2, 4.2). As an anchor tenant, UPM can acquire an overly central position, which can hinder the co-operation between the other participant companies of the Kaukas symbiosis so that these other companies don't form symbiotic relationships with each other effectively. Therefore the Kaukas symbiosis needs a function for coordination and management, which will take all the participants of the symbiosis equally into consideration and will help UPM's partners to establish exchange relationships (3.1, 7, 8.4). The coordinative function should advance and execute the search of new partners and the economic and technical evaluation of potential utilization solutions of wastes and by-products as these tasks cause greatest costs before the beginning of the actual exchange (8.7). Symbiosis participants should include large companies (anchor tenants, like UPM) who provide large waste and by-product flows, which are necessary for the economic success of the symbiosis (4.9). The symbiosis coordination should also concentrate on facilitating collaboration between large and small member companies of the symbiosis as the slow decision-making of large firms is a problem from the point of view of small companies (8.10).

A single symbiosis network can possibly grow only into a certain optimal size, after which the establishment of new exchange relationships slows down significantly or even stops, even in the presence of coordination which works to develop new exchanges (6.1). On the average successful industrial symbioses involve 16-23 exchange relationships (6.2). Therefore, instead of concentrating on developing a single large symbiosis network, a better strategy would be to develop several symbiosis networks in different locations. A single coordinative function could develop and manage several symbiosis networks (in different UPM's sites or industrial regions) and this way be able to transfer experience gained in one network to the development of other networks.

For companies, restrictions imposed by legislation and direct economic benefits (virtually cost savings) are the only real reasons to initiate waste and by-product exchange relationships at the moment (8.6). Therefore potential waste and by-product exchange relationships should be marketed to the future parties of a particular exchange relationship by focusing on the cost savings or revenue increases which can be calculated before the initiation of the exchange. Due to the importance of direct economic benefits, a third party, which participates in the building of the symbiosis network, should communicate these direct benefits to the potential parties of exchange relationships through economic calculation. The precise calculation and communication of costs and profits of the symbiosis are important to ensure that companies decide to participate and remain members of the Kaukas symbiosis in the long term (3.4, 4.6).

An electronic information system should be introduced in order to communicate information on wastes and by-products to the existent and potential members of the symbiosis (3.7, 8.12). The search costs of wastes and by-products can be reduced through the use of an information system. The system should be managed by the coordinative function of the symbiosis, because the coordinative function can then use information from the system to advance the creation of exchange relationships, and be available for all the existing and potential partner companies of the symbiosis, so that they are capable to communicate their wastes and by-products and potential utilizations. By using an electronic information system to which existent and potential symbiosis participants could enter information on their wastes, by-products and utilizations, examine each other’s information and independently form exchange relationships, the Kaukas symbiosis could evolve by self-organization through economically motivated decisions of companies (2, 4.1). This way the strong probability of failure associated with too rigidly planned industrial symbioses could be avoided.

The information system can also automatically connect wastes and by-products and their utilization solutions by analyzing information which the companies have entered into the system (3.7). This kind of algorithms can increase the possibility to find unexpected ways to utilize wastes and by-products as they systematically go through different technical possibilities. Algorithms can also calculate different environmental and economic indicators for exchange relationships, so the information system could at least partly act as the aforementioned third party which performs economic calculations. A crucial feature of the electronic information system for symbiosis development is the capability for social communication between the existing and potential member companies of the symbiosis so that companies can independently network with each other and form exchange relationships (4.10, 8.3, 8.12). Also a very important requirement for this information system is the ability to communicate both explicit and tacit knowledge (3.7, 4.10). The communication of tacit knowledge can be implemented in a web service by using ontology engineering. The new information system must also be able to continuously communicate variations in the composition of the different batches of wastes (8.12). The user interface of the information system also should be simple and intuitive enough so that representatives of different symbiosis members companies can use it independently (4.10).

Because the number of symbiosis participants, like the number of exchange relationships, likely has some limit, the information system should be used for the development of several symbiosis networks right from the start. On the average successful industrial symbioses involve 9-14 participant companies (but this number is not as precise as the average number of exchange relationships) (6.2). Therefore networking between the suppliers and utilizers is probably a very useful feature only if the information system is used for the development of very many symbiosis networks. Few new partners of a single network don’t necessarily pay back the investment to the networking feature of the system. The information system could be marketed to several companies in Finland and abroad. When the system has more customer companies, it has more resources for development and it can collect more customer information which is analyzed in order to find ways to improve the system.

For companies, legislation is the primary external factor which at present hampers the exchange of wastes and by-products (8.5). The symbiosis management should continuously collaborate with those parties which have capability to change legislation more favorable to waste and by-product exchanges (for example, politicians and public servants) (3.8, 4.11, 7). Exchange relationships can bring some environmental benefits (for example, zero waste to landfill) which are advantageous to the wellbeing of the society and general public (3.4). By marketing these public environmental benefits in different media the society could be made to know the benefits of industrial symbiosis and therefore the importance of favorable legislation (and funding) for waste and by-product exchange relationships would be understood among the politicians, the public who votes for them and public servants (8.6).

In the future the symbiosis network of Kaukas could be expanded by executing a program which would seek to identify existing waste and by-product exchange relationships and possibilities for new exchange relationships in the companies located in areas close to Kaukas (7). The scope of the program could, for instance, be the South Karelia. As the representatives of the partner companies of UPM Kaukas weren't interviewed during this thesis project it isn't currently known whether these companies have exchange relationships with some other companies and whether they have some unknown potential (for example, expertise or technology) which can be utilized in the development of the Kaukas symbiosis in the future. We don't yet necessarily known the full size of the symbiosis network as the partner companies of UPM Kaukas may have some exchange relationships with other companies which haven't yet been uncovered. In general the development of the symbiosis network shouldn't be limited in or exclusively concentrate on the industrial area of Kaukas as this can lead to a situation where potential exchange partners are ignored. Only two out of the eight current exchange relationships take place exclusively in the area of Kaukas (UPM's exchanges with Kaukaan Voima Ltd. and Co-operative Otsina).

Because an individual symbiosis network may reach an optimal state of development, efforts should be directed to identify less developed networks of waste and by-products exchange relationships as these networks can have more potential for new further exchange relationships than fully developed networks (6.1). These less developed networks may be more difficult to identify than highly developed networks and therefore there should be a program which systematically goes through different companies in a certain geographical area (like Finland) or which goes through different industries, because less-developed networks may take place in industries which are not normally associated with waste and by-product utilization.

9.2 Absence of special indicators for industrial symbiosis

Originally one goal of this thesis was to identify quantitative indicators which could be used in the development of an industrial symbiosis. The term "indicator" is used to refer to a numerical value which is calculated by inserting the values of different variables into an equation. The value of an indicator should reflect something relevant like the level of development of an industrial symbiosis or the feasibility of a potential exchange relationship. In order to limit the number of evaluated indicators to a reasonable amount, the purpose was to cover new indicators which are specifically designed for industrial symbiosis and eco-industrial parks. In other words more traditional economic and environmental indicators, which can also be used in the development of industrial symbioses (in addition to several other applications) were excluded from the review. Several journal articles were found which seemed to describe indicators for symbiosis, but none of them proved to be capable to reliably measure anything which is significant in the development and management of industrial symbiosis. Their invalidity and unreliability originate from several reasons. First, indicators lacked theoretical background. In other words, their source articles didn't contain logical reasoning which would have showed how the mathematical formulas have been derived or why indicators exactly are really associated with the phenomenon they should measure. Sometimes it appeared that writers had just selected a group of variables and joined them together with arithmetic symbols. One indicator tried to sum variables which basically have different units and reflect completely different things, in this case economic benefit and environmental impact. These two variables may be somehow related, but in order to connect them in one indicator, a logical relationship between them should be outlined.

Very often the description in the source article was so unclear and ambiguous that there was no way to know how an indicator should be really calculated. The writer of this thesis tried to improve and correct indicators in the case of ambiguous descriptions but this didn't make them work and only increased certainty about the weaknesses of the indicators. Some indicators also didn't have any clear application. They may describe some aspects of industrial symbiosis and eco-industrial parks, but these aspects are not likely to be significant or beneficial for the successful operation of a symbiosis in practice. For example, one indicator measured the degree of exchanges so that the more there are exchange relationships between companies the better the value of the indicator. However, the abundance of exchange relationships isn't necessarily only a positive thing because dependency-related risks (explained in the subchapter 4.2) can increase with the number of exchange relationships. Any of the articles didn't mention that these indicators would have been utilized in the practical development of any symbiosis. The application of indicators hadn't demonstrably contributed to the success of any existing industrial symbiosis. Some indicators had been calculated for the values of existing symbioses, but this doesn't prove anything about their validity and reliability. Because the reader doesn't know whether a symbiosis performs well or badly in reality (if such thing can be known in any case) there's no way to say whether the values of indicators are significant or correct. The indicators could as well have been calculated with imaginary values.

It can be quite certainly said that at this point there are no useful special quantitative indicators for industrial symbiosis development. Also literature states that at the moment there is no agreement upon rules, methods and indicators which should be used for the description and assessment of industrial symbioses (Van Berkel 2009, 485). However, this doesn't imply that already existing business and environmental indicators aren't also applicable to industrial symbiosis. These already existing, traditional indicators probably work as well in the case of industrial symbiosis as in any other cases. The result means just that there aren't any indicators which are targeted *especially* for industrial symbiosis. Actually, the absence of special symbiosis indicators can be a positive result because it means that there are no new numerical values which should be monitored and therefore the situation is simpler. The use of dysfunctional indicators will only lead to wrong decisions. An indicator should have a clear significance: if the certain value of an indicator doesn't clearly imply that a company should implement a certain corrective action, then the indicator shouldn't be used at all. Organizations should only measure values which are truly important for them. The industrial symbiosis maturity grid which has been applied in the subchapter 8.13 is the only evaluation method which can be said to be based on well-grounded reasoning. This qualitative method evaluates the practices of companies, other organizations and societal institutions which enable the successful development of industrial symbiosis. As the industrial symbiosis maturity grid is a quite new method (published in 2014) it may develop further when more experience is gained of its implementation.

10 SUMMARY

The objective of this thesis has been to evaluate from the strategic and economic perspective how to implement the concept of industrial symbiosis in practice in the industrial area of Kaukas. This thesis had five research questions:

1. Which success factors and challenges affect the development of industrial symbioses?

The major success factors and challenges (limiting factors) of industrial symbioses were summarized from currently published research literature. There were altogether 15 important success factors and 16 challenges which have been listed in the Table 2 in the chapter 5. The success factors have been explained in more detail in the chapter 3 and the challenges have been explained in the chapter 4.

2. By what means can be the challenges mitigated in order to enjoy the full benefits of the success factors?

It was found out that the success factors and challenges (limiting factors) of the industrial symbiosis were in conflict with each other so that challenges can prevent an individual industrial symbiosis to enjoy the full benefits of the success factors. Therefore solutions to the conflicts between the success factors and challenges were proposed in the chapter 4. The conflicting success factors and challenges and their proposed solutions have been presented in the Table 2 in the chapter 5.

3. Do symbiosis networks reach a stage of development, where the increase of their number of exchange relationships and participants slows down significantly and reaches a limit, or are these networks able to grow all the time?

This question was answered in the chapter 6 by examining the data about the initiation of waste and by-product exchange relationships during the development of the industrial symbiosis in Kalundborg. It was found out that the increase of the number of participants slowed down over the decades. The increase of the number of exchange relationships didn't slow down significantly, but it stopped suddenly, as no new exchange relationships have been recently initiated. The publicity and coordination of the Kalundborg symbiosis seemed to mainly help to create exchange relationships among existing participants. The most probable reason for this is that the involvement of new member companies would require relocation close to other symbiosis members and as a result of this there are no profitable opportunities for new exchange relationships. Because the growth of the Kalundborg symbiosis has stopped, we can conclude that the symbiosis has reached its optimal stage of development. By statistically evaluating a set of 31 successful eco-industrial parks, the average size of a fully developed symbiosis network was estimated. On the average industrial symbioses have 9-14 member companies and 16-23 exchange relationships.

4. According to what kind of process model should be industrial symbioses managed?

The process models for the management of industrial symbioses that are found in the current research literature were examined and the three currently existing models were summarized into a single model. The most important element of this model is that it has two separate main processes. The first process is the internal coordination of the symbiosis network and its waste and by-product exchange relationships. The second process is the influence of the external business environment within which the symbiosis takes place. These two processes are highly interconnected so that symbiosis network coordination identifies developmental needs in the business environment and communicates these developmental needs to the environmental influence process. The environmental influence process involves those parties (for example, politicians, their voters and public servants) who can change the characteristics of the business environment (for example, legislation and public funding) more favorable to industrial symbiosis. Changes in the business environment made by these powerful parties affect the preconditions of the symbiosis network coordination. The model emphasizes close and systematic collaboration between the management of individual symbiosis networks and its external parties. The complete model is explained in the chapter 7.

5. By what means the aforementioned success factors and process model can be specifically implemented and challenges solved in the industrial symbiosis of Kaukas?

In order to answer this research question, a series of interviews was conducted with the representatives of UPM Kaukas, Nordic Innovation Accelerator Ltd. and Green Campus Innovations Ltd. The interview answers which provide relevant information for the development of the Kaukas symbiosis have been summarized and analyzed in the chapter 8. On the basis of interviews answers the presence of the symbiosis barriers and enablers in the case of UPM Kaukas has been evaluated according the industrial symbiosis maturity grid by Golev et al. in the subchapter 8.13. According to this evaluation largest deficiencies in the operation of UPM Kaukas are related to the capabilities to communicate, negotiate and collaborate in the symbiosis network. On the basis of the findings of all the preceding chapters the recommended measures for developing the industrial symbiosis in Kaukas are explained in the chapter 9. The most important measures have been summarized in the following points:

- The dissemination of the concept of industrial symbiosis to the internal and external communication of the participant companies
- The establishment of a function which coordinates the symbiosis network of Kaukas and facilitates its development
- The creation of new exchange relationships in the companies which currently exchange wastes and by-products only with UPM, thus reducing their dependency on a single supplier
- The careful calculation of the direct economic benefits of exchange relationships and the communication of these benefits to the existing and potential symbiosis partners
- The introduction of an electronic information system through which the suppliers and utilizers of wastes and by-products can independently form exchange relationships
- The application of one central coordinative function and information system to manage several symbiosis networks due to the limited development potential of a single network
- Systematical communication and collaboration with politicians, their voters and public servants in order to change legislation and public funding more favorable to the realization of industrial symbiosis

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APPENDICES

Appendix I, 1. The interview questions for the representatives of UPM

Because the interviews were conducted in Finnish, the questions are in Finnish. A certain representative was asked certain questions, anyone of the representatives of UPM wasn't asked all these questions.

Kuinka ammatillinen vastuualueenne liittyy jätteiden ja sivutuotteiden vaihdantaan ja teollisen symbioosin kehittämiseen?

Teollisen symbioosin käsitteistön tuntemus ja käyttö
Voisitteko määritellä teollisen symbioosin käsitteen?
Käytättekö tätä käsitettä yrityksenne sisäisessä viestinnässä ja yhteistyössä sidosryhmienne kanssa?
Voitteko kertoa syitä siihen, miksi tätä käsitettä ei käytetä yrityksessänne?
Millä keinoilla varmistatte, että yrityksenne henkilöstö ja sidosryhmänne omaksuvat teollisen symbioosin käsitteen?

Symbioosia edistävät henkilöt
Ketkä ovat yrityksessänne henkilöitä, joiden vastuulla on jätteiden ja sivutuotteiden vaihdannan edistäminen ja jotka ovat olleet aktiivisia kehittämään vaihdantaa?
Löytyykö ulkoisista sidosryhmistänne henkilöitä, jotka toimivat tuotantonne kestävyyden ja jätteidenne ja sivutuotteidenne vaihdannan edistämiseksi?
Onko näiden henkilöiden tekemä työ riittävää saamaan aikaan Kaukaan teollisen symbioosin syntymisen, vai tarvitaanko enemmän osaamista ja työpanosta?

Symbioottisten suhteiden kartoittaminen
Keiden kanssa teillä on jätteiden ja sivutuotteiden vaihdantasuhteita?
Mitä jätteitä vaihdatte näiden toimijoiden kanssa?
Millä tuotantoteknologialla vaihdetut jätteet prosessoidaan?

Appendix I, 2. The interview questions for the representatives of UPM (continued)

Onko nykyisellään olemassa sellaista symbioosiyhteisöä, jossa jätteiden ja sivutuotteiden vaihdantakumppaninne tekisivät yhteistyötä keskenään. Aiemmista haastatteluista olemme saaneet käsityksen, että teillä on ikään kuin yksittäisiä vaihdantasuhteita eri yritysten kanssa, mutta nämä yhteistyöyritykset eivät verkostoidu keskenään tai tee yhteistyötä, ainakaan Kaukaan symbioosin puitteissa. Eli voidaanko sanoa, että kaikki tämänhetkinen Kaukaan symbioosin yhteistyö tapahtuu UPM:n kanssa?
Aiemmista haastatteluista olemme saaneet tietää, että UPM Kaukaalla on yksittäisiä vaihdantasuhteita eri yritysten kanssa, mutta nämä yhteistyöyritykset eivät verkostoidu keskenään tai tee yhteistyötä, ainakaan Kaukaan symbioosin puitteissa. Kehittyneeseen symbioosiin kuuluu kuitenkin verkostoyhteistyö symbioosin eri jäsenten kesken. Tuleeko UPM jollain tavoin edistämään verkostoyhteistyötä kaikkien osallistuvien yritysten kesken?
Kun olette harkinneet uuden jätteiden ja sivutuotteiden vaihdantasuhteen aloittamista, millaisen prosessin kautta tämä päätös on tapahtunut?
Millaisten kanavien kautta jätteiden ja sivutuotteiden toimittajat ja käyttäjät ovat löytäneet teidät tai te olette löytäneet heidät?
Onko UPM (tai Kaukas) jäsen sellaisissa liiketoimintaverkostoissa, joissa jäsenet etsivät ja löytävät jätteiden ja sivutuotteiden vaihdantakumppaneita?
Onko mikään kolmas taho koskaan ollut mukana luomassa suhdetta UPM:n ja jätteen tai sivutuotteen käyttäjän tai toimittajan välillä?
Ketkä ovat olleet vastuussa jätteiden ja sivutuotteiden vaihdantaan liittyvästä yhteistyöstä toisten yritysten (ja muiden toimijoiden) kanssa?
Kuinka usein teette jätteiden ja sivutuotteiden vaihdantaan liittyvää yhteistyötä toisten yritysten kanssa?
Etsittekö jatkuvasti uusia käyttökohteita omille ja toisten jätteille ja sivutuotteille?
Kuinka usein esimerkiksi harkitsette uuden jätteiden ja sivutuotteiden vaihdantasuhteen aloittamista (toisten jätteiden ja sivutuotteiden käyttämistä tai toisille jätteiden ja sivutuotteiden toimittamista)?
Kohdentaako yrityksenne riittävästi rahaa jätteiden ja sivutuotteiden vaihdannan kehittämiseen?

Appendix I, 3. The interview questions for the representatives of UPM (continued)

Jos integraatin läheisyyteen tulee uusi yritys, aiheuttaako se todennäköisesti ongelmia nykyisessä toiminnassa (esim. lisääntyneen liikenteen ja käytettävissä olevan tilan vähenemisen kautta)?
Kuinka paljon Kaukaan integraatissa on kapasiteettia uusille tuotantolaitoksille?

Suorat taloudelliset hyödyt ja kustannukset
Liittyykö toisten käyttöön toimittamiinne tai itse käyttämiinne jätteisiin ja sivutuotteisiin todennäköisesti huomattavan suuria seuraavien kolmen kategorian kustannuksia: tarvittavien jätteiden ja sivutuotteiden etsintäkustannukset, vaihdannan ehtojen neuvottelukustannukset ja vaihdantasopimusten laadinta- ja vahvistuskustannukset?
Onko jätteiden käsittelykustannusten suuruus usein määrittävä tekijä päätöksissänne?
Mitkä olemassa olevista tai potentiaalisista jätteiden ja sivutuotteiden vaihdantasuhteistanne perustuvat ensisijaisesti suoriin taloudellisiin hyötyihin (tuottojen kasvaminen ja kulujen pieneneminen)?
Millä perusteella tuottojenne tulisi kasvaa tai kustannustenne pienetä, jos nyt aloittaisitte uuden symbioottisen vaihdantasuhteen?
Ovatko tuottamienne jätteiden ja sivutuotteiden käsittelykustannukset niin suuret, että näiden kustannusten välttäminen on ensisijainen syy toimittaa kyseiset jätteet ja sivutuotteet toiselle käyttäjäyritykselle?
Onko vaihdannassa saamienne jätteiden ja sivutuotteiden taloudellinen arvo tuotannontekijöinä tai näistä jätteistä ja sivutuotteista valmistettavien tuotteiden markkina-arvo ensisijainen syy vaihdantasuhteen aloittamiseen?
Oletteko aiemmin aloittaessanne liiketoimintasuhteen pystyneet määrittämään kvantitatiivisesti suhteen aiheuttamat suorat kustannukset ja taloudelliset hyödyt jo suhteen alussa niin tarkasti, ettei myöhempi arviointi ole päätöksentekoon vaikuttavalla tavalla muuttanut käsitystä suhteen kustannuksista ja taloudellisista hyödyistä? (Tässä kysymyksessä ei tarkoiteta tilannetta, jossa itse suhteen toimintaehtojen muutokset ovat muuttaneet kustannuksia ja hyötyjä, vaan tilannetta, jossa uusi arviointi on tarkentanut olemassa olevia kustannuksia ja hyötyjä.)
Ovatko tarkemmat tiedot kustannuksista ja hyödyistä saaneet teidät muuttamaan osallistumistanne liiketoimintasuhteeseen (esim. vetäytymään suhteesta)?

Appendix I, 4. The interview questions for the representatives of UPM (continued)

Onko jätteiden ja sivutuotteiden vaihdannan suorien kustannusten ja suorien taloudellisten hyötyjen kvantitatiivisessa määrittämisessä erityispiirteitä, jotka erottavat sen muusta liiketoiminnan taloudellisesta kvantifioinnista?
Voidaanko lainsäädännön asettamien rajoitusten ja suorien kustannussäästöjen tällä hetkellä olevan ainoat todelliset syyt jätteiden ja sivutuotteiden vaihdantasuhteiden aloittamiseen?

Korkean lisäarvon tuotteet
Tiedättekö menetelmiä, joilla jätteistänne ja sivutuotteistanne voi valmistaa uusia korkean lisäarvon tuotteita? Voisitteko mainita näistä menetelmistä potentiaalisimpia?
Tiedättekö menetelmiä, joilla voitte valmistaa toisten jätteistä ja sivutuotteista uusia korkean lisäarvon tuotteita? Voisitteko mainita näistä menetelmistä potentiaalisimpia?
Vaatiiko näiden korkean lisäarvon tuotteiden valmistaminen suuria investointeja?

Epäsuorat taloudelliset hyödyt
Mitkä olemassa olevista jätteiden ja sivutuotteiden vaihdantasuhteistanne perustuvat ensisijaisesti epäsuoriin taloudellisiin hyötyihin?

- Epäsuoria taloudellisia hyötyjä: riskien pieneneminen, toimialan laajentaminen (diversifioituminen), resurssien hyötykäyttö, kaatopaikkajätteen poistuminen, parantuneet suhteet yhteisöihin ja hallintoon, parantunut yrityksen tai brändin maine

Onko näköpiirissä sellaisia potentiaalisia jätteiden ja sivutuotteiden vaihdantasuhteita, jotka tulisivat perustumaan ensisijaisesti epäsuoriin taloudellisiin hyötyihin (suorien taloudellisten hyötyjen sijaan)?
Olemme aikaisemmista haastatteluista saaneet käsityksen, että epäsuoria taloudellisia hyötyjä pidetään periaatteessa tärkeinä, mutta lähes varmasti ne eivät tule olemaan lähitulevaisuudessa uusien vaihdantasuhteiden aloittamisen perusteena. Johtuuko tämä näkökanta siitä, että aiemmissa vaihdantasuhteissa (tai muissa liiketoimintasuhteissa) epäsuorat taloudelliset hyödyt eivät ole olleet merkittäviä vai siitä, ettei epäsuoria taloudellisia hyötyjä ole tutkittu tarpeeksi, jotta niiden vaikutusta vaihdantasuhteiden kannattavuuteen voidaan arvioida tarkasti?
Tuottavatko jätteiden ja sivutuotteiden vaihdantasuhteet julkisia ympäristöhyötyjä, joita voitaisiin markkinoida suurelle yleisölle?

Appendix I, 5. The interview questions for the representatives of UPM (continued)

Onko symbioosin markkinoinnilla medioissa käytännön vaikutusta symbioosin menestyksekkääseen kehittymiseen?
Millaisissa kanavissa ja kenelle symbioosia ylipäätään tulee markkinoida?
Onko teollisen symbioosin käsite helposti markkinoitava (verrattuna esimerkiksi Metsä Groupin Äänekosken biotuotetehtaaseen, joka käytännössä muistuttaa symbioosia)?

Taloudelliset riskit

Mitkä ovat keskeiset riskit, jotka näette olevan uuden jätteiden ja sivutuotteiden vaihdantasuhteen aloittamisen esteenä?
Ovatko nämä riskit aiemmin aiheuttaneet merkittäviä ongelmia liiketoimintasuhteissanne?
Onko yrityksenne markkinaympäristössä sellaisia tekijöitä, jotka aiheuttavat voimakkaita heilahteluja varsinkin jätteiden ja sivutuotteiden ja niistä valmistettujen tuotteiden kysynnässä?
Jos jätteen tai sivutuotteen käyttäjä lopettaisi suhteen yhtäkkiä (esim. lietteen mädätyksen tapauksessa), löytyisikö Kaukaan toimittamalle jätteelle tai sivutuotteelle todennäköisesti nopeasti muu käyttökohde?
Onko tällainen riski todennäköinen jätteiden ja sivutuotteiden vaihdantasuhteiden kohdalla?
Jos jätteen tai sivutuotteen toimittaja lopettaisi suhteen yhtäkkiä, olisiko Kaukaan tuotannossa tarvitsema raaka-aine (esim. mäntyöljy) todennäköisesti mahdollista hankkia nopeasti muulla tavoin?
Ovatko aikaisemmassa liiketoimintayhteistyössänne toiset yhteistyön osapuolet sivuuttaneet tietyt tarpeenne ja vaatimuksenne, jotka saattaisivat todennäköisesti jäädä huomiotta myös Kaukaan symbioosiyhteistyössä?
Onko jätteiden ja sivutuotteiden vaihdantasuhteiden kehittämisessä teille tällä hetkellä tärkeämpää suhteiden kannattavuus lyhyellä vai pitkällä tähtäimellä?
Voiko symbioottinen suhde olla aluksi tappiollinen jos se todennäköisesti ajan myötä muuttuu kannattavaksi?
Ovatko harkittavat symbioottiset suhteet yleensä alussa tappiollisia?

Appendix I, 6. The interview questions for the representatives of UPM (continued)

Tuottojen ja kustannusten jakautuminen

Valvotaanko Kaukaan yritysten välillä tapahtuvan liiketoiminnan tuottojen ja kustannusten jakautumista näiden yritysten kesken järjestelmällisesti?

Onko aikaisemmassa liiketoimintayhteistyössänne ilmennyt niin suurta tuottojen ja kustannusten epätasaista jakautumista, että se on saanut teidät tai jonkun toisen yhteistyön osapuolen vetäytymään yhteistyöstä tai harkitsemaan yhteistyöstä vetäytymistä?

Arviointimenetelmät

Käytättekö indikaattoreita tai muita mittausmenetelmiä jätteiden ja sivutuotteiden vaihdannan taloudellisen ja ekologiseen arviointiin?

Millä perusteella käytätte juuri näitä kyseisiä mittareita?

Alueellinen keskittyminen ja pitkät välimatkat

Voivatko pitkät kuljetusvälimatkat jollain tavoin huonontaa vaihtamienne jätteiden ja sivutuotteiden laatua?

Symbioosin koordinointi

Koordinoiko mikään taho tällä hetkellä Kaukaan symbioosin (jätteiden ja sivutuotteiden vaihdannan) taloudellista kokonaiskannattavuutta ja ympäristöystävällisyyttä?

Voiko UPM toimia symbioosin veturiyrityksenä (eli johtaa suurena jätteiden ja sivutuotteiden vaihtajana Kaukaan symbioosiverkostoa)?

Ennakkoasenteet

Onko aikaisemmassa liiketoimintayhteistyössänne ilmennyt sellaisia toisten osapuolten ennakkoluuloista ja asenteista johtuvia yhteistyöongelmia jotka ovat merkittävästi haitanneet yhteistyötä ja jotka voisivat mahdollisesti muodostua ongelmaksi myös Kaukaan symbioosin toteutuksessa?

Onko yhteistyössä julkisten tahojen (valtion tai kunnan) kanssa ilmennyt ennakkoluuloja?

Onko olemassa yrityksiä, joiden kanssa ette voi helposti ajatella lähtevänne symbioosiyhteistyöhön (esimerkiksi aikaisempien huonojen yhteistyökokemusten tähden tai koska yritys tekee yhteistyötä kilpailijoiden kanssa)?

Appendix I, 7. The interview questions for the representatives of UPM (continued)

Eri toimialoilta saatava asiantuntemus ja yrityskulttuurien erot

Jos ajatellaan tulevia potentiaalisia symbioosikumppaneitanne, millaisia toimialoja ja erityisasiantuntemusta he todennäköisesti edustavat?

Onko potentiaalisia uusia toimialoja, joiden yritysten kanssa UPM:llä ei vielä ole vaihdantasuhteita?

Saattako vaihdantasuhteiden kautta myös muuta hyötyä kuin ainoastaan käyttökohteita jätteillenne tai sivutuotteillenne tai tarvitsemianne jätteitä tai sivutuotteita (esimerkiksi teknistä tai liiketoiminnallista asiantuntemusta)?

Ovatko epämuodolliset vuorovaikutuskanavat (esimerkiksi verkostoitumistilaisuudet) alallanne merkittävässä roolissa yhteistyösuhteiden synnyttämisessä?

Onko yrityksenne liiketoimintayhteistyössä ilmennyt sellaisia yrityskulttuurien eroista johtuvia yhteistyövaikeuksia, joita todennäköisesti voi ilmetä myös Kaukaan symbioosiyhteistyössä?

Onko esimerkiksi pienten yritysten kulttuuri erilainen?

Teknologinen kyvykkyys

Pystyykö yrityksenne aina arvioimaan tarkasti, onko tehokkaampaa vähentää jätteitä ja sivutuotteita tuotantovaiheessa teknologiaa kehittämällä vai toimittamalla syntyneet jätteet ja sivutuotteet toisen yrityksen käyttöön?

Ovatko toisten käyttöön toimittamanne tai itse käyttämänne jätteet ja sivutuotteet sellaisia, joiden hyödyntäminen tuotannossa vaatii harvinaista erityisasiantuntemusta?

Tulisiko teknologista osaamistanne kehittää, jotta kykenette tunnistamaan mahdollisuudet käyttää toisten yritysten jätteitä ja sivutuotteita tuotannossanne?

Tulisiko teknologista osaamistanne kehittää, jotta kykenette tunnistamaan mahdollisuudet hyödyntää tuottamianne jätteitä ja sivutuotteita toisten, eri toimialojen yritysten tuotannossa?

Jätteiden ja sivutuotteiden ominaisuudet

Mitkä tuottamienne jätteiden ja sivutuotteiden ominaisuudet täytyy viestiä, jotta käyttäjä pystyy hyödyntämään niitä tuotannossaan?

Ovatko jotkin jätteiden ja sivutuotteiden ominaisuudet erityisen haastavia viestiä niiden käyttäjälle?
Onko näiden ominaisuuksien viestiminen tuottanut liiketoimintasuhteissanne vaikeuksia?
Voivatko jätteiden ja sivutuotteiden laatuvaihtelut ja näiden vaihtelujen viestiminen tuottaa vaikeuksia vaihdannassa?

Sähköiset tietojärjestelmät

Onko yrityksessänne tai toimialallanne käytössä sähköisiä kuvauskieliä, joilla voi viestiä jätteiden ja sivutuotteiden ominaisuuksia?
Onko yrityksessänne tai toimialallanne käytössä tietojärjestelmiä, joita käytetään tai voidaan käyttää jätteiden ja sivutuotteiden sähköiseen kuvaamiseen niiden vaihdannassa?
Kerätäänkö jäte- ja sivutuotevirroista tietoja tietokantoihin?
Toteutetaanko jäte- ja sivutuotevirtojen kokonaisoptimointia tietyn sähköisen työkalun avulla?
Ketkä näitä tietojärjestelmiä käyttävät?
Onko tietojärjestelmissä puutteellisuuksia, jotka tulee korjata, jotta jätteiden ja sivutuotteiden sähköinen kuvaaminen tapahtuu tehokkaasti?
Harjoitatteko sosiaalista vuorovaikutusta (toisin sanoen muuta vuorovaikutusta kuin pelkkien teknisten faktojen viestintää) sähköisten työkalujen avulla?
Rajoittaako nykyisten sähköisten työkalujen sosiaalisen vuorovaikutuksen puute uusien jätteiden ja sivutuotteiden vaihdantasuhteiden syntyä?
Olisiko UPM:llä tai Kaukaalla tarpeellista olla käytössä jätteiden ja sivutuotteiden vaihdantaa varten tietojärjestelmä, jonka avulla jätteistä ja sivutuotteista viestittäisiin nykyisille ja potentiaalisille yhteistyökumppaneille?
Voiko tietojärjestelmän puute estää nykyisellään Kaukaan jätteiden ja sivutuotteiden vaihdannan kehittämisen?

Yhteistyö kansallisten ja alueellisten toimijoiden kanssa

Miten alueelliset liiketoimintaympäristön tekijät (esim. paikallinen yrityskulttuuri ja sekä kansallisen ja kunnallisen tason politiikka) voivat vaikuttaa yrityksenne jätteiden ja sivutuotteiden vaihdantasuhteiden kehitykseen?

Millä tavoin yrityksenne on tehnyt yhteistyötä muiden toimijoiden kuin toisten teollisuusyritysten kanssa jätteiden ja sivutuotteiden vaihdannan edistämiseksi (tällaisia toimijoita ovat esimerkiksi korkeakoulut, tutkimuslaitokset, valtion ja kunnan organisaatiot, asiantuntijapalveluita tarjoavat yritykset sekä suurelle yleisölle viestivät mediat)?

Uskotteko näiden samojen tahojen voivan myös tulevaisuudessa edistää tehokkaasti symbioottisille vaihdantasuhteille otollisten olosuhteiden syntymistä?

Ovatko edellä mainitut tahot vaikeuttaneet sivutuotteiden vaihdantaa?

Voiko tehoton viranomaisyhteistyö olla syynä siihen, että jätteiden ja sivutuotteiden sääntelyä ja vaihdantaa ei kehitetä parhaalla mahdollisella tavalla?

Voitteko kertoa esimerkin viranomaisyhteistyön ongelmista?

Symbioosiin vaikuttava lainsäädäntö

Onko jätteiden ja sivutuotteiden vaihdantaa koskeva lainsäädäntö ajan tasalla vai vaikeuttaako se vaihdantaa?

Tukeeko verotus jätteiden ja sivutuotteiden vaihdantaa?

Edistävätkö vai haittaavatko verotuet teollisen symbioosin syntyä pitkällä tähtäimellä?

Millaisia muutoksia lakeihin tulisi tehdä, jotta vaihdanta toteutuisi paremmin?

Appendix II, 1. The interview questions for the representative of NIA

Because the interview was conducted in Finnish, the questions are in Finnish.

Kuinka ammatillinen vastuualueenne liittyy jätteiden ja sivutuotteiden vaihdantaan ja teollisen symbioosin kehittämiseen?

Millä keinoilla Nordic Innovation Accelerator (johon tästä eteenpäin viitataan lyhenteellä NIA) voi edistää Kaukaan symbioosin kehittämistä?

Teollisen symbioosin käsitteistön tuntemus ja käyttö

Voisitteko määritellä teollisen symbioosin käsitteen?

Käytättekö tätä käsitettä yrityksenne sisäisessä viestinnässä ja yhteistyössä sidosryhmienne kanssa?

Symbioosia edistävät henkilöt

Kuinka NIA:n edustajat tulevat työskentelemään Kaukaan teollisen symbioosin synnyttämiseksi?

Löytyykö ulkoisista sidosryhmistänne henkilöitä, jotka tulevat todennäköisesti toimimaan Kaukaan tuotannon kestävyyden ja jätteiden ja sivutuotteiden vaihdannan edistämiseksi?

Symbioottisten suhteiden luominen

Mitkä ovat vaiheet prosessissa, jonka avulla jätteiden ja sivutuotteiden toimittajat ja käyttäjät saatetaan yhteistyöhön?

Tietojemme mukaan UPM haluaa ulkopuolisen toimijan kehittävän itselleen valmiin sovellettavan teknisen ratkaisun jätteiden ja sivutuotteiden hyödyntämiseen. Miten edesautetaan sitä, että jätteiden ja sivutuotteiden toimittajat (UPM) ja hyödyntäjät tekevät riittävän tiivistä yhteistyötä, jotta toimiva käytännön tekninen ratkaisu syntyy?

Ovatko aloitteet vaihdantasuhteiden luomiseen tulleet pelkästään Kaukaalta vai myös muilta potentiaalisilta yhteistyöyrityksiltä?

Millaisten kanavien kautta jätteiden ja sivutuotteiden toimittajat ja käyttäjät tavoitetaan?

Onko NIA jäsen sellaisissa liiketoimintaverkostoissa, joissa jäsenet etsivät ja löytävät jätteiden ja sivutuotteiden vaihdantakumppaneita?

Kuinka usein teette jätteiden ja sivutuotteiden vaihdantaan liittyvää yhteistyötä toisten yritysten kanssa?
Etsittekö jatkuvasti käyttökohteita jätteille ja sivutuotteille?
Ovatko yritykset halukkaita kohdentamaan riittävästi rahaa jätteiden ja sivutuotteiden vaihdannan kehittämiseen?

Taloudelliset hyödyt ja kustannukset

Voidaanko lainsäädännön asettamien rajoitusten ja suorien kustannussäästöjen tällä hetkellä olevan yrityksille ainoat todelliset syyt jätteiden ja sivutuotteiden vaihdantasuhteiden aloittamiseen?
Vaikuttavatko epäsuorat taloudelliset hyödyt yritysten päätöksiin aloittaa jätteiden ja sivutuotteiden vaihdantasuhde (verrattuna suoriin taloudellisiin hyötyihin)?

- Epäsuoria taloudellisia hyötyjä: riskien pieneneminen, toimialan laajentaminen (diversifioituminen), resurssien hyötykäyttö, kaatopaikkajätteen poistuminen, parantuneet suhteet yhteisöihin ja hallintoon, parantunut yrityksen tai brändin maine

Suorat taloudelliset hyödyt (tuottojen kasvaminen ja kustannusten pieneneminen) ovat tähän mennessä saamiemme tietojen mukaan määrittävä tekijä vaihdantasuhteiden aloittamispäätöksissä. Kommunikoiko NIA jollain tavalla yhteistyön osapuolille näitä suoria taloudellisia hyötyjä (esimerkiksi taloudellisen laskennan avulla)?

Taloudelliset riskit

Mitkä ovat keskeiset riskit, jotka näette olevan uuden jätteiden ja sivutuotteiden vaihdantasuhteen aloittamisen esteenä NIA:lle ja sen yhteistyöyrityksille?
Ovatko nämä riskit aiemmin aiheuttaneet merkittäviä ongelmia liiketoimintasuhteissanne?
Jos jätteen tai sivutuotteen käyttäjä lopettaisi suhteen yhtäkkiä, kykenisikö NIA löytämään UPM:n (tai muun toimijan) toimittamalle jätteelle tai sivutuotteelle todennäköisesti nopeasti muun käyttökohteen?
Vaatiiko yritysten tarjoamien teknisten ratkaisujen toteuttaminen yleensä suuria investointeja?
Ovatko yritysten harkitsemat symbioottiset suhteet yleensä alussa tappiollisia?

Appendix II, 3. The interview questions for the representative of NIA (continued)

Tuottojen ja kustannusten jakautuminen

Onko aikaisemmassa liiketoimintayhteistyössänne ilmennyt niin suurta tuottojen ja kustannusten epätasaista jakautumista, että se on saanut teidät tai jonkun toisen yhteistyön osapuolen vetäytymään yhteistyöstä tai harkitsemaan yhteistyöstä vetäytymistä?

Arviointimenetelmät

Tulisitteko arviomaan jätteiden ja sivutuotteiden vaihdantasuhteita taloudellisilla tai ekologisilla mittareilla?

Symbioosin koordinointi

Aiemmista haastatteluista olemme saaneet tietää, että UPM Kaukaalla on yksittäisiä vaihdantasuhteita eri yritysten kanssa, mutta nämä yhteistyöyritykset eivät verkostoidu keskenään tai tee yhteistyötä, ainakaan Kaukaan symbioosin puitteissa. Kehittyneeseen symbioosiin kuuluu kuitenkin verkostoyhteistyö symbioosin eri jäsenten kesken. Tuleeko NIA jollain keinoilla edistämään verkostoyhteistyötä kaikkien symbioosiin osallistuvien yritysten kesken?

Voiko UPM ottaa keskeisen roolin syntyvän symbioosiverkoston koordinoinnissa (eli johtaa suurena jätteiden ja sivutuotteiden vaihtajana Kaukaan symbioosiverkostoa)?

Mielestämme riskinä on, että yhteistyössä UPM voi saada liian keskeisen roolin, mikä voi haitata muiden Kaukaan symbioosiin osallistuvien yritysten välistä yhteistyötä, siten, etteivät nämä muut yritykset muodosta tehokkaasti keskenään suhteita. Tästä syystä tarvittaisiin koordinointi- ja johtamistoiminto, joka ottaisi huomioon kaikki symbioosiin osallistujat. Millainen pitäisi työnjaon olla NIA:n, GCI:n ja UPM:n välillä, jotta Kaukaan symbioosia johdettaisiin tehokkaasti?

Tulisiko symbioosin johtamiseen ja koordinointiin osallistumaan myös muita osapuolia?

Appendix II, 4. The interview questions for the representative of NIA (continued)

Ennakkoasenteet

Onko aikaisemmassa liiketoimintayhteistyössänne ilmennyt sellaisia toisten osapuolten ennakkoluuloista ja asenteista (NIA:a tai toisia yhteistyöyrityksiä kohtaan) johtuvia yhteistyöongelmia jotka ovat merkittävästi haitanneet yhteistyötä ja jotka voisivat mahdollisesti muodostua ongelmaksi myös Kaukaan symbioosin toteutuksessa?

Onko olemassa yrityksiä, joiden kanssa ette voi helposti ajatella lähtevänne symbioosiyhteistyöhön (esimerkiksi aikaisempien huonojen yhteistyökokemusten tähden tai koska yritys tekee yhteistyötä kilpailijoiden kanssa)?

Eri toimialoilta saatava asiantuntemus ja yrityskulttuurien erot

Millaisia toimialoja ja erityisasiantuntemusta potentiaaliset symbioosin jäsenyritykset näillä näkymin todennäköisesti edustavat?

Löytyykö niistä verkostoista, joissa NIA on jäsenenä, kyseisiä toimialoja ja erityisasiantuntemusta edustavia yrityksiä?

Onko yrityksenne liiketoimintayhteistyössä ilmennyt sellaisia yrityskulttuurien eroista johtuvia yhteistyövaikeuksia (joissa NIA tai toiset yritykset ovat olleet osapuolena), joita todennäköisesti voi ilmetä myös Kaukaan symbioosiyhteistyössä?

Ovatko epämuodolliset vuorovaikutuskanavat (esimerkiksi verkostoitumistilaisuudet) merkittävässä roolissa jätteiden ja sivutuotteiden vaihdantasuhteiden synnyttämisessä?

Sähköiset tietojärjestelmät

Onko yrityksessänne tai toimialallanne käytössä sähköisiä kuvauskieliä, joilla voi viestiä jätteiden ja sivutuotteiden ominaisuuksia?

Voidaanko NIA:n verkkopalvelua käyttää jätteiden ja sivutuotteiden sähköiseen kuvaamiseen niiden vaihdannassa?

Ketkä kaikki tätä verkkopalvelua käyttävät?

Tuleeko palvelua kehittää, jotta sitä voidaan soveltaa jätteiden ja sivutuotteiden vaihdantasuhteiden tehokkaaseen luomiseen?

Voiko verkkopalvelulla viestiä esimerkiksi jatkuvasti jätteiden ja sivutuotteiden koostumuksen (laadun) vaihteluja käyttäjäyritykselle vai onko se tehtävä jollakin muulla työkalulla?

Appendix II, 5. The interview questions for the representative of NIA (continued)

Kuinka haun kohteena olevien potentiaalisten yhteistyöyritysten joukko määritellään ja rajataan?

Yhteistyö kansallisten ja alueellisten toimijoiden kanssa

Miten alueelliset liiketoimintaympäristön tekijät (esim. paikallinen yrityskulttuuri ja sekä kansallisen ja kunnallisen tason politiikka) voivat vaikuttaa yrityksenne jätteiden ja sivutuotteiden vaihdantasuhteiden kehitystyöhön?

Millä tavoin yrityksenne on tehnyt yhteistyötä muiden toimijoiden kuin teollisuusyritysten kanssa jätteiden ja sivutuotteiden vaihdannan edistämiseksi (tällaisia toimijoita ovat esimerkiksi korkeakoulut, tutkimuslaitokset, valtion ja kunnan organisaatiot, asiantuntijapalveluita tarjoavat yritykset sekä suurelle yleisölle viestivät mediat)?

Uskotteko näiden samojen tahojen voivan myös tulevaisuudessa edistää tehokkaasti symbioottisille vaihdantasuhteille otollisten olosuhteiden syntymistä?

Ovatko edellä mainitut tahot vaikeuttaneet sivutuotteiden vaihdannan kehittämistä?

Symbioosiin vaikuttava lainsäädäntö

Onko jätteiden ja sivutuotteiden vaihdantaa koskeva lainsäädäntö ajan tasalla vai vaikeuttaako se vaihdantaa?

Tukeeko verotus jätteiden ja sivutuotteiden vaihdantaa?

Millaisia muutoksia lakeihin tulisi tehdä, jotta vaihdanta toteutuisi paremmin?

Symbioosin markkinointi

Millaisissa kanavissa ja kenelle symbioosia tulee markkinoida?

Onko symbioosin markkinoinnilla medioissa käytännön vaikutusta symbioosin menestyksekkääseen kehittymiseen?

Onko teollisen symbioosin käsite helposti markkinoitava (verrattuna esimerkiksi Metsä Groupin Äänekosken biotuotetehtaaseen, joka käytännössä muistuttaa symbioosia)?

Appendix III, 1. The interview questions for the representative of GCI

Because the interview was conducted in Finnish, the questions are in Finnish.

Kuinka ammatillinen vastuualueenne liittyy teollisen symbioosin kehittämiseen?
Millä keinoilla Green Campus Innovations (johon tästä eteenpäin viitataan lyhenteellä GCI) voi edistää Kaukaan symbioosin kehittämistä?

Teollisen symbioosin käsitteistön tuntemus ja käyttö
Voisitteko määritellä teollisen symbioosin käsitteen?
Käytättekö tätä käsitettä yrityksenne sisäisessä viestinnässä ja yhteistyössä sidosryhmienne kanssa?
Millä keinoilla varmistatte, että yrityksenne henkilöstö ja sidosryhmänne omaksuvat teollisen symbioosin käsitteen?

Symbioosia edistävät henkilöt
Kuinka GCI:n edustajat tulevat työskentelemään Kaukaan teollisen symbioosin synnyttämiseksi?
Löytyykö ulkoisista sidosryhmistänne henkilöitä, jotka tulevat todennäköisesti toimimaan Kaukaan tuotannon kestävyyden ja jätteiden ja sivutuotteiden vaihdannan edistämiseksi?
Onko Kaukaan symbioosin kehittämiseen näillä näkymin osallistuvien henkilöiden tekemä työ riittävää saamaan aikaan Kaukaan symbioosin syntymisen, vai tarvitaanko enemmän osaamista ja työpanosta?

Jätteiden ja sivutuotteiden hyödyntämisratkaisujen luominen
Mitkä ovat vaiheet prosessissa, jonka avulla jätteiden ja sivutuotteiden toimittajat ja käyttäjät saatetaan yhteistyöhön uuden teknologisen ratkaisun luomiseksi?
Millä perusteilla potentiaaliset jätteiden ja sivutuotteiden hyödyntämisratkaisut valitaan kaupallistettavaksi ja sijoituskohteiksi?
Tulevatko sijoituskohteenne olemaan pieniä teknologiayrityksiä?
Onko yritysten kehittämien jätteiden ja sivutuotteiden hyödyntämisen teknologiaratkaisujen oltava sellaisia, joita tullaan markkinoimaan kansainvälisillä markkinoilla?

Appendix III, 2. The interview questions for the representative of GCI (continued)

Mitkä ovat todennäköisesti tärkeimmät kehityshaasteet, jotka on ratkaistava, jotta potentiaalisesta jätteiden ja sivutuotteiden hyödyntämisen teknologiasta tulee menestyvä kaupallinen tuote?
Tietojemme mukaan UPM haluaa ulkopuolisen toimijan kehittävän itselleen valmiin sovellettavan teknisen ratkaisun jätteiden ja sivutuotteiden hyödyntämiseen. Miten edesautetaan sitä, että jätteiden ja sivutuotteiden toimittajat (UPM) ja hyödyntäjät tekevät riittävän tiivistä yhteistyötä, jotta toimiva käytännön tekninen ratkaisu syntyy?
Ovatko aloitteet jätteiden ja sivutuotteiden hyödyntämiseen tulleet pelkästään Kaukaalta vai myös muilta potentiaalisilta yhteistyöyrityksiltä?
Oletteko jo sijoittaneet jätteiden ja sivutuotteiden hyödyntämiseen liittyvään teknologiaratkaisuun?
Millaisten kanavien kautta jätteiden ja sivutuotteiden hyödyntäjät tavoitetaan?
Onko GCI jäsen sellaisissa liiketoimintaverkostoissa, joissa jäsenet etsivät ja löytävät jätteiden ja sivutuotteiden vaihdantakumppaneita?
Kuinka usein teette jätteiden ja sivutuotteiden hyödyntämiseen liittyvää yhteistyötä toisten yritysten kanssa?
Etsittekö jatkuvasti käyttökohteita jätteille ja sivutuotteille?
Ovatko yritykset halukkaita kohdentamaan riittävästi rahaa jätteiden ja sivutuotteiden hyödyntämisen kehittämiseen?

<u>Taloudelliset hyödyt ja kustannukset</u>
Voidaanko lainsäädännön asettamien rajoitusten ja suorien kustannussäästöjen tällä hetkellä olevan yrityksille ainoat todelliset syyt jätteiden ja sivutuotteiden vaihdannan aloittamiseen ja hyödyntämiseen tuotannossa?
Vaikuttavatko epäsuorat taloudelliset hyödyt yritysten päätöksiin hyödyntää jätteitä ja sivutuotteita tuotannossa (verrattuna suoriin taloudellisiin hyötyihin)?

- Epäsuoria taloudellisia hyötyjä: riskien pieneneminen, toimialan laajentaminen (diversifioituminen), resurssien hyötykäyttö, kaatopaikkajätteen poistuminen, parantuneet suhteet yhteisöihin ja hallintoon, parantunut yrityksen tai brändin maine

Appendix III, 3. The interview questions for the representative of GCI (continued)

Suorat taloudelliset hyödyt (tuottojen kasvaminen ja kustannusten pieneneminen) ovat tähän mennessä saamiemme tietojen mukaan määrittävä tekijä jätteiden ja sivutuotteiden vaihdantasuhteiden aloittamispäätöksissä. Kommunikoiko GCI jollain tavalla yhteistyön osapuolille näitä suoria taloudellisia hyötyjä (esimerkiksi taloudellisen laskennan avulla)?

Taloudelliset riskit

Mitkä ovat keskeiset riskit, jotka näette olevan jätteiden ja sivutuotteiden hyödyntämisen aloittamisen esteenä GCI:lle ja sen yhteistyöyrityksille?

Ovatko nämä riskit aiemmin aiheuttaneet merkittäviä ongelmia liiketoimintasuhteissanne?

Jos jätteen tai sivutuotteen hyödyntäjä lopettaisi suhteen yhtäkkiä, kykenisikö GCI löytämään UPM:n (tai muun toimijan) toimittamalle jätteelle tai sivutuotteelle todennäköisesti nopeasti muun käyttökohteen?

Vaatiiko yritysten tarjoamien teknisten ratkaisujen toteuttaminen yleensä suuria investointeja?

Ovatko yritysten harkitsemat jätteiden ja sivutuotteiden hyödyntämisratkaisut yleensä alkuvaiheessa tappiollisia?

Tuottojen ja kustannusten jakautuminen

Onko aikaisemmassa liiketoimintayhteistyössänne ilmennyt niin suurta tuottojen ja kustannusten epätasaista jakautumista, että se on saanut teidät tai jonkun toisen yhteistyön osapuolen vetäytymään yhteistyöstä tai harkitsemaan yhteistyöstä vetäytymistä?

Arviointimenetelmät

Tulisitteko arviomaan jätteiden ja sivutuotteiden hyödyntämisratkaisuja taloudellisilla tai ekologisilla mittareilla?

Millä perusteella käytätte juuri näitä kyseisiä mittareita?

Appendix III, 4. The interview questions for the representative of GCI (continued)

Symbioosin koordinointi

Aiemmista haastatteluista olemme saaneet tietää, että UPM Kaukaalla on yksittäisiä vaihdantasuhteita eri yritysten kanssa, mutta nämä yhteistyöyritykset eivät verkostoidu keskenään tai tee yhteistyötä, ainakaan Kaukaan symbioosin puitteissa. Kehittyneeseen symbioosiin kuuluu kuitenkin verkostoyhteistyö symbioosin eri jäsenten kesken. Tuleeko GCI jollain keinoilla edistämään verkostoyhteistyötä kaikkien symbioosiin osallistuvien yritysten kesken?

Voiko UPM ottaa keskeisen roolin syntyvän symbioosiverkoston koordinoinnissa (eli johtaa suurena jätteiden ja sivutuotteiden vaihtajana Kaukaan symbioosiverkostoa)?

Mielestämme riskinä on, että yhteistyössä UPM voi saada liian keskeisen roolin, mikä voi haitata muiden Kaukaan symbioosiin osallistuvien yritysten välistä yhteistyötä siten, etteivät nämä muut yritykset muodosta tehokkaasti keskenään suhteita. Tästä syystä tarvittaisiin koordinointi- ja johtamistoiminto, joka ottaisi huomioon kaikki symbioosiin osallistujat. Millainen pitäisi työnjaon olla GCI:n, NIA:n ja UPM:n välillä, jotta Kaukaan symbioosia johdettaisiin tehokkaasti?

Tulisiko symbioosin johtamiseen ja koordinointiin osallistumaan myös muita osapuolia?

Ennakkoasenteet

Onko aikaisemmassa liiketoimintayhteistyössänne ilmennyt sellaisia toisten osapuolten ennakkoluuloista ja asenteista (GCI:tä tai toisia yhteistyöyrityksiä kohtaan) johtuvia yhteistyöongelmia jotka ovat merkittävästi haitanneet yhteistyötä ja jotka voisivat mahdollisesti muodostua ongelmaksi myös Kaukaan symbioosin toteutuksessa?

Onko yhteistyössä julkisten tahojen (valtion tai kunnan) kanssa ilmennyt ennakkoluuloja?

Onko olemassa yrityksiä, joiden kanssa ette voi helposti ajatella lähtevänne symbioosiyhteistyöhön (esimerkiksi aikaisempien huonojen yhteistyökokemusten tähden tai koska yritys tekee yhteistyötä kilpailijoiden kanssa)?

Appendix III, 5. The interview questions for the representative of GCI (continued)

Eri toimialoilta saatava asiantuntemus ja yrityskulttuurien erot

Tähän mennessä UPM:n puolelta esille tulleita jätteiden ja sivutuotteiden hyödyntäjien toimialoja ovat olleet biokaasuyritykset, mädätteen hyödyntäjät, lannoiteyritykset, erotustekniikan hallitsijat, komposiittivalmistajat, rakennusmateriaalit, biomateriaalit, mineraaliset materiaalit, mineraalien käsittely, tuhkan käsittely ja loppukäyttö, energiantuotanto ja energiaintensiiviset käyttökohteet. Onko GCI:llä tiedossa potentiaalisia näiden edellä mainittujen toimialojen yhteistyökumppaneita?

Onko näillä näkymin tiedossa muita potentiaalisia yhteistyökumppanien toimialoja?

Onko yrityksenne liiketoimintayhteistyössä ilmennyt sellaisia yrityskulttuurien eroista johtuvia yhteistyövaikeuksia (joissa GCI tai toiset yritykset ovat olleet osapuolena), joita todennäköisesti voi ilmetä myös Kaukaan symbioosiyhteistyössä?

Onko esimerkiksi pienten yritysten kulttuuri erilainen kuin suurten yritysten?

Ovatko epämuodolliset vuorovaikutuskanavat (esimerkiksi verkostoitumistilaisuudet) merkittävässä roolissa jätteiden ja sivutuotteiden hyödyntämisratkaisujen löytämisessä?

Yhteistyö kansallisten ja alueellisten toimijoiden kanssa

Miten alueelliset liiketoimintaympäristön tekijät (esim. paikallinen yrityskulttuuri ja sekä kansallisen ja kunnallisen tason politiikka) voivat vaikuttaa yrityksenne jätteiden ja sivutuotteiden hyödyntämisen kehitystyöhön?

Millä tavoin yrityksenne on tehnyt yhteistyötä muiden toimijoiden kuin teollisuusyritysten kanssa jätteiden ja sivutuotteiden hyödyntämisen edistämiseksi (tällaisia toimijoita ovat esimerkiksi korkeakoulut, tutkimuslaitokset, valtion ja kunnan organisaatiot, asiantuntijapalveluita tarjoavat yritykset sekä suurelle yleisölle viestivät mediat)?

Uskotteko näiden samojen tahojen voivan myös tulevaisuudessa edistää tehokkaasti jätteiden ja sivutuotteiden hyödyntämiselle otollisten olosuhteiden syntymistä?

Ovatko edellä mainitut tahot vaikeuttaneet jätteiden ja sivutuotteiden hyödyntämisen kehittämistä?

Jätteiden ja sivutuotteiden hyödyntämiseen vaikuttava lainsäädäntö

Edistääkö vai vaikeuttaako lainsäädäntö tuotteiden valmistamista jätteistä ja sivutuotteista uusilla teknologioilla?

Appendix III, 6. The interview questions for the representative of GCI (continued)

Millaisia muutoksia lakeihin tulisi tehdä, jotta jätteiden ja sivutuotteiden hyödyntäminen tuotannossa toteutuisi paremmin?

Symbioosin markkinointi

Millaisissa kanavissa ja kenelle symbioosia tulee markkinoida?

Onko symbioosin markkinoinnilla medioissa käytännön vaikutusta symbioosin menestyksekkääseen kehittymiseen?

Onko teollisen symbioosin käsite helposti markkinoitava (verrattuna esimerkiksi Metsä Groupin Äänekosken biotuotetehtaaseen, joka käytännössä muistuttaa symbioosia)?

Appendix IV. The definitions of industrial symbiosis given by different interviewees

When interviewing the representatives of UPM, NIA and GCI, the following definitions of industrial symbiosis were obtained as answers. The definitions have been transcribed from the answers given by the interviewees.

- Companies, which are present in a same industrial site, engage in cooperation which benefits each company by finding uses for side streams.
- A network of companies and other agents is created in an industrial region or site and this network exchanges and uses waste and by-product streams.
- Companies operating in a same region cooperate by exchanging and using each other's wastes and by-products and utilities.
- Companies exchange wastes and by-products with each other in a way which benefits all the exchange participants economically.
- Companies, which are located in a same area, use each other's wastes and by-products as raw materials and exchange also such utilities as electricity, heat, water and compressed air.
- Companies use each other's wastes and by-products as raw materials. Those wastes and by-products, which can be used as raw materials of products, will be used for this purpose.
- Companies use each other's wastes and by-products and also other utilities such as energy.
- New products are manufactured and new businesses are created from raw materials currently classified as waste.

Appendix V, 1. The industrial symbiosis maturity grid (Golev et al. 2014, 144)

IS barriers	*Stage 1 (not recognized)*	*Stage 2 (initial efforts)*	*Stage 3 (active)*	*Stage 4 (proactive)*	*Stage 5 (forming the future)*
Commitment to SD	SD is not recognized as a part of business strategy and practice.	SD is a part of company strategy, but no indicators are used to measure the SD performance.	Some SD indicators are used and reported, but there is a lack of proven methods/skills to standardize this process.	The system of indicators and proven methods are used to ensure that the SD goals are effectively deployed to every level of the company and successfully achieved.	Long-term perspectives and benefits dominate in the decision-making process. Local industries cooperatively take the responsibility for the regional SD.
Information	There is no exchange of information between companies in the area. Minimum environmental data are released to the public domain.	Most companies release environmental reports that are publicly available, but there is a lack of detailed information on waste streams.	Environmental reporting for public interest is a standard practice. Some reports that combine the information in order to see the "full picture" may also exist.	Summary of the overall environmental situation in the area is released regularly. There is an agreed coordination mechanism (or body) for the environmental data sharing and analysis.	The database on existing waste streams in the area is regularly updated and well maintained. Any additional details can be easily obtained through existing communication systems.
Cooperation	Every company looks solely for its waste reuse opportunities. There is a lack of trust between companies that hampers any collaboration.	Cooperation between industries predominantly happens when they are facing serious challenges together.	There is growing interest (and trust) for cooperation with neighboring industries. Coordination for these initiatives is predominantly at the top management level.	Cooperation between companies in the area happens often in different spheres. Coordination for these initiatives gradually proceeds from the top level to lower levels.	Cooperation between companies is constructive and happens regularly at different levels. There is continuous effort to improve it.
Technical	The waste reuse opportunities outside of a single company are not considered to be worthwhile. Cost minimization for waste disposal is the preferred strategy.	Some opportunities for waste reuse between industries may exist, but only well-known and proven projects can proceed with implementation.	Several possibilities for waste reuse in the area have been identified, but there is still not enough information to proceed with these projects.	Opportunities for waste reuse were analyzed in detail by experts. The most promising projects have been realized; others are under further investigation.	There is a list of long-term research projects for the waste reuse and minimization; industries often proceed to the implementation as pioneers. The current level of technical expertise is at the edge of scientific progress.

Appendix V, 2. The industrial symbiosis maturity grid (continued) (Golev et al. 2014, 145)

IS barriers	*Stage 1 (not recognized)*	*Stage 2 (initial efforts)*	*Stage 3 (active)*	*Stage 4 (proactive)*	*Stage 5 (forming the future)*
Regulation	Waste reuse opportunities are not well recognized in the current legislation. The regulation is more restrictive, rather than encouraging.	Recycling is announced in legislation as an important element, but no specific regulation exists. Decisions are usually made on a case-by-case basis.	Recycling and waste reuse issues are an integral part of current regulation. Several well-known examples are included in official documents to encourage the implementation of the best-known waste reuse practices.	Legislation recognizes both well-known and potential waste reuse options. There is continuous improvement of regulation for better environmental outcomes.	Recycling and waste reuse is the main focus of environmental regulation. Most recyclable wastes are forbidden for disposal (compulsory recycling). The taxation system makes the reuse option strongly preferable for most types of wastes.
Community	Community is not recognized as an equal part in negotiation process for industrial development, which mostly depends on the government policy and the interests of industry and investors.	Community opinion may be important in some situations; people are kept informed about most important environmental aspects.	Informing community about environmental issues is a part of business strategy. There is a well-established communication system. The feedback and any community member claims are well analyzed, responded to, and reported.	Contribution to community capacities is recognized as one of the most important outcomes of industrial development in the area. An official community body exists and effectively negotiates with industries and government; it may also participate in environmental assessments.	Community is an active power in the decision-making process for current and future industrial development in the region.
Economic	Maximizing of profit is the main driver for industrial development in the region.	Industries have a special budget for environmental projects to comply with current regulation. General opinion is that environmental projects sound good, but are too costly.	There is an understanding that wastes may be a valuable resource. The information on costs for the disposal of every ton of waste is well known and used in decision making.	Waste reuse projects have proven their efficiency. There is a continuous investigation for new opportunities. Long-term benefits and risks are considered as a priority for project approval. Some projects have been accepted even if they are not feasible from a short-term perspective.	Close collaboration with other industries in the area is seen as a key competitive advantage. "By the reuse of wastes we make profit, secure our resources base, minimize environmental risks, and ensure regional SD."