Vaasan yliopisto
UNIVERSITY OF VAASA

Ville Ahola

Success factors of industrial ecosystems

Case Sodankylä

School of Technology and Innovations

Vaasa 2020

VAASAN YLIOPISTO
Tekniikan ja innovaatiojohtamisen akateeminen yksikkö
Tekijä: Ville Ahola
Tutkielman nimi: Success factors of industrial ecosystems : Case Sodankylä
Tutkinto: Kauppatieteiden maisteri
Oppiaine: Tuotantotalous
Työn ohjaaja: Ville Tuomi
Valmistumisvuosi: 2020 **Sivumäärä:** **68**

Tiivistelmä :

Teollisen ekosysteemin kriittisistä menestystekijöistä ei ole kovin paljon aiempaa tutkimusta. Tämä tutkimus selittää case esimerkkiä, aikaisempia tutkimuksia ja haastatteluja hyödyntäen, kuinka yritykset voivat kierrättää resurssejaan teollisen ekosysteemin sisällä menestyksekkäällä tavalla ja miten teolliset ekosysteemit voivat olla menestyksellisiä. Tutkimuksessa hyödynnetään teollisten ekosysteemien ja kiertotalouden teoriaa.

Tutkimuksessa hyödynnetään laadullista menetelmää. Kerätty data analysoidaan sisällönanalyysillä. Sisällönanalyysissä materiaali spesifioidaan, siitä etsitään samankaltaisuuksia ja erilaisuuksia, lopuksi datasta tehdään yhteenveto (Tuomi & Sarajärvi, 2002, p. 105). Tämänkaltainen analyysitapa sopii tutkimukseeni, sillä siinä yhdistetään keskustelut ja haastattelut, jonka jälkeen ne linkitetään aiempiin tutkimuksiin. (Leinonen Rita, 2018). Avoimet haastattelukysymykset sopivat todella hyvin tähän tutkimukseen, koska niissä haastateltavat saavat vapauden ilmaista itseään omalla luovalla tavallaan. Dataa kerätään myös aiemmista tutkimuksista, jotka koskevat teollisia ekosysteemejä ja kiertotaloutta. Tämän lisäksi tein muutamia avoimia haastatteluja LUKEn tutkijoille ja Sodankylän kunnan kehitysjohtajalle.

Tutkimuksen tarkoitus on löytää vastaus siihen mitä teolliset ekosysteemit ovat, mitä hyötyä niistä on ja mitkä ovat kriittisiä menestystekijöitä teollisille ekosysteemeille. Tutkimuksessa pyritään löytämään vastaus näihin kysymyksiin: Mitä teolliset ekosysteemit ovat? Mitkä ovat teollisten ekosysteemien hyötyjä? Mitkä ovat teollisen ekosysteemin kriittiset menestystekijät?

Peck S. (2002) mukaan teollinen ekosysteemi on yritysrypäs, jossa yritykset tekevät yhteistyötä keskenään ja paikallisen yhteisön kanssa jakaen resurssejaan tehokkaasti saavuttaakseen hyötyä ympäristöllisestä ja taloudellisesta näkökulmasta, samalla voimistaen työvoiman tuottavuutta niin yrityksen kuin yhteiskunnannkin näkökulmasta.

Tutkimus onnistui selvittämään, mitkä ovat teollisten ekosysteemien kriittiset menestystekijät ja tärkeimmät hyödyt. Tutkimus kokosi myös laajan tietopaketin, koskien teollisia ekosysteemejä ja kiertotaloutta.

Avainsanat: teollinen ekosysteemi, teollinen symbioosi, kiertotalous

UNIVERSITY OF VAASA
School of Technology and Innovations
Author: Ville Ahola
Topic of the master's thesis: Success factors of industrial ecosystems : Case Sodankylä
Degree: Master of Science in Economics and Business Administration
Major subject: Industrial Management
Instructor: Ville Tuomi

Year of Completing the master's thesis: 2020 **Pages:** **68**

Abstract:

Literature of industrial ecosystems lack of knowledge about success factors of profitable industrial ecosystems. In general, this study explains, mostly by using case Sodankylä, former case, previous studies, and interviews, how companies can circulate resources through industrial ecosystems in a successful way and how these industrial ecosystems can be successful.

In this study, I will use a qualitative method. The data will be analyzed with content analysis. In content analysis the material is viewed by specifying it, seeking similarities and differences from there and summarizing it. (Tuomi & Sarajärvi, 2002, p. 105). This kind of analysis is good for my study, because it sums up conservations and interviews and links them to previous studies. (Leinonen Rita, 2018). Open-ended interviews are great for this study because that way interviewees gain more freedom to express their own opinions in their own way. Data is gathered from previous studies of industrial ecosystems and circular economy. In addition to these I conducted some open-ended interviews which were answered by LUKE researchers and a development manager of Sodankylä municipality.

Purpose of this study is to find out, what is an industrial ecosystem, what are the benefits of industrial ecosystems and what are the critical success factors of profitable industrial ecosystems. This study tries to answer these questions: What is an industrial ecosystem? What are the benefits of industrial ecosystems? What are the critical success factors of profitable industrial ecosystems? I have plenty of questions, but I am still trying to answer them as wide as possible.

According to Peck S. (2002) an industrial ecosystem is a pack of companies, who are cooperating and with the local community to share their resources effectively for gaining benefits in environmental perspective, economic aspect and to intensify labor efficiency inside the company and the community.

The study succeeds to found out critical success factors and key benefits for industrial ecosystems, it also provided wide package of information about industrial ecosystems and circular economy.

Keywords: industrial ecosystem, industrial symbiosis, circular economy, CHP, eco-industrial park

Table of contents

List of figures

List of tables

LIST OF ABBREVIATIONS

IE	**Industrial ecosystem**
IS	**Industrial symbiosis**
EIP	**Eco-industrial park**
CE	**Circular economy**
CHP	**Combined heat and power**

1 Introduction

1.1 Background

In this world we have seen many profitable industrial ecosystems such as Kalundborg symbiosis, which is a leading industrial ecosystem in the world. These examples gave an inspiration to this study and, also the fact that structures of the study are built on to Case Sodankylä, which hopefully will someday be a great industrial ecosystem as well, showing example to whole business area in Finland, how to make products in an environment friendly and profitable way at the same time, like Kalundborg symbiosis does.

Industrial ecosystem is a group of companies or other operators who use the natural recycling model to lower costs and carbon dioxide emissions. This includes resource sharing where usually other's waste is another's resource. The cooperation is minimizing the system virgin material and energy input, which leads to decreasing of waste and environmental impact from the whole system. (Korhonen, J., Wihersaari, M., & Savolainen, I., 2001).

According to Descrochers (2002b) and Heino & Koskenkari (2004) industrial ecosystems lower production costs by using more efficiently energy and materials in production. This includes combination of heat and power, lower costs of waste incineration by using subcontracting, education, security, information sharing, lower use of virgin resources, mutual benchmarking, and better products when every company in the system can do what they are best in.

Industrial ecosystems also provide some benefits for environment by lowering emissions, lowering use of natural resources by circulating resources, reducing transportation emissions. (Descrochers, 2002 b) and (Heino & Koskenkari, 2004).

Industrial ecosystems are not just for lowering production costs, providing more economic benefits or even for minimizing environmental damage, but they are also doing good for local societies by creating new sources of income, creating jobs, creating new infrastructure, providing local energy sources. (Descrochers, 2002b) and (Heino & Koskenkari, 2004).

Key point of industrial ecosystems, industrial symbiosis and eco-industrial parks are co-operation between companies, municipalities, and local authorities. Through the cooperation with these different organizations, which operates in various business sectors can be achieved change in economic structures, intensifying environmental problems and increasing demand-related requirements. (Sitra, 2020). According to Sitra (2020), These all mean that companies need to come up with more resource-intensive solutions like sharing resources and information with others. In today's highly competitive markets co-operation is vital for every company which are looking for success. This study research, how companies can find more successful ways to compete trough industrial ecosystems and circular economy. These two are tightly connected to each other in this study. In this study, I do not distinguish between industrial symbiosis and industrial ecosystem. I prefer word industrial ecosystem in this study, and I use it throughout the study expect in the section 2.4, which presents the Kalundborg symbiosis.

In some countries the development of industrial ecosystems is going forward fast. For example, China is adopting industrial ecology fast. In fact, it is one of the leading countries doing it. China's central government adopted circular economy already in 2002. However, China is not the only one. Also, in Europe there are several eco-industrial parks working, soon to be working and planned to be built. One of these is the industrial ecosystem network in Kalundborg, which is the world famous. (Sakr D., Baas L., El-Haggar S. & Huisingh D., 2011). In my opinion, we cannot give too much lead for China and other countries in the development of industrial ecosystems, in order that our companies are capable to compete with companies over the world in terms of clean production and profitability.

Somebody may think that industrial ecosystem is just some kind of new “trying to be green project”. However, this claim is far from truth. Industrial ecosystems can be highly profitable and there are many examples proving this. Hereby Building a functioning industrial ecosystem is not just about working together for the sake of each other and the environment. It is mostly a try to find and adapt a new more benefit business models. (Ellen MacArthur Foundation, 2020b). Pollution prevention and cleaner production comes up usually always when considering of industrial ecosystems, because they clearly share purpose and similar objectives (Lowe E.A, 2001). This is the reason why also this research deals with cleaner production, circular economy, and pollution prevention.

When talking about industrial ecosystems, we can see that development has happened if compared to past, where individual companies took care of their own plot, when considered to environmental impacts. Next step is to connect those firms to wider industrial ecosystems and eco-industrial parks, which leads to even better results. (Gibbs and Deutz, 2007).

> *« Eco-industrial parks are designed to address the industrial system as a whole, where it considers technologies, process economics, the inter-relationships of businesses, financing, overall governmental policy, and the entire spectrum of issues that are involved in the management of commercial enterprises as equally important as environment protection and optimizing the use of scarce resources (Erkman, 2001). »*

1.2 Purpose of the study

Main purpose of this study is to find out, what are the benefits of industrial ecosystems and what are the critical success factors of profitable industrial ecosystems. I am doing this research also to gather an information, collected form industrial ecosystem, which is under development to Sodankylä. When I began to research the subject, I noticed that there is not that many research, which have been researching success factors of industrial ecosystems, so the study is really good source of information for all of those who are thinking to develop a new industrial ecosystem. The subject is also highly topical and needs some illustration, so everybody could understand benefits of IE. At the moment many company could increase their profits and decrease their carbon footprint by developing some kind of IE to their area.

1.3 Research questions

The aim of this thesis is to answer these three questions:
-*What is an industrial ecosystem?*
-*What are the benefits of industrial ecosystems?*
-*What are the critical success factors of profitable industrial ecosystems?*

I have plenty of questions and couple of them are quite hard to disassemble, but I am still trying to answer them as wide as possible. I took these questions for my research questions, because there is not quite many research, which answers widely to these questions even they are so important to understand, when companies and municipalities are developing new IEs, EIPs and ISs.

The first question is *What is an industrial ecosystem?* This question is my easiest one to answer. To answer this question, I am going to search sources, which gives an overview to industrial ecosystems and make a tight summary of industrial ecosystem.

The second question is *What are the benefits of industrial ecosystems?* This is way harder to research than the first question. I am going to research environment benefits as well as economic benefits, so an answer to this question could be as comprehensive as possible.

The last question is *What are the critical success factors of profitable industrial ecosystems?* This is hard question to answer as well and I think this is also the single most important part of my whole study. I am going to answer this question by researching former studies of this subject, but there is not that many researches available, which have answered to this question, so I have to conduct some interviews for LUKE researchers etc., who have been involved to Sodankylä industrial ecosystem and have brand new first-class information about the subject.

1.4 Positioning of the study

According to Helo Petri, Tuomi Ville, Kantola Jussi & Sivula Ari, (2019 p. 15) this study is nomothetical empirical case study. The study is obviously a qualitative study, more specifically, an empirical case study, because it is based on experiences from the field. The study is trying to gather widely information of IEs and then develop a package of that information, where it is easy to figure out the critical success factors and key benefits of industrial ecosystem. Knowing these, it is easier to start developing IEs.

Industrial ecosystems are not getting as much interest from researcher than many other subject areas, which are promoting green production. At the beginning of the study, it was quite hard to even find good references for success factors and key benefits of IEs. There are many former studies about industrial ecosystems, but it took for a while to find Sakr D., Baas L., El-Haggar S. & Huisingh D. (2011). Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context. This study had list of critical success factors, which I used in my study. However, I created interviews and researched the core success factors of IE from other studies so that I could verify the reliability of the study conducted by Sakr D., Baas L., El-Haggar S. & Huisingh D. (2011). I had to certify the study, because it was only study, which I found that has conducted list of success factors of IE and the context of that study was in Egypt, so I had to certify that the study is also reliable elsewhere.

According to Sakr D., Baas L., El-Haggar S. & Huisingh D. (2011), most important success factors for industrial ecosystems are relationships that are symbiotic, producing economic value, knowledge and information sharing, policy & regulatory frameworks, organizational and institutional setups, and technical aspects. There are good picks, but I would add environmental aspects to that list according to other studies and my interviews. My list of six critical success factors of IE would seem like this: Cooperation of companies, producing economic value, environmental aspects, knowledge, and information sharing, none of these companies are in a direct competition and common values

There are also more studies, which have stated benefits of IE and motivations behind it, but none of them did not conclude critical success factors in addition for study of Sakr D., Baas L., El-Haggar S. & Huisingh D. (2011). For example, studies, which have stated important success factors of EIPs like Gibbs and Deutz (2007) and Chertow (2007), who is a pioneer of IE.

Even though this study utilizes lot of previous studies of industrial ecosystem, the study different from most of the previous studies by researching key benefits and critical success factors of IE, which is not common purpose of previous studies. This is done by compounding previous studies and by doing own interviews.

1.5 Structure of the study

The study begins with the introduction, which covers background, purpose and research questions of the study. After introduction comes the theory part of the study. First part of the theory section is chapter two, which covers comprehensively the theory of industrial ecosystems. Second part is the theory of circular economy, which comes in chapter three. Next chapter is an empirical part including methodology and case study of Sodankylä industrial ecosystem. Finally, comes chapter five, the conclusion, which concludes the study and answer to the research questions. Figure 1. is presents the structure of the study.

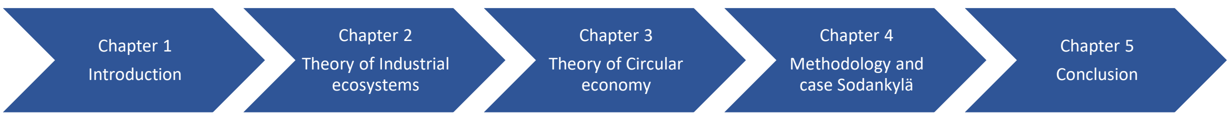

Figure 1. Structure of the study.

2 Industrial ecosystem

According to Jouni Korhonen and Rupert J. Baumgartner (2009), vision of industrial ecosystem is an ecological sustainability. They have 3 claims of IE, which are:

"IE does not systematically increase concentrations of substances extracted from the Earth's crust. IE does not systematically increase concentrations of substances produced by society. IE does not systematically contribute to the degradation of nature by physical mean". (*Jouni Korhonen and Rupert J. Baumgartner, 2009)*

Figure 2. below introduces concept of IE. In the figure the 4 IEs lead to improvements in areas of sustainable development, ecological and social improvements as well as economic profits. (Jouni Korhonen and Rupert J. Baumgartner, 2009).

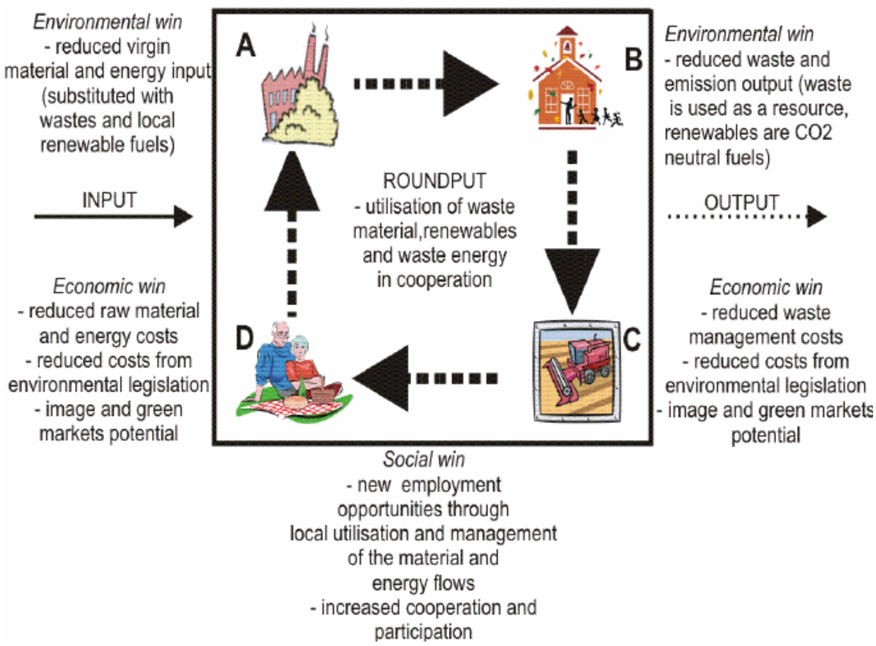

Figure 2. The industrial ecosystem. (Jouni Korhonen Rupert J. Baumgartner, 2009).

2.1 Overview to industrial ecosystems

The key concepts of industrial ecology are industrial ecosystems and eco-industrial parks. The aim of IE is to minimize inefficient material and energy use by utilising local by-product and energy flows. (Lehtoranta S., Nissinen A., Mattila T. & Melanen M., 2011). This means recycling waste is the core principle. So, the goal is to increase the flow from production and consumption to the recyclers and from there back to producers. Here close physical proximity of production, consumption and recycling is important so that the process uses energy as little as possible by itself (Korhonen J., 2001b.).

In an industrial ecosystem, a group of industries are interconnected through mass and energy exchanges for gaining mutual benefits. This ecosystem is an important approach for sustainable development and for business perspective. (Singh Aditi, Lou Helen H., Yaws Carl L., Hopper Jack R., Pike Ralph W., (2007). Industrial ecosystem approach simplifies the emergence of an industrial system, which is based on co-operation between the actors of the system which share some resources with each other in the system, for example energy or waste. Commonly this means that companies in this system use each other waste material or other resources on their own purpose and then share their own waste materials or energy etc. In a best way scenario this approach reduces wastes and emissions of companies which are part of the industrial ecosystem and allows these companies gain from waste materials and energy as input to their own production (Korhonen J., 2001b.).

Ecosystems must fulfil four principles which are presented in Table 1. below.

Round put	diversity
locality	gradual change

Table 1. Four principles of ecosystems. (Korhonen J., 2001a.)

Principle number one is round put, which means recycling of energy. This can be satisfied by recycling and reusing products. Principle number two is diversity, which means diversity of actors, inputs, and outputs. This can be meet by suggesting mix of producers, raw materials, and finished products. Principle number three is locality, which means that local nature should be respected, and local resources should be used. this can be accomplished with mix of local and national production. Last principle is gradual change, which refers to that it is not possible to change ecosystem types overnight and therefore there should be time for use and when changing the ecosystem, it should be done step by step. (Korhonen J., 2001a.)

Business ecosystems based around industrial ecosystems are usually providing more added value than traditional business ecosystems. This is made possible by using fewer natural resources than traditional industrial value chains. For example, in business life, this means more efficient energy and water consumption as well as reduced waste (Sitra, 2020). Aim of industrial ecosystems is to provide a win-win for the economy and the environment for the local region. This goal of sustainable development of the local region provides both, benefits for local business and more environmentally friendly solutions which helps local surroundings. (Liu Changhao, Ma Chunyuan & Zhang Kai, 2012). There might be seen some unexpected environmental impacts, which are caused by mass and energy exchange of companies, which are part of the industrial ecosystems. This is, why it is vital to evaluate these environmental impacts beforehand, as well as possible, to provide a clear guidance for the decision-makers. (Singh Aditi, Lou Helen H., Yaws Carl L., Hopper Jack R., Pike Ralph W., 2007).

Table 2. below introduce some key benefits of industrial ecosystems. There is many more of them, but this is a brief explanation about some of them in an easy-to-understand table. The factors of the table are vital for every successful company of 2020 decade.

Some key benefits of industrial ecosystem			
			Skills
Reduction of environmental impact of waste through recovery, reuse, and recycling.	Creation of economic value from waste material.	Reduction of GHG emissions from waste transport and raw material extraction.	Extension of knowledge and practical know - how of how waste management can be transformed into a sustainable and growth-oriented business.
Bio stabilisation reduces the environmental impacts and risks associated with wastes that are sent to landfill.	Creation of economic value from waste material.	Reduction of reliance on fossil fuels and decrease of emissions of NOx, SO2, CO2.	

Table 2. Key benefits of industrial ecosystem. (European Commission, 2020).

Industrial ecosystem is an ecosystem where unused or residual resources of one company are used by another company of industrial ecosystem, like Figure 2. introduces. This results in mutual economic as well as social and environmental benefits. Usually, it is a process involving some companies, which in a best-case-scenario complement one another to provide mutual added value through efficient use of raw materials, technology, services, and energy (Sitra, 2020). These industrial ecosystems are usually developed through spontaneous action of economic actors, for gaining of economic benefit as well as environmental benefits, but these systems can be designed and promoted via policy instruments as well. (Lehtoranta S., Nissinen A., Mattila T. & Melanen M., 2011).

Industrial ecosystems usually need an anchor tenant. This anchor tenant serves as the driver of some of the main resource flow such as energy. Anchor tenant can also be managing and controlling resource flows of whole industrial system. The anchor tenant facilitates the use of waste material and waste (residual) energy as input resources and as valuable output products in the regional recycling system. (Korhonen J., 2001b.). The anchor tenant can also be a person, an organizer. Great organizers are charismatic and visionary leaders. They must be able to guide and inspire people, resolve conflicts, and motivate people. These organizers should be an invested leader, who are fully engaged to project and are passionate about it. They do not have to be technically the most competent, but their emotional intelligence should be advanced. (Hewes A.K., 2005).

In the USA, the current industrial ecosystem is substantially type 1 system, which means they act like resources are unlimited and they lack about concern of wastes. At best, the USA's current industrial ecosystem is starting to go to type 2 system, which means they are trying to save some resources and minimize wastes. Nowadays industrial ecologists are developing type 3 industrial ecosystems like industrial ecosystems, which is trying to generate zero wastes, when waste from some process become input to other process. In the best scenario type 3 system gets the needed energy from solar panels and use minimal resources. (Krones j., 2012).

It is a necessary goal to improve our industrial ecosystems to Type 3, which lifts reusable, recyclable, and renewable industrial ecosystems. Type 3 industrial ecosystems will reduce energy consumption, wastes and emissions, including CO2. This will be achieved by introducing new carbon-technology based materials that are reusable again and again. Those materials must replace materials that are hard to recycle and reuse and causes lots of emissions when produced. (Tonn Bruce, Frymier Paul D., Stiefel Dorian, Skinner Soro Leah, Suraweera Nethika & Tuck Rachel, 2014).

“Increasing recycling rates of traditional industrial materials, such as glass and plastics; and substituting sustainably-produced renewable materials for materials, produced from non-renewable resources that are energy-intensive to process.” (Tonn Bruce, Frymier Paul D., Stiefel Dorian, Skinner Soro Leah, Suraweera Nethika & Tuck Rachel, 2014).

Below in Figure 3. is presented vision of a type 3 industrial ecosystem for United states. this system emits 80% less carbon dioxide by 2050 than in 2010. The focus here is on the change in C02 from changing energy and production emissions, which can be achieved by introducing new more environment friendly materials and favour local production.
(Tonn Bruce, Frymier Paul D., Stiefel Dorian, Skinner Soro Leah, Suraweera Nethika & Tuck Rachel, 2014).

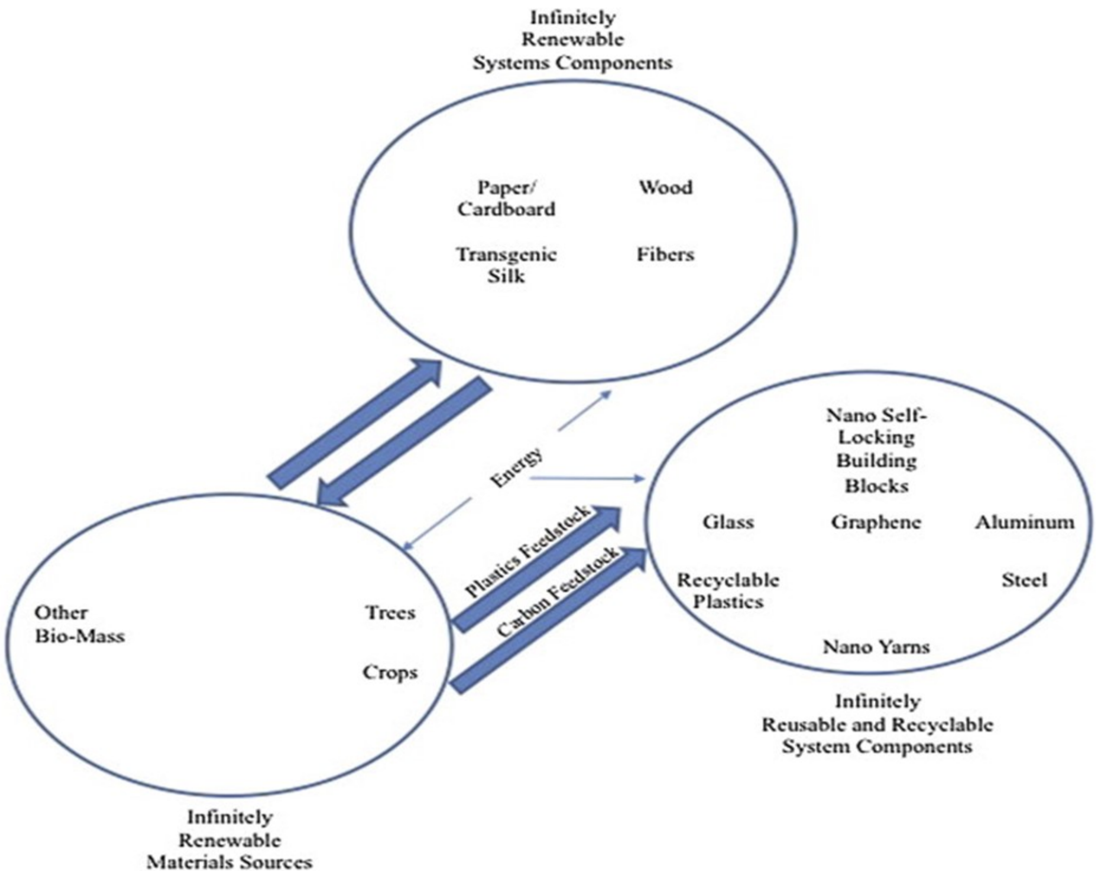

Figure 3. Infinitely reusable, recyclable, and renewable industrial ecosystem (IR3). (Tonn Bruce, Frymier Paul D., Stiefel Dorian, Skinner Soro Leah, Suraweera Nethika & Tuck Rachel, 2014).

According to Tonn Bruce et. al. (2014) this system has 2 main classes of materials which are 1) infinitely renewable materials (produced by trees, crops, and genetically modified ambers of the biota) and 2) infinitely reusable and recyclable materials. Renewable resource materials, which can be used in many products directly and can also be used as plastic and carbon feedstock to produce reusable and recyclable materials.

Figure 4. below is easy to understand figure, how industrial ecosystems are working. The main thing there is to understand, how other’s waste is another’s input and how resources are circulating on an ecosystem. Everybody should benefit from the ecosystem in environmental and economical way.

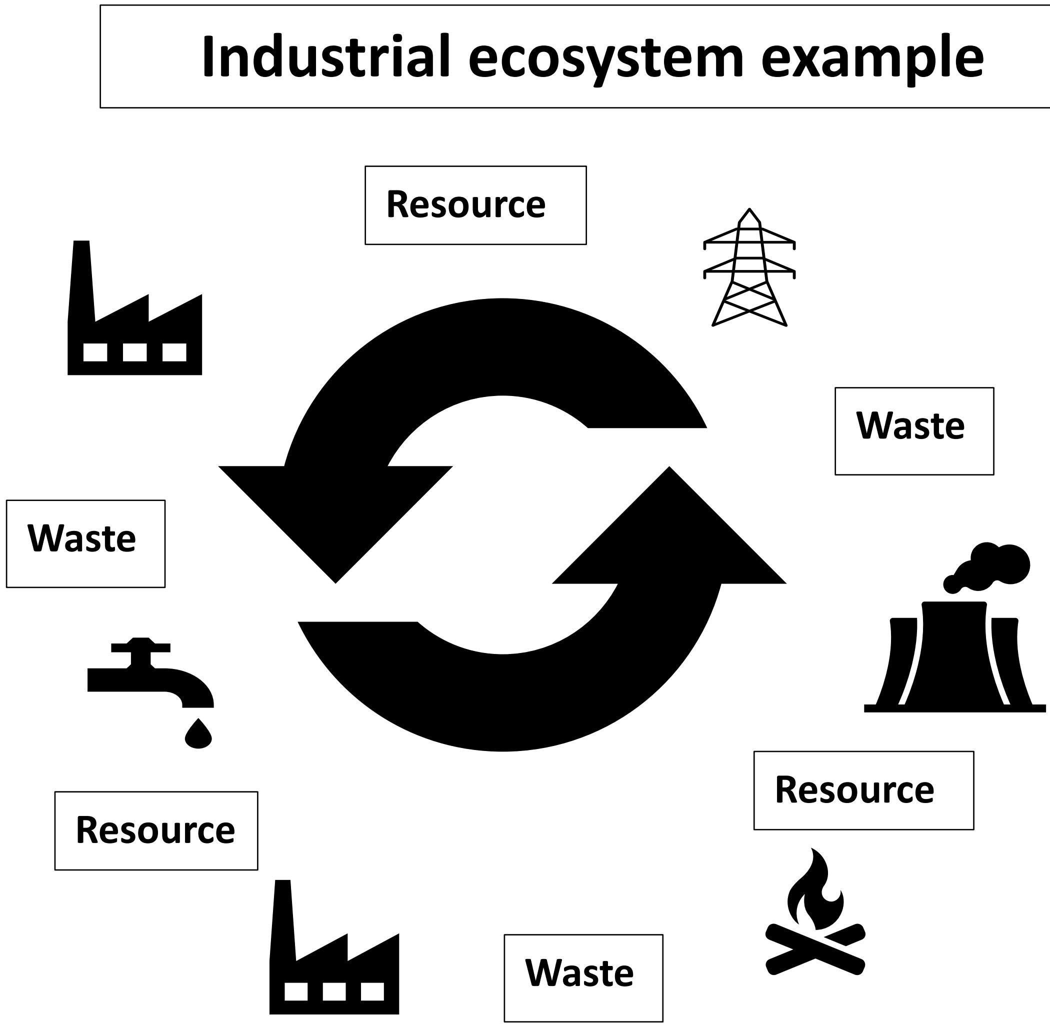

Figure 4. industrial ecosystem example.

2.2 Industrial ecosystems promote green energy production

It is said that the production and consumption of energy is one of the major questions of today's environmental problems which means it is one of the most important tasks to solve for today's human race. Even though there are many options available, energy production still leans heavily to non-renewable fossil stock sources like coal, oil, and natural gas. It is easy to answer why it is so and most common answer is that there is plenty of non-renewable energy sources available, which are easy to use with today's technics and of course there is always money as well. Why should not we use those energy sources, is easy to link to the fact that this production way creates CO2 emissions that most likely increases the risks involved with climate change (Korhonen J., 2001b.).

There are many ways to reduce use of non-renewable sources of energy when producing energy and heat, but this study focuses on industrial ecosystem so let me explain, how industrial ecosystems can be part solution to this problem.

Here is one example of industrial ecosystems, which generates energy and heat, presented on the figure 5. below. By using industrial ecosystems for energy production is in many cases very useful, because energy and heat can be circulated in the ecosystem and it can be made by using some company's renewable wastes like wood etc. Combined heat and power (CHP) mean that in the process both heat and energy is produced.

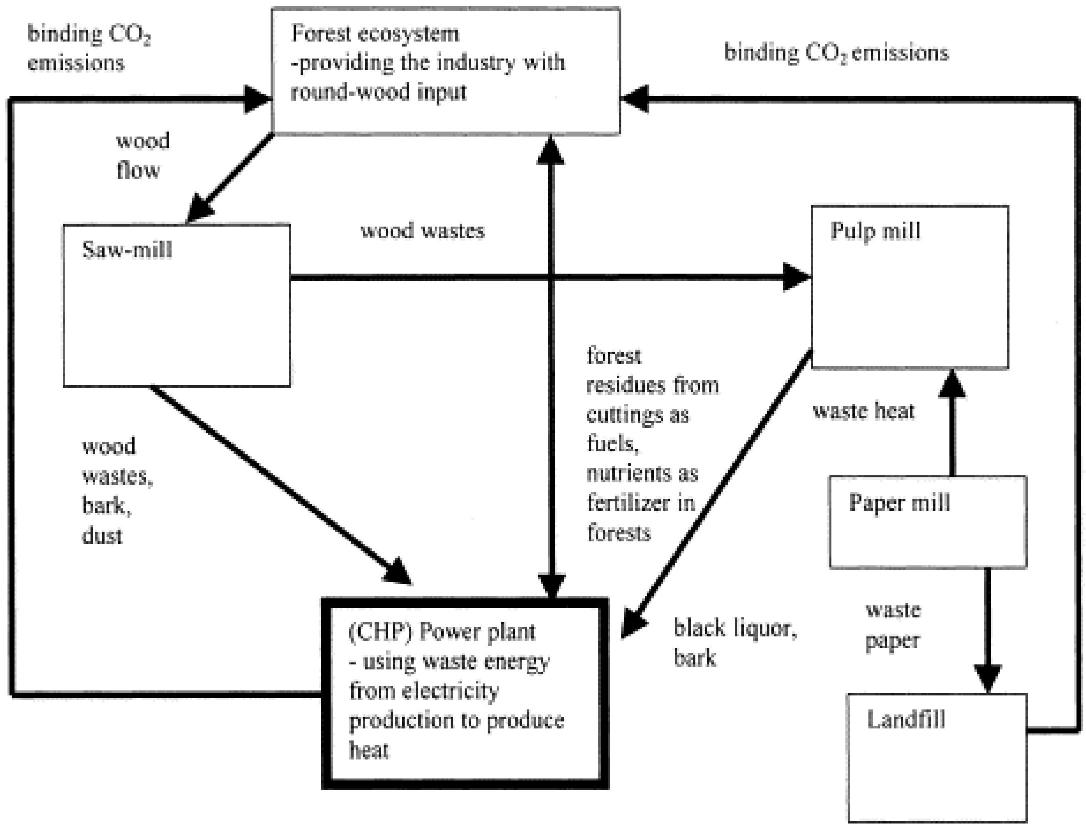

Figure 5. Recycling of matter and cascading of energy in a forest industry system. (Korhonen J., 2001b).

CHP uses the waste energy to create heat so that the waste will not be dumped into the air or water ecosystem as showed in Figure 3. above. The technique of fluidised bed burning allows to use of a relatively heterogenous fuel basis like waste fuel of modern CHP plant itself. This technique allows as the possibility to use fuels like biomass or waste fuels which more traditional techniques such as pulverised coal burning system would not let us do. (Korhonen J., 2001b.).

CHP is also efficient way to generate heat and power. When CHP plant uses waste heat, it can reach efficiency ratings of 80%. This is huge, if we compare that with the efficiency of Coal-fired plant with an efficiency of around 38%. (The Association of Decentralised Energy, 2020).

It is calculated that in the forest industry energy generation in Finland approximately 70% of the fuels used are waste fuels. The number is good, but there is plenty to improve. In CHP plants something like 94% of energy which it uses is in reuse already. Still part of the fuel used there is from non-renewable fossil fuels such as coal and oil. (Korhonen J., 2001 b).

2.3 Success factors of industrial ecosystems

In this section there is listed some eco-industrial park success and limiting factors, these factors are based on worldwide experiences and prior studies (Sakr D., Baas L., El-Haggar S. & Huisingh D., 2011). The factors are presented in the Table 3. below and explained more widely in becoming paragraphs.

1)	Relationships that are symbiotic
2)	Produce economic value
3)	Knowledge and information sharing
4)	Policy & regulatory frameworks
5)	Organizational and institutional setups
6)	Technical aspects

Table 3. Success factors of IE Briefly. (Sakr D., Baas L., El-Haggar S. & Huisingh D., 2011).

2.3.1 Relationships that are symbiotic

In initial stage of EIP there can be some matchmaking between companies, but lack of interest is dangerous, and it cannot exist in initial EIP development. This is because companies invest lots of money and effort to planning and designing an exchange infrastructure. Experiences have taught that trust, good personal relationships, and cooperation between companies are crucial for an EIP development. (Gibbs and Deutz, 2007).

Short distances are vital for industrial ecosystems and eco industrial parks because short distances help the cooperation between these companies. Industrial ecosystems are easier to get working properly if they are clustered around one vital plant and companies are co-located as they usually are. Short distances allow easier and more profitable by-product and waste exchange between the companies of industrial ecosystem. Especially this is important for heat and water exchange. (Shi H., Chertow M.& Song Y., 2010)

Short distances between plants are important success factors for EIPs. Unfortunately, physical location is not the only important thing. Many time companies are socially isolated from others even they are near others physically. This is not a community and here relational assets have to be built from beginning of the EIP. (Sakr D., Baas L., El-Haggar S. & Huisingh D., 2011).

Research indicates the Dutch EIPs are more successful than Us EIPs. This is usually so, because US EIPs are initiated by local and regional governments, which sees these projects an opportunity to improve the local economy with help of government funds, which the project is gaining. These funds lead to that US companies are seeking them not a development, which EIPs bring to them. Dutch EIPs are instead of government initiated by the companies involved with the financial support and advisory from local government and university faculties. This leads to improvement of Dutch EIPs. (Heeres et al., 2004).

One of the biggest challenges of EIPs seeking successful initiation and implementation is the collaboration between companies. How can those different companies ally and balance their different interests so that they can move toward common goal? The cooperation between companies cannot come from above through regulations, but it must come over time through motivation. Also, successful inter-organizational cooperation needs trust between involved companies (Sakr D. et al., 2011).

It is said that a successful industrial ecosystem should be built on core values, which makes successful partnership possible. For example, trust, confidentiality, openness, equality, and cooperation are great values in a successful industrial ecosystem. These values strengthen and renew the partnership of industrial ecosystem companies. (Ellen MacArthur Foundation, 2020 b).

2.3.2 Produce economic value

Producing economic value can be ranked the second most important eco-industrial park success factor. (Sakr D. et al., 2011).

Trust and cooperation between the companies which are part of the EIP is very important, but they need to gain some value from this system. (Gibbs and Deutz, 2007).

The trust is important for every industrial ecosystem, but besides trust they also need good contracts. If there are no good contracts between partners of industrial ecosystem, especially small ones are vulnerable to any companies leaving the system, because it might affect the entire chain and sustainability of this industrial ecosystem. (Tudor T., Adam E., Bates M., 2007).

Common interest in reducing expenses and increasing profits are good examples of strong motivations to develop EIPs, because benefits of resource sharing, increasing availability of critical resources such as some kind of scarce raw materials as well as regulatory pressure to increase efficiency and eliminate waste pushes companies to cooperation. (Chertow, 2007)

For engaging to EIPs business economic benefits are one of the most important affairs. Even companies know that they could gain huge benefits from engaging to EIPs, the top management may not have time, commitment, or capabilities to take advantages of these opportunities (Sakr D. et al., 2011).

At the beginning of establishing a new EIP, it is wise to start from projects that are low risk and brings high benefits, which encourages to participation in further projects with greater risk when companies have good experiences from previous projects. Those previous projects should be ready before starting a new one, so that involved companies can see benefits of EIP (Gibbs and Deutz, 2007).

When companies notice the potential economic benefits of resource and energy efficiency as well as pollution reduction and resource sharing, they will automatically start developing EIPs without even getting external financial support from governments. (Sakr D. et al., 2011).

2.3.3 Knowledge and information sharing

Very few companies even know benefits of EIP concept when building-up the social networks. That is why it is crucial to inform companies about EIP and introduce some successful case studies, when building-up new eco-industrial park. This should be done by leading company of community. The informing can be done through networking with key organizations by organizing public events, launching a website and so on. (Lowe, 2001).

It is important to provide technical assistance and right information especially for small and mid-size companies, so that they will not feel like drowning down from overwhelming content and information flow. It may be hard for small companies to internalize all the new information about EIP without good instructor. (Koenig, 2005). Also, Chertow (2007) says that coordinative function is needed so that management can handle the information flows, get information about recycling opportunities, and get assistance in their application.

Sharing information is crucial since it helps companies to find suitable business matches and encourages to share tools and resources within the community (Heeres et al., 2004). EIP managers are usually the best candidates for information exchange, but they do not have an obligation to provide that for tenants. (Koenig, 2005).

Energy and material exchange can exist in industrial estates even when that estate is not considered yet as an eco-industrial park. This may happen because of environment or economic regulatory as was the case in the Kalundborg ecosystem at the beginning. These informal EIPs are usually uncovered by third party like universities, who have implemented material and energy sharing activities beforehand (Chertow, 2007).

2.3.4 Policy and regulatory frameworks

Government policy should provide political, coordinative, educational, and infrastructural support for resource exchange projects such as industrial ecosystems. (Gibbs and Deutz, 2007). Two most important lessons to learn from former industrial ecosystems are to establish incentives-based regulatory framework, which encourages by-product utilization and continuous improvement in area of environmental performance. (Desrochers P., 2002a). According to that government should bring current environment legislation and policies in line with EIP principles, so that it is easier for companies to adopt these systems. (Sakr D. et al., 2011).

Somehow Asian countries have taken lead in government policies concerning EIPs. Many of them have national agenda to develop these environment friendly ecosystems. For example, China have declared EIPs as the foundation of its CE strategy and similarities can be seen from other Asian countries when they are trying to reduce environmental pollution. (Koenig, 2005).

Attaching EIP into country's national strategy is crucial for successful EIP development This is already happening in China, but Europe should follow. EIPs should be linked to national plans, budgets, and local policies. This would lead for economic growth and to adapt sustainable industrial development. (Sakr D., Baas L., El-Haggar S. & Huisingh D. (2011).

Otherwise in USA in Fairfield, Baltimore and Maryland Local politicians introduced EIP as a job creation project, not as a project which is both economical profitable and benefits environment. This approach did not convince companies to participate (Heeres et al., 2004).

Government should have 3 roles to advance industrial ecosystems. These roles are introduced in the Table 4. below. It is important for governments not to involve in the development to EIPs too much as happened in US case where politician only caused harm for EIP development. (Chertow, 2007).

Inform about EIP projects that are not getting attention
Bring assistance for EIPs that are taking shape
Provide incentives for new EIPs by identifying precursors to ecosystems

Table 4. Government should have three roles to advance industrial ecosystems. (Chertow, 2007).

2.3.5 Organizational and institutional setups

> *A successful strategy to make EIP an integrated scheme is to fit the planned bilateral planned exchanges into the corporate organizational structure of each involved firm and in the overall management system of the park. (Sakr D. et al., 2011).*

Collaboration is crucial for EIPs. the traditional mindset of management, where management often thinks, it is high risk to cooperative with competitive companies, have to be changed to mindset that encourages companies to collaborate together. This helps companies to achieve common goals more effectively in the EIP. (Erkman, 2001)

Nowadays IT technologies are great friend for company collaboration and information sharing. For example, case INES used the BIM-Network3 in the project organization structure. It helped companies to communicate and for doing it those companies achieved better in the EIP. (Heeres et al., 2004)

Organizational culture plays its own role in EIPs. Sometimes there are so high behaviour barriers that even high economic advantages cannot break the borders of organization to cooperate with companies. This may be because in the area where this company is operating, there is few inter-firm cooperation. Sometimes a company itself wants to co-operative, but a parent company prevents that cooperation (Gibbs and Deutz, 2007).

2.3.6 Technical aspects

Internationally accepted standards like ISO certificates are one of the most challenging technical issue facing EIPs development. It causes confusion if it is not easy to define EIP, to guide their planning and to evaluate EIPs performance by ranking and benchmarking them among other EIPs (Sakr D. et al., 2011).

Now there is only few common criteria to define EIPs, but even them are not worldwide accepted. One of those criteria is a “3-2”, which is a minimum criterion to distinguish EIPs from other resource exchange types. This criterion says that “At least three different entities must be involved in exchanging at least two different resources to be counted as a basic type of industrial ecosystems” (Chertow, 2007).

Also, inability to identify and evaluate industrial ecosystems opportunities and benefits, implementing the technologies and measures needed to realize EIP benefits are examples of technical problems (Sakr D. et al., 2011).

Some parties are even arguing that EIPs are causing extra pollution and others that EIPs negatively affect firm-level environmental measures. (Lowe, 2001). This confirms the need for standardized measurement tools.

2.4 Former industrial ecosystem example – case Kalundborg symbiosis

Figure 6. is a pre-digested example of the Kalundborg symbiosis. It shows how resources and information is shared between different actors of the ecosystem.

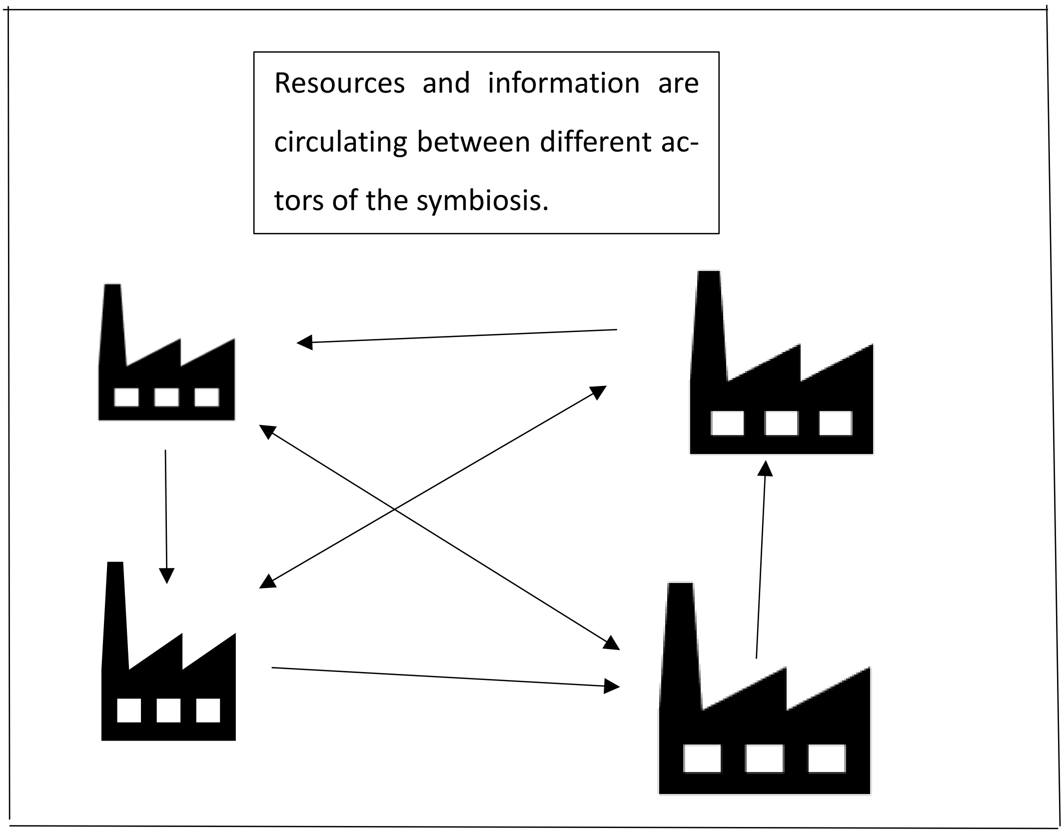

Figure 6. Pre-digested example of the Kalundborg symbiosis.

My former example of industrial ecosystem is a Kalundborg symbiosis, located in Denmark, which is made up of 25 different streams including water, energy, and material flows. In this example I prefer a word industrial symbiosis over industrial ecosystem even if in this study they mean the same. The Kalunborg symbiosis began in 1961, at first with area's water supply. Nowadays, the resource flows exchange includes 6 industrial and 3 public sector organizations. At the beginning of the symbiosis, it was not called as industrial symbiosis, but just a smart way to work together. Today, the target is a little bit higher when the vision of the Kalundborg symbiosis is to be the world's leading industrial symbiosis with a circular approach to production. (Ellen MacArthur Foundation, 2020b).

The symbiosis is the world's first working one. It is a local collaboration including public and private enterprises, who buy and sell residual products in terms of materials, water, and energy, resulting in mutual and environmental benefits. it is an industrial ecosystem, where circulate economy is working well, companies use each other residual product and waste and offers their own residual products for others to use, in a closed loop. It is selling, sharing, and reusing resources to gain value for every partner of the symbiosis. The collaborative approach of this industrial ecosystem adds value, reduce costs, and helps environment by closing of material and energy cycles. (Green cluster, 2020).

Kalundborg symbiosis was not planned to be a symbiosis, in fact at the beginning it was series of projects, which were independent from one another. At the first stage, there were not joint management, but they managed the system with bilateral agreements. Those days the symbiosis did not evolve any academic environmental network theories, but it was just an economical management practice. (Desrochers P., 2002a).

The common purpose of industrial symbiosis is to create circles of technical or biological materials when at the simultaneously minimizing the leakage and waste in the circles. The Kalundborg symbiosis seems to work well. The results show that the closed loop cooperation between these companies save more than 24 million euros on the bottom line annually, while socio-economic benefits are more than 14 million euros. This means that the enterprises of the symbiosis can leverage competitive power because of the interconnectivity, while the public sector can save money, for instance in pensions. It is not just about money, the emission reduction of the Kalundborg symbiosis, which is 635,000 tonnes of CO_2 equivalents, equals to the average carbon footprint of almost 40,000 Danes. (Ellen MacArthur Foundation, 2020b).

The motivation behind many exchanges of the symbiosis system was originally to reduce costs and try to follow the local environmental legislation, which were quite tight. The companies of the system tried to seek income-producing uses for their waste. Published information of the Kalundborg industrial symbiosis informs that the firms of the symbiosis have saved up to 160 million US dollars by 2001. This means 15 million US dollars of annual savings for 18 projects, where total investments were 75 million US dollars. This means that average payback time is less than 5 years for these projects. (Erkman, 2001 & Lowe, 2001).

The symbiosis has also been attracting several start-ups near the symbiosis, so that they can benefit cooperative nature and innovative mindset as well. The symbiosis has provided great opportunities for these start-ups. Kalundborg symbiosis has shown that industrial symbiosis works well as a platform for innovative test and demonstration projects. (Ellen MacArthur Foundation, 2020b).

The Kalundborg symbiosis core values, which have made all the successful partnership possible are shown below in a Table 5. These values help enterprises included the symbiosis to renew and strengthen their partnership, to connect flows of energy, water, and materials, when at the same time promoting the symbiotic mindset to others everywhere in the world. The collaboration is at the time second nature, so every new decision made must been evaluating, because the decision may affect the whole symbiosis. Only shared values make it possible to do so and the fact that none of these companies are in a direct competition with each other among the symbiosis. (Ellen MacArthur Foundation, 2020 b).

trust	confidentiality	openness
equality	cooperation	

Table 5. The core values of Kalundborg symbiosis. (Ellen MacArthur Foundation, 2020b).

What we should replicate from this IS? The number one thing, which comes in mind is to promote positive image of industrial by-products. Others could be to share knowledge, how to reuse industrial waste and remove barriers from there. Also forming new recycle linkages at the local, regional, national, and international levels is important thing to learn from the IS. (Desrochers P., 2002a).

2.5 Summary of industrial ecosystem

Industrial ecosystem is a system where group of companies circulate resources in the ecosystem. They use others waste as their resource so that the amount of waste could be reduced, and resources would be cheaper. The main goals of industrial ecosystems are to lower the cost of production, to lower the use of natural resource, to reduce carbon footprint and to lower transportation costs. In some case companies are also seeking to secure their resource availability.

Somebody may think, what is the difference between industrial ecosystem and industrial symbiosis. I think that there is no substantive difference between these two and that is why in this study I only speak about industrial ecosystem and I do not distinguish them. Some could think differently, but I think it would only confuse this study if I would use two different word to the same thing.

In my opinion the profits of industrial ecosystems for companies in most cases come from cooperation, resource sharing and reduce of logistic costs. When companies will notice that it is not necessary to do everything by themselves, they can achieve better. Nobody is good at everything and that is why cooperation is crucial. In cooperation, you can focus on things where you are the best and leave the things which are not in your area of expertise to those who are more capable of doing them. The cooperation is at its best, when two different companies can support others in areas, where they are the best in. When developing a new industrial ecosystem this should be considered.

In industrial ecosystem, industrial operations, energy production, primary production, waste processing etc. combined are providing a way to maximize use of production waste, while still fulfilling customer's and end-users needs perfectly. (Sitra, 2020). Optimizing resource use is good for environment, but it is also a great way to rise profits of a company, because it allows companies to gain benefits of their waste trade with other companies which are involved to this industrial ecosystem.

Resource sharing and especially sharing of waste in industrial ecosystem should be win-win for every participant. For example, in agricultural some IEs could be formed of a ranch, a biogas plant and a fertilizer factory. A ranch gives away their cow dung. The part of it goes to a biogas plant which generates electricity and heat to the ranch and the fertilizer factory. Then they sell rest of their production as biogas for local citizens. The other part of the ranch's cow dung goes to a fertilizer factory, who makes organic fertilizer from it. A fertilizer factory then gives part of its products to the ranch and then sells rest of it to a local supermarket. This is a win-win situation for everybody.

Non-renewable fossil fuels are still main resource basis of industrial energy production. Fossil fuels creates CO2 emissions, which the ecosystem has difficulty in tolerating. This is the reason why one of the main goals of Industrial ecology should be substituting the non-renewable stocks with renewable flows. (Korhonen J., 2001b). Industrial ecosystems can be big step forward to create more sustainable energy production network. As a human race, we must lean more on renewable sources of energy. We must focus more environment friendly solutions which also industrial ecosystems are representing. In best case scenario, industrial ecosystem creates efficient synergies between companies, which joins to the ecosystem. These synergies can be energy utility synergies, by-product synergies or some other synergies.

Industrial ecosystems are step closer to more sustainable production. I predict that there is more industrial ecosystem in the future because industrial ecosystems benefits companies, local people, local municipality, and the environment. If they would not be profitability, I would not give that prediction, but now when they tend to be profitable as well, I am pretty sure of that prediction.

2.5.1 Summary of critical success factors of industrial ecosystem

In this section I have summed up the success factors of industrial ecosystem. I made an easy-to-read Table 6. to present the key points of these SuccessFactors. The table is below.

Relationships that are symbiotic	Produce economic value	Knowledge and information sharing	Policy & regulatory frameworks	Organizational & institutional setups	Technical aspects
Core values	Good contracts	Introduce Case studies and share the information	Government policy	Collaboration mindset	ISO certificates
Common interests	Common interest to reduce costs	trust	Legislation	Organizational culture	Defining EIPs clearly
Short distances between plants	Common interest to increase profits	cooperation			Clarify facts

Table 6. Key success factors explained Briefly.

The table 6. above is a variation from Table 4. Success and limiting factors of eco-industrial parks. (Sakr D., Baas L., El-Haggar S. & Huisingh D., 2011). Data is added from different references, which are (Ellen MacArthur Foundation, 2020 b; Shi H., Chertow M.& Song Y., 2010; Gibbs and Deutz, 2007; Chertow, 2007; Heeres et al., 2004 & Lowe, 2001).

3 Making industrial ecosystem environment friendly by taking advantage of circular economy?

How can we answer to environment friendly policies while at the same time we should keep our profits up? The answer is called circular economy, which is a new way to design, make and use things with a way that will not cause damage as much as old ways, but still can help to maximize our profits. Everyone must involve this system so that it can be the most effective for protecting the environment. This should be used by businesses as well as governments and individuals. Our cities, our products and our jobs should be part of it. By circular economy, we design out waste and pollution and keep our materials in use by inventing reuse possibilities for them, which may eventually lead reinventing of everything in our current world. (Ellen MacArthur Foundation, 2020a).

In industrial ecosystem, industrial operations, energy production, primary production, waste processing etc. combined are providing a way to maximize use of production waste, while still fulfilling customer's and end-users needs perfectly. (Sitra, 2020). Optimizing resource use is good for environment, but it is also a great way to rise profits of a company, because it allows companies to gain benefits of their waste trade with other companies which are involved to this industrial ecosystem. It is common to hear that profits and environment friendly production cannot walk hand by hand, but I must say that industrial ecosystems at least are big step forward to that kind of world where those two are going side by side.

Industrial ecosystem is disrupting the old system, which is usually based on linear economy, with new one, which is circular economy. In industrial ecosystem the companies involved are trading their waste to each other and then using that waste on their production and this is like textbook example of circular economy. Transform all the elements of take-make-waste system is vital for our vulnerable planet with limited resources. We need to think again how we manage our resources, how we make and use our products as well as what we do with the materials afterwards. These are key elements of creating thriving economy that can benefit all of us without causing huge harms to our planet earth. (Ellen MacArthur Foundation, 2020a).

3.1 Circular economy

Circular economy is a way to promote sustainable development. The objective of circular economy is to reduce production-consumption material and energy throughput flows. This can be done by applying materials cycles, renewable and cascade-type energy flows etc. High value material cycles, traditional recycling and cooperation with producers, consumers and societies are all are all part of circular economy. (Korhonen Jouni, Nuur Cali, Feldmann Andreas, Birkie Seyoum Eshetu, 2018).

Table 7. above describes strategies, how circular economy system operates in theory by using the term operational principles, which defines how interaction of parts when they implement the goal of overall technology. There are 2 target operational principles, 3 core operational principles and 2 transversal operational principles explained in this section. (Suárez-Eiroa Brais, Fernández Emilio, Méndez-Martínez Gonzalo, Soto-Oñate David, 2019).

Target operational principles, the principles 1 and 2, are directly coming from the theoretical objectives of CE. They have some practical strategies to accomplish and the direct connection between theoretical aims of CE. (Suárez-Eiroa Brais et al., 2019).

Priciples 3, 4 and 5 are core operational principles. They are not directly coming from theory, but still they are crucial to execute. Which makes them crucial is the fact that they are able to channel strategies that indirectly adjust inputs of resources to the system. (Suárez-Eiroa Brais et al., 2019).

Transversal operational principles, principles 6 and 7, are needed to help other operational principles succeed. They make all other principles stronger by taking part of the process. (Suárez-Eiroa Brais et al., 2019).

Operational priciple 1	Operational priciple 2	Operational priciple 3	Operational priciple 4	Operational priciple 5	Operational priciple 6	Operational principle 7
adjusting inputs to the system to regeneration rates.	adjusting outputs from the system to absorption rates	closing the system	maintaining resource value within the system	reducing the system's size	designing for circular economy	educating for circular economy
distinguishing between renewable and non-renewable resources becomes essential	also requires distinguishing between technological and biological outputs.	aims at connecting the waste management stage to the resource acquisition stage.	generates a broad consensus in the scientific literature	reduce the total quantity of resources that circulate within the system	Design covers multiple perspectives of the CE model.	requires values, knowledge and skills
minimize – and even eliminate – the inputs of non-renewable resources	promotes strategies that minimize the outputs of technological wastes	integrates 3R philosophy	improving durability of products	reducing the total quantity of products	product can be designed to be easily recovered and recycled, to be easily repaired	involve everybody to collaboration
adjust the extraction rate of renewable resources	adjust the extraction rate of renewable resources		recirculating resources	producing and consuming more sustainable products	Innovation is also needed in social, organizational, financial or political issues	setting up a new consumption culture

Table 7. Operational principles. (Suárez-Eiroa Brais et al., 2019).

Table 8. presents a list of practical strategies and their features. Seven operational principles were presented previously and in order to corroborate the validity of the operational principles, we present 7 practical strategies to implement these principles. When the operational priciples were communication channels between the theoretical objectives of circular economy, the practical strategis are all about implementation. Practical strategies are grouped by the proposed operational principles. (Suárez-Eiroa Brais et al., 2019).

Principle 1	Principle 2	Principle 3	Principle 4	Principle 5	Principle 6	Principle 7
Adjusting inputs to the system to regeneration rates	Adjusting outputs from the system to absorption rates	Closing the system	Maintaining resource value within the system	Reducing the system's size	Designing for circular economy	Educating for circular econom
Substituting non-renewable inputs by renewable inputs	Substituting materials which lower technical outputs	Separating biological and technical wastes properly	Interconnecting stages	Informing consumers properly	Eco-design	Adjusting educational curricula to the current challenges
Substituting materials of faster regeneration rates	Substituting products of lower waste generation rates	Re-produce products and components	Promoting industrial ecosystems	Expanding the Extended Consumer Responsibility		Promoting knowledge and skills that ensure performance of CE
Adjusting subsidies of tech. based on their resource regeneration rates	Adjusting subsidies of tech. based on the waste generation rates	Promoting and improving downcycling, recycling and upcycling of wastes	Increasing durability	Promoting functional service economy and sharing economy	Designing transparent, reproducible and scalable products	Promoting habits and individual actions in favor of circular economy
Saving energy and materials		Promoting energy recovery	Reducing obsolescence	Promoting green procurement	Evolving new utilities for stuff	
Fostering renewable mobility		Promoting Extended Producer Responsibility		Adjusting selling doses to consumer doses	Designing new business models	

Table 8. Practical strategies of Circular Economy grouped by the proposed operational principles. (Suárez-Eiroa Brais et al., 2019).

Circular economy is answer to linear economy's inabilities to reduce pollutions by circulating waste, which is others resource. Main idea of circular economy is to design out waste and pollution, to keep products and materials in use, and to regenerate natural systems (Ellen MacArthur Foundation, 2020a). Commonly circular economy tries to minimize waste through cycles of re-duction, reuse, and recycling with limited leakage and minor environmental impact (Ellen MacArthur Foundation, 2016). Figure 7. below introduces what happens to biosphere, when economic system changes from linear to circular ecosystem.

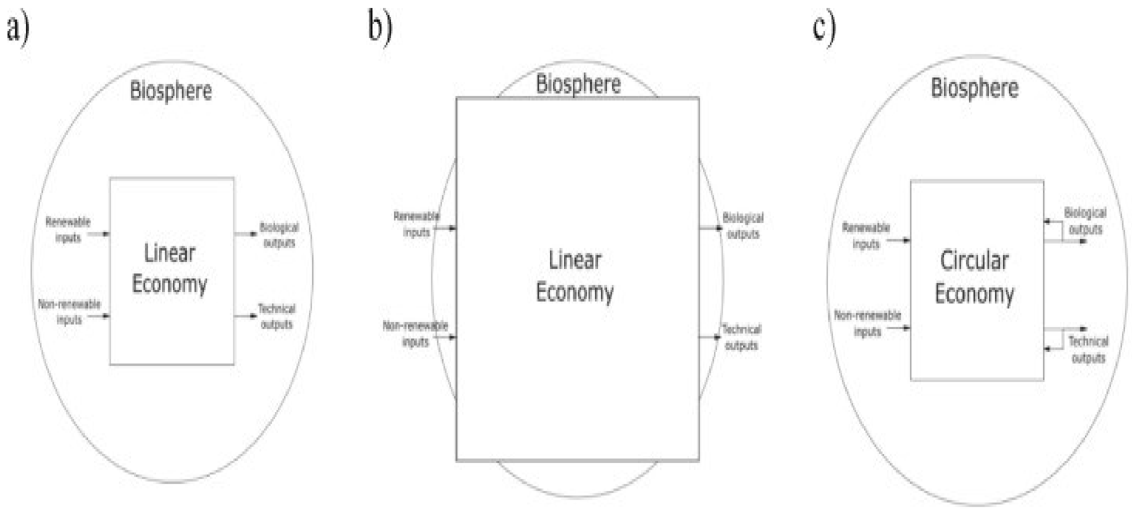

Figure 7. Relationship between the economic system and the biosphere. (Suárez-Eiroa Brais et al., 2019).

Linear economy system was feasible in the past (a). Currently, the linear economy system's size is bigger than the biosphere's size in terms of consumption and extraction rates (b). Circular economy aims to adjust these rates to planetary boundaries again (c). (Suárez-Eiroa Brais et al., 2019).

Unfortunately there is only few industrial exambles of companies that have implemented a circular economy paradigm, even though the benefits of circular economy are fairly understood. (Parida Vinit, Burström Thommie, Visnjic Ivanka & Wincent Joakim, 2019).

As it is easy to be seen from figure 8. below the circular economy logic challenges the traditional linear economy logic. In circular economy logic of make-remake-use-return, products are reused and circulated, but in linear economy logic of take-make-use dispose the product and sometimes also materials life cycle ends when customer disposes the product. In circular economy logic, which supports an economic model, where resource inputs and wastage are removed through a holistic perception of the system (Ellen MacArthur Foundation, 2016). In other words circular economy allows us to close material flow loops throughout the entire economic with its 3Rs, where circular economy drives us. These 3Rs are reduce, reuse and recycle. The circular economy is now a leading concept and industrial practise to address resource scarcity and environmental problems (Frishammar J. & Parida V., 2018).

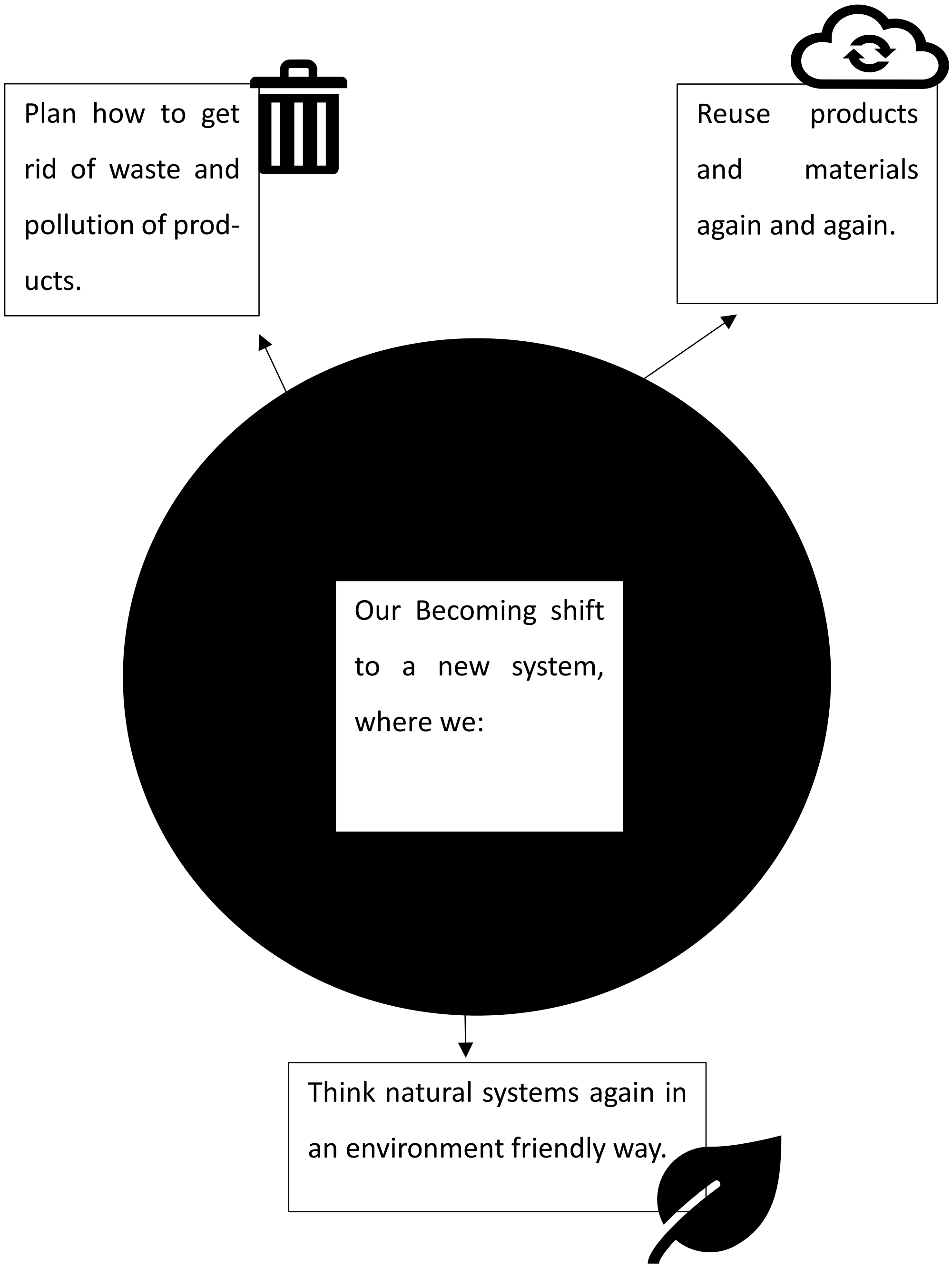

Figure 8. Vision and approach of circular economy gives endless possibilities to create thriving economy (Ellen MacArthur Foundation, 2020a).

Circular economy is today assessing individual products from a holistic vision. This needs paradigm change, because we need to analyse a whole product life cycle from a reductionist perspective. (Suárez-Eiroa Brais, Fernández Emilio, Méndez-Martínez Gonzalo, Soto-Oñate Da-vid , 2019).

3.2 Shifting a business model to CE business model

To make transition to a circular economy is important goal for everybody from individu-als to societies, especially in resource-intensive manufacturing industries. It is necessary to orchestrate this transition ecosystem-wide because it is difficult, and complexity and no single company can do it alone. (Parida Vinit et al., 2019). Transition toward a circular economy is achieved in two stages, first is ecosystem readiness assessment and second is ecosystem transformation. Specific and complementary mechanisms are deployed in both stages. (Parida Vinit et al., 2019).

« transition to CE needs to occur at three levels which can be interpreted as three levels of the CE system: The macro, the meso and the micro system. While the macro-systems perspective highlights the need to adjust industrial composition and structure of the entire economy, the meso-systems perspective usually focuses on eco-industrial parks as systems. »
(Sakr D., Baas L., El-Haggar S. & Huisingh D., 2011).

Companies tend to hesitate, moving from resource intensive product-centric linear busi-ness models toward service-centric business models which are for example pay-per use models as electric scooters are or outcome-based contracts like usually salesman’s pay. (Parida Vinit et al., 2019). Still, these service-centric business models are future and al-ready today. Moving toward those models will eventually reduce environment pollution so companies should think, how can they use this kind of business models so that they will not drop their profits.

The main circular economy business model, which this study focus on is an industrial ecosystem, where waste is circulating in the ecosystem so that companies use another's waste as their resource to gain mutual benefits. There is also CE business models like pay-per-use models etc, but this study does not pay much an attention to those models.

When a company considers transition to a business model like industrial ecosystem, there is one notable aspect involved which creates lot of uncertainty. This aspect is the myriad interdependence in their ecosystem. (Parida Vinit et al., 2019). It is easy to understant that it causes gray hair for employer, who has always made his own strategy and choices, when she joins to industrial ecosystem where all the companies has to work together for gaining benefits of cooperation. Here the great orchestrator is priceless.

The orchestrator is important especially when considering IE business model. The most important thing what orchestrators of industrial ecosystem has to deal with is coordinating and managing diverse interest as well as ensuring alignment between industrial ecosystem partners. (Parida Vinit et al., 2019). In industrial ecosystems the leaders of ecosystem orchestrates business activities so that the shared vision of the values of industrial ecosystems forms. Forming is crucial stage at the beginning of IE. (Nambisan S. & Sawhney M., 2011). However, the leader of industrial ecosystem should be a company which is resourceful, is able to create healthy ecosystem, can simplify connection among stakeholders and engourages innovation as well as creating niche markets. (Iansiti M. & Levien R., 2004).

Industrial ecosystem orchestration includes always enforcing common rules, which every partner follows and respects. It is orchestrator's job to monitor if rules are followed or not. Usually transparency between partners is vital to controlling risks and also orchestrator's ability to even exclude stakeholders who disregard the rules is important to successful industrial ecosystems. (Williamson P.J. and De Meyer A., 2012).

As it is said the key role of industrial ecosystem orchestrators is to manage and coordinate the diverse interest as well as to ensure alignment between the companies of industrial ecosystem. (Parida Vinit et al., 2019).

3.3 Summary of circular economy

Circular economy logic challenges the traditional linear economy logic. In circular economy logic of make-remake-use-return, products are reused and circulated, but in linear economy logic of take-make-use dispose the product and sometimes also materials life cycle ends when customer disposes the product. In circular economy logic, which supports an economic model, where resource inputs and wastage are removed through a holistic perception of the system (Ellen MacArthur Foundation, 2016).

Circular economy is important step to more sustainable production and consumption. It should be used in every business area in some way. The objective of circular economy should be increased revenues, decreased environmental harms and lower use of materials. I would like to bring up that by adding circular economy to company's practices, profitability can increase as well as environmental friendliness.

Increasing material cycles by re-using and recycling products and materials is possible to prevent overloading of landfills and in the long run even destroy the whole idea that used materials must be dumbed. In someday there can be an economy where waste is minimized to almost zero and all the materials are re-used and recycled. That should be done to decrease the carbon footprint and to minimize environment impact of human lives.

How circular economy then connects to industrial ecosystem? Circular economy encourages companies to recycling and reusing materials. It also encourages companies to local cooperation so that material inputs could be minimized. These are also the main drivers of industrial ecosystems, which are group of companies who seek to increase their profits and decrease their environment impacts by sharing their wastes to a company who can use that waste as a resource. So, we can say that industrial ecosystem is using circular approach in their production.

In addition, industrial ecosystem is a circular economy business model, where waste is other’s resource. Industrial ecosystem is a system where group of companies circulate resources in the ecosystem. They use others waste as their resource so that waste is minimized, and resources are cheap. For example, if a company produces logs, they cause some waste in their production. Then another company of the industrial ecosystem can use that log waste as resource for example to produce heat and electricity. This process minimizes the waste and increases profits of both company if we assume that log producer should transport that waste somewhere without the other company who gain their inputs from that waste.

4 Methodology

This study is empirical study which focused on finding advanced understanding of industrial ecosystems. In this study, I used a qualitative method. Data was gathered from previous studies, case example and from semi-structured interviews. First, I collected data from previous studies and the literature of industrial ecosystem and circular economy. After gathering basic knowledge of industrial ecosystem and circular economy, I studied some case examples as Kalundborg symbiosis. There I got some practical knowledge how industrial ecosystems are working in business life and I was able to strengthen the reliability of the study. After that I made some semi-structured interviews, which were related to themes of the study purpose. I chose semi-structured interview, because that offers the freedom to ask questions around the themes and there are not tight frames on interviews (Hirvisjärvi S. & Hurme H., 2000, p. 48). From interviews I got further data of industrial ecosystems. Open-ended interviews are great to this kind of research. They offer freedom to express interviews thoughts so that they can explain even hard to understand things on their own way. I had 5 interviews from Luke and 1 interviewee from Sodankylä municipality. Luke interviewees were chosen due to their participation to Sodankylä industrial ecosystem project, which were the case study of this research. Luke interviewees were Research scientists, a Principal scientist, and a Senior scientist. One Interviewee was development manager of Sodankylä municipality. He was also part of the case project. I will not use interviewees names in this study, because some interviewees would not like to reveal their names. The data were analysed by using content analysis. In content analysis the material is viewed by specifying it, seeking similarities and differences from there and summarizing it. (Tuomi & Sarajärvi, 2002, p. 105). This kind of analysis is good for my study, because it sums up conservations and interviews and links them to previous studies. (Leinonen Rita, 2018). The case study offered empirical view to my study. Case Sodankylä offered practical overall picture of basics of industrial ecosystem. Even if the case example was only on the design phase, I was able to gain valuable information to this study, which enriched the whole paper. Without the case, this study would have been only one more paper without any practical aspect of industrial ecosystems.

4.1 Industrial ecosystem example - Case Sodankylä

Sodankylä IE is the case example of this study. The purpose of this case study is to find out practical information of industrial ecosystems and to find more complete answer to my research questions.

Sodankylä IE will be a District heating plant-model of the new generation. It will be carbon-neutral energy and food production industrial ecosystem based on local ingredients and industrial side streams. The key idea of this IE is to reduce the need for energy investments and increase yields (energy, nutrients) for used energy raw materials using multiple forms of production and decentralized production, storage, and intelligent control (savings and synergy in production). The aim of the project is to create a new platform for a new generation district heating plant-model. This reproducible platform is targeted to the areas with the wood-based bio surplus production. (Luke, 2020).

Purpose of this study is to find out, how industrial ecosystems can be profitable and what are the critical success factors of profitable industrial ecosystems. To answer these questions completely I studied a case example and made interviews for 5 interviewees from Luke and 1 interviewee from Sodankylä municipality. Every interviewee was chosen due to their participation to Sodankylä industrial ecosystem project, which were the case study of this research. Luke interviewees were Research scientists, a Principal scientist, and a Senior scientist. An Interviewee from Sodankylä was a development manager of Sodankylä municipality. This section is based on the interviews and their answers are compared to theory of this study.

4.2 Profitability of Sodankylä industrial ecosystem

In interviews I asked if it is possible that IE in Sodankylä is profitable according to current perception? It is not easy to answer to that question yet, because the case IE is not working yet and there are not ready calculations, which predicts if this ecosystem is profitable, but still four of six interviewees predicted that according to current perception most likely this ecosystem will be profitable. Only one interviewee doubted that this IE will be profitable according to current parameters. Things that affect to the profitability of this IE, according to interviewees are what companies will join it, legislation, local markets, and long distances.

4.3 Main success factors of Sodankylä industrial ecosystem

Table 9. here is to refresh your memory and to conclude industrial ecosystem success factors. These success factors are compared to interviewees answers so that theory and practise can be compound.

The First factor	Establishment of the social network between companies and stakeholders and maintaining their continuous interest, mutual trust, and involvement.
The second factor	Gaining added economic value to all involved parties whether increased revenues, reduced costs, or taxes, or even to have a better competitive edge.
The third factor	Awareness raising and effective information sharing between firms.
The fourth factor	Establishment of the national vision and objectives for industrial ecology and adapting relevant legislation.
The fifth factor	Fit industrial ecosystem to corporate policies and organizational culture and promote IE acceptance
The sixth factor	develop internationally recognized IE standards and providing technical knowhow locally

Table 9. Conclusion of main success factors of industrial ecosystems (Sakr D., Baas L., El-Haggar S. & Huisingh D., 2011).

I asked from my interviewees what do they think are the core success factors of IE in Sodankylä? The five most common answers to that questions were:
Demand of local markets, Brand image, affordable energy, financial matters, and environmental issues.

The most popular answer to this question was the demand of local markets. This came to me as little surprise, but I can understand that local markets are critical especially for places like Sodankylä, where the distances are long. This is obvious when considering about food production, which will be one of the main products of Sodankylä industrial ecosystem.

Brand image was the second popular answer to the core success factors of Sodankylä IE. I agree that brand image is important element of IE and it helps IE's to promote their economic and environmental benefits and maybe to create local demand for their products as well. Brand image is also important to spread the information of IE's. When companies notice the potential economic benefits of resource and energy efficiency as well as pollution reduction and resource sharing, they will automatically start developing IE's without even getting external financial support from governments. (Sakr D., Baas L., El-Haggar S. & Huisingh D., 2011). Knowledge and information sharing are also considered as third important success factors of IE. (Sakr D. et al., 2011). According to Desrochers P., (2002 a) The number one thing to learn from Kalundborg industrial ecosystem is to promote positive image of industrial by-products. Others could be to share knowledge, how to reuse industrial waste and remove barriers from there.

According to interviewees the third most important success factors of IE is affordable energy. Affordable energy is a great aspect to most critical success factors of Sodankylä IE. Many IE's are built around a key player (an anchor tenant). Industrial ecosystems usually need an anchor tenant. This anchor tenant serves as the driver of some of the main resource flow such as energy as in Sodankylä. (Korhonen J., 2001b). According to

Descrochers (2002 b) and Heino & Koskenkari (2004) industrial ecosystems lower production costs by using more efficiently energy and materials in production so this can also be considered as financial matters.

According to interviewees the fourth most common success factor of Sodankylä IE was financial matters. The theory of this study claims this aspect little bit higher. It is the second important success factors of IE. (Sakr D. et al., 2011). Also, when I asked interviewees to explain what is the most important thing to consider when building a profitable IE? Five of six interviewees answered that Overall economic viability is the most important thing. One interviewee said that without overall economic viability an industrial ecosystem could not even work.

Environmental issues were the fifth common answers to the question of the most critical success factors of Sodankylä IE. This is really good answer and even the table 6., which introduces the critical success factors of IEs, will not consider environmental issues as one of the critical success factors, I think it is one of them. The aim of IE is to minimize inefficient material and energy use by utilizing local by-product and energy flows. (Lehtoranta S., Nissinen A., Mattila T. & Melanen M., 2011). This means recycling waste is the core principle. So, the goal is to increase the flow from production and consumption to the recyclers and from there back to producers. IE is an important approach for sustainable development and for business perspective. (Singh Aditi, Lou Helen H., Yaws Carl L., Hopper Jack R., Pike Ralph W., 2007). The Commonly IE approach means that companies in this system use each other waste material or other resources on their own purpose and then share their own waste materials or energy etc. In a best way scenario this approach also reduces wastes and emissions of companies which are part of the industrial ecosystem (Korhonen J., 2001b.). Also, the European Commission, (2020) claims that Reduction of environmental impact of waste through recovery, reuse and recycling and Reduction of GHG emissions from waste transport and raw material extraction are key benefits of IE

I was a bit surprised when relationships were not in top five answers to this question. According to Sakr D. et al. (2011) relationships are the most important success factors of industrial ecosystems. Also, Sitra (2020) names cooperation between companies, municipalities, and local authorities as the key point of industrial ecosystems. In Kalundborg symbiosis the relationships are considered as vital element of the symbiosis. Trust, confidentiality, openness, equality, and cooperation are the core values of Kalundborg symbiosis. (Ellen MacArthur Foundation, 2020b). The location does not matter here when considering about importance of relationships in IE. I would lift relationships as one of the core successes factors of Sodankylä IE as well.

When I asked what are the main benefits of IE in Sodankylä for the companies involved? The most common answers were in order: Economic viability, Affordable energy, utilization of by-products and brand benefits. Here the financial aspects were number one priority.

4.4 Possible pitfalls of Sodankylä industrial ecosystem

When I asked from my interviewees, can they see any possible stumbling blocks for Sodankylä industrial ecosystem? I got many answers. The most common answers to this question were: the faraway location, technological aspects, Forming the IE, lack of cooperation, permits and legislation, management, and agreements and finally the fear that if the risk is too high when compared to returns.

4.5 Future of industrial ecosystems in Finland

When I asked my interviewees, can they briefly explain the future of industrial ecosystems in Finland, what do they think, is there more of them and what should be changed before they are more common in Finland? I got predicts that there will be more industrial ecosystems in Finland, because resources will be utilized more efficiently. Competition of resources will be stronger. In the future there will be more products, which are produced sustainable. For getting more industrial ecosystems to Finland the legislation should be facilitated, the competence should be improved, and the grants should be targeted better for industrial ecosystems.

Most of my interviewees agreed that there will be more industrial ecosystems in Finland. Especially, grants are important thing, when building new industrial ecosystems, so politics have a great opportunity to influence this development directly.

5 Conclusions

In this section I will conclude the study. I answer to all my research questions, give suggestion for further studies, and provide an assessment of the reliability of the study.

5.1 Summary of findings

The Purpose of this study was to find out what is an IE, what are the benefits of industrial ecosystems and what are the critical success factors of profitable industrial ecosystems.

My first research question was: *What is an industrial ecosystem?* An answer to this question is that industrial ecosystem is an ecosystem where unused or residual resources of one company are used by another company of industrial ecosystem. This results in mutual economic as well as social and environmental benefits. Usually, it is a process involving some companies, which in a best-case-scenario complement one another to provide mutual added value through efficient use of raw materials, technology, services, and energy (Sitra, 2020).

The aim of IE is to minimize inefficient material and energy use by utilising local by-product and energy flows. (Lehtoranta S., Nissinen A., Mattila T. & Melanen M., 2011). The aim of industrial ecosystems provides a win-win situation for the economy and the environment for the local region. This goal of sustainable development of the local region provides both, benefits for local business and more environmentally friendly solutions which helps local surroundings. (Liu Changhao, Ma Chunyuan & Zhang Kai, 2012).

In industrial ecosystem, industrial operations, energy production, primary production, waste processing etc. combined are providing a way to maximize use of production waste, while still fulfilling customer's and end-users needs perfectly. (Sitra, 2020). Optimizing resource use is good for environment, but it is also a great way to rise profits of a company, because it allows companies to gain benefits of their waste trade with other companies which are involved to this industrial ecosystem.

My second research question was: *What are the benefits of industrial ecosystems?* According to European commission (2020) the key benefits of IE are rreduction of environmental impact of waste through recovery, reuse and recycling, creation of economic value from waste material, reduction of GHG emissions from waste transport and raw material extraction and extension of knowledge. There were more of them, but I think these were the key benefits. Moreover, As Kalundborg case example has proved the collaborative approach of industrial ecosystem adds value, reduce costs, and helps environment by closing of material and energy cycles. (Green cluster, 2020).

In adding to key benefits of industrial ecosystem Jouni Korhonen and Rupert J. Baumgartner (2009) claims that in industrial ecosystems economic wins are coming from both input and output stages. In the input stage the benefits are reduced raw material and energy costs as well as reduced costs from environmental legislation. At output stage the financial benefits are reduced waste management costs and reduced costs from environmental legislation.

My final research question was: *What are the critical success factors of profitable industrial ecosystems?* When I asked my interviewees to explain briefly 5 most important success factors of industrial ecosystems. They answered that number one is economic viability, the second was good cluster of companies, the third common answer were environmental aspects, the fourth was Brand aspects and the fifth most common answer was markets for final products. According to Sakr D. et al. (2011) most important success factors for industrial ecosystems are relationships that are symbiotic, producing economic value, knowledge and information sharing, policy & regulatory frameworks, organizational and institutional setups, and technical aspects.

There are good picks in both lists and there is also lot of similarities. From interviews I would pick up environmental aspects, which I would add to other list of critical success factors. My list of six critical success factors of IE would seem like this: cooperation of companies, producing economic value, environmental aspects, knowledge, and information sharing, none of these companies are in a direct competition and common values

The other part of the theory of this study deals with circular economy. Circular economy is an answer to linear economy's inabilities to reduce pollutions by circulating waste, which is others resource. Main idea of circular economy is to design out waste and pollution, to keep products and materials in use, and to regenerate natural systems (Ellen MacArthur Foundation, 2020a). Commonly circular economy tries to minimize waste through cycles of reduction, reuse, and recycling with limited leakage and minor environmental impact (Ellen MacArthur Foundation, 2016).

Why is CE theory included to this study is that IE is a circular economy business model, where waste is circulating in the ecosystem so that companies use another's waste as their resource to gain mutual benefits. Business ecosystems based around industrial ecosystems are usually providing more added value than traditional business ecosystems. This is made possible by using fewer natural resources than traditional industrial value chains. For example, in business life, this means more efficient energy and water consumption as well as reduced waste (Sitra, 2020).

What else should you remember from this study is that industrial ecosystems usually need an anchor tenant. This anchor tenant serves as the driver of some of the main resource flow such as energy. Anchor tenant can also be managing and controlling resource flows of whole industrial system. The anchor tenant facilitates the use of waste material and waste (residual) energy as input resources and as valuable output products in the regional recycling system (Korhonen J., 2001b.).

The former case example of Kalundborg symbiosis proved that shared values make effective collaboration possible and the fact that none of the companies are in a direct competition with each other among an IE. The values of Kalundborg symbiosis are trust, confidentiality, openness, equality, cooperation. (Ellen MacArthur Foundation, 2020b).

5.2 Discussion

Eventually, industrial ecosystems and circular economy could be part solutions for reducing carbon dioxide emissions when at the same time keep companies' profitability on a good level or even increase the profitability. IE and CE will not create carbon neutral humankind by themself, but they can and will help to achieve goal of making it. Everything is needed to save the environment and clearly industrial ecosystems and circular economy is step forward in this. In addition, IE and CE offers new ways of doing business in the way that maximize use of materials and resources.

For example, of industrial ecosystem good environment- and economic impacts together are CHPs, where industrial ecosystems can generate and then use energy and heat among the ecosystems. By using industrial ecosystems for energy production is in many cases very useful, because energy and heat can be circulated in the ecosystem and it can be made by using some company's renewable wastes like wood etc.

One of my interviewees wondered what it would take from a company to join in a profitable industrial ecosystem so that the company itself would make a loss from joining in the system, but the industrial ecosystem would benefit from the company. That would be interesting to study more, because I believe that this is the case in many industrial ecosystems, and it would be great to figure out business model to situations like that.

All in all, the study has achieved its objective. I found answers to all my research questions and the study fulfilled all the objectives which I set for it. Also, I believe that the reliability of this study is good at least when considering theory part and the conclusions. I found quite new references from wide scale to the theory sections and the theory were backed by interviews. However, as usual for empirical studies, there are some limitations which reduce generalizability of results in empirical part of the study. The interviews were conducted from only among one case example, which is not enough to make the empirical part of this study reliable for every industrial ecosystem cases. Due to time limitations and the fact that the case project is not yet operating, I got less interviewees than I would have liked to participate to this study. Furthemore, the study is a good source of information for all of you who are planning to ramp-up a new industrial ecosystem.

References

Chertow Marian R. (2007). “Uncovering” Industrial Symbiosis. Journal of Industrial Ecology, volume 11, Issue 1. Available: https://onlinelibrary-wiley-com.proxy.uwasa.fi/doi/epdf/10.1162/jiec.2007.1110.

Desrochers P. (2002a). Cities and industrial symbiosis some historical perspectives and policy implications. Journal of Industrial Ecology, volume 5, issue 4. Available: https://onlinelibrary-wiley-com.proxy.uwasa.fi/doi/epdf/10.1162/10881980160084024.

Descrochers P. (2002b). Industrial ecology and the rediscovery of inter-firm recycling linkages: historical evidence and policy implications. Industrial and Corporate Change, volume 11, issue 5, pp. 1031–1057. Available: https://doi.org/10.1093/icc/11.5.1031.

Ellen MacArthur Foundation. (2016). Ellen MacArthur Foundation
About the Ellen MacArthur Foundation. Available: http://www.ellenmacarthurfoundation.org/ (2016).

Ellen MacArthur Foundation. (2020a). What is the circular economy? Available: https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy.

Ellen MacArthur Foundation. (2020b). Case Studies: Kalundborg Symbiosis -
Effective industrial symbiosis. Available: https://www.ellenmacarthurfoundation.org/case-studies/effective-industrial-symbiosis.

Erkman S. (2001). Industrial ecology: a new perspective
on the future of the industrial system. Swiss Medical Weekly, volume 131, pp. 531-538. Available:

https://smw.ch/journal-file/view/artcle/ezm_smw/en/smw.2001.09845/3e65b207f0b94147d4cd879dc50f32695b81332e/smw_2001_09845.pdf/rsrc/jf.

European Commission (2020). Industrial Symbiosis. Available: https://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2018/05/Industrial_Symbiosis.pdf.

Frishammar J. & Parida V. (2018). Circular business model transformation: A roadmap for incumbent firms. California Management Review. Available: https://doi.org/10.1177/0008125618811926.

Gibbs D. & Deutz P. (2007). Reflections on implementing industrial ecology through eco-industrial park development. Journal of Cleaner Production, volume 15 issue 17, pp. 1683-1695. Available: https://www-sciencedirect-com.proxy.uwasa.fi/science/article/pii/S095965260700039X.

Green cluster. (2020). Kalundborg Symbiosis. Available: https://www.greenclustercy.org/en/practises/kalundborg-symbiosis/.

Heeres R.R., Vermeulen W.J.V. & de Walle F.B. (2004). Eco-industrial park initiatives in the USA and the Netherlands: first lessons. Journal of Cleaner Production, volume 12, issues 8–10, pp. 985-995. Available: https://www-sciencedirect-com.proxy.uwasa.fi/science/article/pii/S0959652604000873.

Heino J. (2006). HARJAVALLAN SUURTEOLLISUUSPUISTO TEOLLISEN EKOSYSTEEMIN ESIMERKKINÄ KEHITETTÄESSÄ HIILITERÄKSEN YMPÄRISTÖMYÖNTEISYYTTÄ. Acta Univ. Oul. C 254, 2006. Työnohjaaja Professori Jouko Härkki Esitarkastajat Professori Heikki Jalkanen Tutkimusprofessori Jouni Korhonen, ISBN 951-42-8196-9. Available:

http://docplayer.fi/13103114-Harjavallan-suurteollisuuspuisto-teollisen-ekosysteemin-esimerkkina-kehitettaessa-hiiliteraksen-ymparistomyonteisyytta.html.

Heino J & Koskenkari T. (2004). Harjavallan Suurteollisuuspuisto Teollisena ekosysteeminä. Oulunyliopisto, Oulu.

Helo Petri, Tuomi Ville, Kantola Jussi & Sivula Ari. (2019). Quick guide for Industrial Management thesis works. University of Vaasa Reports, 14. ISBN 978-952-476-871-9 (online). Available: https://osuva.uwasa.fi/bitstream/handle/10024/8190/978-952-476-871-9.pdf?sequence=2&isAllowed=y.

Hewes A.K. (2005). The Role of Champions in Establishing Eco-Industrial Parks. Department of Environmental Studies, Antioch New England Graduate School. Available: https://search.proquest.com/openview/c477419855b6f78f5bd477e5fe939bf6/1?pq-origsite=gscholar&cbl=18750&diss=y.

Hirvisjärvi S. & Hurme H. (2000). Tutkimushaastattelu: Teemahaastattelun teoria ja käytäntö. Helsinki University Press. ISBN 951-570-458-8.

Iansiti M. & Levien R. (2004). Strategy as ecology. Harvard Business Review, volume 82, issue 3, pp. 68-81.

Koenig A. (2005). Quo vadis EIP? How eco-industrial parks are evolving. Journal of Industrial Ecology, volume 9, issue 3. Available: https://onlinelibrary-wiley-com.proxy.uwasa.fi/doi/epdf/10.1162/1088198054821663.

Korhonen J. (2001a.). Four ecosystem principles for an industrial ecosystem
J. Clean. Prod., volume 9, pp. 253-259.

Korhonen J. (2001b.). Co-production of heat and power: an anchor tenant of a regional industrial ecosystem. Journal of Cleaner Production. volume 9, issue 6, pp. 509-517. Available: https://www-sciencedirect-com.proxy.uwasa.fi/science/article/pii/S0959652601000099.

Korhonen, J. Wihersaari, M., & Savolainen, I., (2001). Industrial ecosystem in the Finnish forest industry: Using the material and energy flow model of a forest ecosystem in a forest industry system. Ecological Economics, volume 39, issue 1, pp. 145-161. Available: https://doi.org/10.1016/S0921-8009(01)00204-X.

Korhonen J & Baumgartner R. J. (2009). The industrial ecosystem balanced scorecard. International Journal of Innovation and Sustainable Development, volume 4, issue 1. Available: https://www.researchgate.net/publication/247835077_The_industrial_ecosystem_balanced_scorecard.

Korhonen Jouni, Nuur Cali, Feldmann Andreas, Birkie Seyoum Eshetu. (2018). Circular economy as an essentially contested concept. Journal of Cleaner Production, volume 175, pp. 544-552.

Krones J. (2012). The Best of Both Worlds: A Beginner's Guide to Industrial Ecology. Available: http://web.mit.edu/murj/www/v15/v15-Features/v15-f6.pdf.

Lehtilä A., Savolainen I. & Tuhkanen S. (1997). Indicators of CO2 emissions and energy efficiency: comparison of Finland with other countries, VTT, Technical Research Centre of Finland, Espoo, pp. 14-18.

Lehtoranta S., Nissinen A., Mattila T. & Melanen M. (2011). Industrial symbiosis and the policy instruments of sustainable consumption and production. Journal of Cleaner Production, volume 19, issue 16, pp. 1865-1875. Available: https://www-sciencedirect-com.proxy.uwasa.fi/science/article/pii/S0959652611001181.

Liu Changhao, Ma Chunyuan & Zhang Kai. (2012). Going beyond the sectoral boundary: a key stage in the development of a regional industrial ecosystem. Journal of Cleaner Production, volume 22, issue 1, pp. 42-49. Available: https://doi.org/10.1016/j.jclepro.2011.09.022.

Lowe E.A. (2001). Eco-industrial Park Handbook for Asian Developing Countries". Based upon Eco-Industrial Parks, a Handbook for Local Development Teams (1995–98), Indigo Development Working Papers in Industrial Ecology (1997–2001), and Field Experience in the Philippines, Thailand, and China. Report to Asian Development Bank. Indigo Development 2001.

Luke. (2020). District heating plant-model of the new generation – carbon-neutral energy and food production industrial ecosystem based on local ingredients and industrial side streams. Available: https://www.luke.fi/en/projektit/sodankyla/.

Nambisan S. & Sawhney M. (2011). Orchestration processes in network-centric innovation: Evidence from the field. Academy of Management Perspectives, volume 25, issue 3, pp. 40-57.

Parida Vinit, Burström Thommie, Visnjic Ivanka & Wincent Joakim. (2019). Orchestrating Industrial Ecosystem in circular economy: A two-stage transformation model for large manufacturing companies. Journal of Business Research, volume 101, pp. 715-725, ISSN 0148-2963. Available:
https://doi.org/10.1016/j.jbusres.2019.01.006.
(http://www.sciencedirect.com/science/article/pii/S0148296319300062).

Peck S. (2002). When Is an Eco-Industrial Park Not an Eco-Industrial Park? Journal of Industrial Ecology, volume 5, issue 3, pp. 3–5.

Sakr D., Baas L., El-Haggar S. & Huisingh D. (2011). Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context. Journal of Cleaner Production, volume 19, issue 11, pp. 1158-1169. Available: https://www.sciencedirect.com/science/article/abs/pii/S0959652611000059.

Shi H., Chertow M.& Song Y. (2010). Developing country experience with eco-industrial parks: a case study of the Tianjin economic-technical development in China.
Journal of Cleaner Production, volume 18, Issue 3, pp. 191-199. Available: https://www-sciencedirect-com.proxy.uwasa.fi/science/article/pii/S0959652609003242.

Singh Aditi, Lou Helen H., Yaws Carl L., Hopper Jack R., Pike Ralph W. (2007). Environmental impact assessment of different design schemes of an Industrial Ecosystem. Resources, Conservation and Recycling, volume 51, issue 2, pp. 294-313, ISSN 0921-3449. Available:
https://doi.org/10.1016/j.resconrec.2006.10.002.
(http://www.sciencedirect.com/science/article/pii/S0921344906002424).

Sitra. (2020). Industrial symbiosis: New business via industrial symbiosis. Available: https://www.sitra.fi/en/topics/industrial-symbiosis/.

Suárez-Eiroa Brais, Fernández Emilio, Méndez-Martínez Gonzalo, Soto-Oñate David. (2019). Operational principles of circular economy for sustainable development: Linking theory and practice. Journal of Cleaner Production, volume 214, pp. 952-961.

The Association of Decentralised Energy. (2020). Combined heat and power. Available:
https://www.theade.co.uk/resources/what-is-combined-heat-and-power.

Tonn Bruce, Frymier Paul D., Stiefel Dorian, Skinner Soro Leah, Suraweera Nethika & Tuck Rachel. (2014). Toward an infinitely reusable, recyclable, and renewable Industrial Ecosystem. Journal of Cleaner Production, volume 66, pp. 392-406, ISSN 0959-6526.

Available: https://doi.org/10.1016/j.jclepro.2013.11.008. (http://www.sciencedirect.com/science/article/pii/S0959652613007701).

Tudor T., Adam E., Bates M. (2007). Drivers and limitations for the successful development and functioning of EIPs (eco-industrial parks): a literature review
Ecological Economics, volume 61, issues 2–3, pp. 199-207. Available: https://www-sciencedirect-com.proxy.uwasa.fi/science/article/pii/S0921800906005453.

Williamson P.J. and De Meyer A. (2012). Ecosystem advantage: How to successfully harness the power of partners. California Management Review, volume 55, issue 1, pp. 24-46.

Attachments

Attachment 1. Interview form

Teollisen ekosysteemin kriittiset menestystekijät

Ville Ahola, Vaasan yliopisto

Tämä kysely on osa opinnäytetyötäni, jonka empiiriseen osioon on valittu Sodankylän uuden sukupolven kaukolämpölaitoshanke, jossa energiatuotannon virtojen ja sivuvirtojen ympärille tunnistetaan ja mallinnetaan energian ja ruuan teollinen ekosysteemi. Kyselyn tarkoituksena on saada selville, mitkä ovat teollisen ekosysteemin suurimmat hyödyt ja mitkä ovat kannattavan teollisen ekosysteemin kriittiset menestystekijät. Tutkimuksessa pyritään saamaan vastaus kysymyksiin, jotka ovat: Mitä teolliset ekosysteemit ovat? Mitkä ovat teollisten ekosysteemien hyötyjä? Mitkä ovat teollisen ekosysteemin kriittiset menestystekijät? Kysymyksiin vastaamalla autat keräämään talteen tärkeää tietoa, mitä on kerääntynyt projektin aikana.

Kiitos osallistumisestasi!

Teollisen ekosysteemin määritelmä:

Teollinen ekosysteemi on Peckin (2002) määritelmän mukaan liikeyritysten yhteisö, joka tekee yhteistyötä keskenään ja ympärillä olevan yhteiskunnan kanssa jakaakseen tehokkaasti resurssit (tieto, materiaalit, energia, infrastruktuuri ja luonnollinen elinpiiri) saavuttaakseen parannuksia ympäristön laadussa, taloudellisuudessa ja henkilöstön voimavarojen hyödyntämisessä, sekä yrityksissä että ympäröivässä yhteiskunnassa.

1. **Mitkä ovat teollisen ekosysteemin suurimmat hyödyt siihen osallistuville yrityksille?**
   -
2. **Mikä on suurin yksittäinen tekijä, joka tulisi ottaa huomioon, kun rakennetaan uutta teollista ekosysteemiä? Miksi?**
   -
3. **Selitä lyhyesti viisi teollisen ekosysteemin tärkeintä menestystekijää.**
   -
4. **Mitkä ovat suurimmat hyödyt yrityksille, jotka osallistuvat Sodankylän teolliseen ekosysteemiin?**
   -
5. **Onko Sodankylän teollisella ekosysteemillä mahdollisuus olla taloudellisesti kannattava, tämänhetkisten olosuhteiden vallitessa?**
   -

6. **Jos ei, niin miten Sodankylän teollinen ekosysteemi voisi olla kannattava?**
   -
7. **Mitkä ovat mielestäsi Sodankylän teollisen ekosysteemin tärkeimmät menestystekijät?**
   -
8. **Minkälaisia mahdollisia kompastuskiviä Sodankylän teollinen ekosysteemi tulee kohtaamaan?**
   -
9. **Voitko selittää lyhyesti, millainen tulevaisuus teollisilla ekosysteemeillä on Suomessa? Onko Suomessa enemmän teollisia ekosysteemejä tulevaisuudessa? Mitä tulisi muuttaa, että ne alkaisivat yleistyä Suomessa?**
   -

Kiitos vastauksistasi!