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VALUE CREATION IN ECO-INDUSTRIAL CLUSTERS

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ABSTRACT

Sustainability is generally seen as a social undertaking for greater social and environmental good. However, sustainability as a business model can be utilized through form of industrial symbiosis and industrial ecology by clustering together activities that utilize the waste flows of each other, in order to create added value. Due to this a research gap exists in the merits of eco-industrial clustering in the sense of not only environmental, but also financial sustainability.

Using case studies of companies in the field of greenhouse farming, fish farming, waste and energy management, the paper seeks to define a concept where actors from this field can co-exist in a symbiotic structure, creating and adding value to their activities in an eco-industrial cluster. The paper seeks to understand what is needed in order to create a profitable and sustainable eco-industrial cluster with aquaponics operations in its center.

The process requires extensive planning, governing, mindsets, investments and key actors, of which most important are energy providers and the core operations of aquaponics. The clustering adds value to each actors operation through cost savings, joint investments, shared infrastructure and perceived value through sustainable image of a product and company. The challenges involved are increased costs of investment, extensive planning, creating an efficient system and avoiding bottlenecks within a system, which can cascade on to other actors, hindering their operations.

KEYWORDS: Eco-industrial Clusters, Industrial Ecology, Sustainability, Industrial Symbiosis, Circular Economics

1. INTRODUCTION

1.1 Motivation for the study

The concept of sustainability is not only the concept of creating less strain for environment, but rather overall sustainability of possibility of running a prolonged business operation or a system. Sustainability is therefore a critical aspect of any organization or business. In this paper, the sustainability will be inspected in the economic as well as environmental perspective as a value adding factor to a company or actor. This consists of an idea, that a sustainable industry takes the optimal amount of input and produces optimal amount of output, minimizing waste. In addition this strives to use the by-products and other industries and organizations outputs in order to achieve as much output as possible, with as little waste as possible. This concept is apparent currently on policy level in Finland for example. The amount of municipal waste deposited to landfills in Finland has been decreasing sharply since the early 2000's to the present day, resulting in only one tenth of municipal waste to be deposited in landfills. The reminder of the waste is either recovered in material (recycled) or energy (incinerated). (Official Statistics of Finland, 2016) There is no doubt that there is a trend to minimize waste and increase efficiency by utilizing waste, rather than depositing it to landfill. This concept is not new by all means, but in the light of statistics, the transition to utilizing waste has caught up in last ten years. While not only beneficial environmentally and by government run economic policy, this concept has much potential to be utilized by businesses in a form of economic clusters. An example of industrial utilization of this concept, is Kalundborg Industrial Ecosystem, by placing relevant actors together and creating waste, material and energy flows between different actors, in order to minimize waste. (Ehrenfeld & Gertler, 1997)

Due to the ever-increasing need for materials and energy, the previous linear models of economy produce waste, that could be utilized more efficiently. As the material and energy needs keep rising, utilizing this waste in an efficient fashion would prove to be beneficial in ways of profitability, producing less waste, utilizing more resources and building a more sustainable economic system. The study will concentrate finding synergies in these systems in a cluster ecosystem. The concept of eco industrial cluster will be studied and evaluated how different actors can benefit in their area from each other, breaking the traditional linear model of economy and examining different types of efficiencies and synergies that are possible between these different actors situated in a cluster. A prime example of these systems are eco-industrial parks, which seek to create a concept of symbiosis between actors and organizations.

The paper will seek to understand the conditions for a successful clustering, mapping out benefits, needs and challenges of companies in addition to recognizing and interacting successfully with actors and stakeholders involved in an ecological cluster, in order to create value and benefit for related stakeholders.

1.2 Research gap

The current research of industrial ecology is generally concentrated on examining industries as ecosystems and understanding them on system level as well as comparing them to biological ecosystems (Hess, 2010). The practical concept of the theory considers the ways of utilizing energy and waste flows in systems point of view in order to minimize waste. This kind of sustainability can be achieved in practice in form of Eco Industrial parks (Bellantuono & al, 2017). This ecological emphasis in fact is the core of the whole concept, however a study concentrating on how to utilize this system level thinking and close loop system for companies benefit and value creation does not have the same emphasis in the field.

Therefore, studying the concept from the value creation perspective could provide valuable insight for companies willing to enter the ecological production field in order to create value for all parties involved in the system, including public and private. (Arbolino et al,

2018) As the trend of green ideas and values is topical and growing, the value creation potential in the field could yield benefits for businesses. In addition, examining the topic from this perspective could reveal underlying savings and efficiency optimization possibilities for businesses seeking to create links with their partners, by situating together in a cluster of activities.

1.3 Research questions

The paper will seek to answer the following research questions:

Research question 1:
How to create an eco-industrial cluster, utilize crucial components and needs in order to create successful symbiosis.

Research question 2:
How can businesses and actors create and perceive value from their activities through clustering together and utilizing their inputs and out-puts?

The first research question will inspect the subject from more general, systems related perspective. What are the underlying requirements, the extent of symbiosis, degree of sustainability and the challenges and feasibility of creating a closed loop ecosystem?

The second question focuses more on the actor-level, in order to understand how single organizations or actors can benefit or exist in a symbiotic cluster and the interdependencies between each other, as well as the benefits of co-existing in a cluster.

1.4 Thesis structure

The paper introduces the underlying theoretical background and history of the theories implemented to give a context. Core theories of industrial ecology and symbiosis will be defined and examined, along with tangible examples in implementation of these theories in form of eco-industrial parks, examples in interconnectedness and the added value associated in this. The barriers and challenges in this theory will be handled in the late stages of theoretical analysis. From the theoretical analysis a framework will be crystalized, which will guide the research, as well as later compare the findings back to the theory.

The methodological part dals with the research method used, as well as justification for the used method. A three step data collection plan is constructed to give a logical and planned flow for the data gathering process to ensure a strategy throughout the methodological part. Context will be given to the particular study in the form of a focused, conceptualized case which is limited to symbiosis of food and energy production. Furthermore data analysis methods are discussed later, with considerations to validity and reliability.

The empirical findings are gone through on more detailed model of the conceptualized cluster, which the empirical findings are based around. The empirical chapter seeks to systematically map out the crucial aspects defined in the theoretical framework: clustering and interconnectedness, risks and challenges as well as added value. Findings are summarized at the end by a table with key factors to success, considerations to interconnectedness, as well as barriers to entry.

The final chapter concludes the research and provides a brief rundown of the findings. This is presented through key findings, theoretical contribution, managerial implications, as well as limitations and future research.

2. VALUE THROUGH ECO-INDUSTRIAL CLUSTERS

The chapter examines the existing literature on the core theory of the paper; Industrial ecology, Eco-industrial clusters, Value adding factors as well as industrial symbiosis. The aim is to understand and differentiate industrial clusters to eco-industrial clusters as well as understand how industrial symbiosis is implemented. Furthermore the interconnectedness of actors inside an eco-industrial cluster is examined in the perspective of symbiosis and value creation.

2.1.Theoretical Foundation

The main theories inspected and applied in the research are **Industrial ecology** and **Industrial Symbiosis**. The application of these theories can be seen in the form **of Eco-industrial parks**, which will be analyzed further how in practice these theories are applied. These theories are closely related to circular economics; therefore, the circular potential and nature of these theories will be given attention in the analysis.

2.1.1. Industrial Ecology

John Ehrenfeld (1994) describes the history of the term of industrial ecology originating from Japan from early 1970's as a term used by a research group, developing industrial policy for the Ministry of Internal Trade and Industry. The American pioneers on the subject, according to Ehrenfeld, defines the Industrial Ecology as a means of achieving a state of sustainable development that can be approached and sustained; and that *"It consists of a systems view of human economic activity and its interrelationship with fundamental biological, chemical, and physical systems with the goal of establishing and maintaining the human species at levels that can be sustained indefinitely to given continued economic,* *cultural, and technological evolution."* (Ehrenfeld, 1994: p. 15) In addition, Ehrenfeld & Gertler (1997) explain, that transition from a linear feed system in to a close loop system of energy and material flow, are the key themes of industrial ecology (Ehrenfeld & Gertler 1997: p. 68)

The general concept of industrial ecology is explained by S. Erkman as a continuation of industrial metabolism. An idea where the entirety of materials and energy moves through the complete industrial system, that seeks to explain and understand material and energy flows that is relevant to human activities. These activities range from acquisition to final and unavoidable reintegration eventually into the overall system (Erkman, 1997 p. 1) - a logic that closely resembles the basic principles and developing of the ideas of circular economics as well. The Industrial economy goes past the idea of Industrial metabolism. This is examined by understanding how the industrial system, regulation of the system, and the relation of the system to biosphere works. This is then followed by available knowledge on hand of the ecosystem of how to restructure and implement it to work in the same fashion as natural ecosystem would work. (Erkman, 1997 p. 2)

Erkman explains the practical idea of the industrial ecology's immediate application possibilities in the concept of "food webs between companies". This manifests is in form of creating zones or clusters where the by- products, waste and residue of certain industries are utilized by other industries or companies as raw materials or resources to fuel their operations. This is used as an explanation of the concept of Eco-Industrial clustering. In addition, the concept can be viewed in more general matter of creating "industrial biocenoses" around a specific industrial activity, such as thermo-power, steel / paper manufacturing, agriculture etc. in order to create a cluster, which would then have reduced and minimal emissions. This in addition would provide areas of sustainability along with efficiency by minimizing cost and optimizing the flows of energy on raw materials. (Erkman, 1997 p. 6)

These ideas are similar to Frosch & Gallopoulos' definition of Industrial ecosystem, by which they compare to naturally occurring phenomena in ecosystem, by describing it following: *"The industrial ecosystem would function as an analogue of biological ecosystems. (Plants synthesize nutrients that feed herbivores, which in turn feed a chain of carnivores whose wastes and bodies eventually feed further generations of plants)"* (Frosch & Gallopoulos, 1989: p. 144) The applicability of this logic could be seen in the context of creating Eco Industrial parks, to capture the synergies together. This will create create smaller ecosystems in order to attain efficiency through optimizing flows and feeding the industry's waste to the closed ecosystem. The final goal being to attain efficiency and to achieve minimum waste. However, the article argues, that ideal industrial ecosystem might never be possible to be attained in practice. Instead the industries would have to change their way of working in terms of manufacturing and waste, in order to attain sustainability and for less industrialized regions and countries to raise their standard of living, without having a negative impact on the environment. (Frosch & Gallopoulos, 1989: p. 144)

While the concept may not be possible to be implemented in practice, it gives a decent guideline and a point to aspire towards to, and gives a solid theoretical basis for working of eco industrial parks, as an environment and an ecosystem. Frosch & Gallopoulos take a more macro level view on the ecosystem view, looking at the industry as whole as an ecosystem, thus having a very broad scope, as opposed of looking at a certain cluster of activities as an ecosystem. However, the logic and the concept can be applied to smaller clusters and ecosystems, than only on grand scale of industry.

Brad Allenby (2006) On the other hand acknowledges the idea, that the industrial ecology has similarities in ecosystems found in nature and that industries share same and similar traits with these natural ecosystems. This makes the study of natural-ecosystems beneficial in order to understand complex industrial webs, which are eco-systems in itself, hence industrial ecology. (Allenby, 2006: p. 29) Allenby concludes, that industrial ecology has an evident and necessary interplay between different and even mutually exclusive ontologies, making it very different from many other traditional fields of studies.

The main characteristic of the industrial ecology study however, is that industrial ecology deals with complex and adaptive systems. These systems are therefore unable to be handled or conceptualized by only one approach. However, the parts of these systems can be approached and examined by a single and uniform approach (Allenby, 2006: p. 36) This further reinforces the idea, that the industry as a whole to be inspected as an ecosystem could be too broad as a scope to be efficiently or coherently approached and inspected. Therefore, the possibility of looking at a more isolated and simpler system and ecosystem through the theory of industrial ecology would prove to be more successful. This could explain the examples of eco-clusters and eco-industrial parks being heavily associated with industrial ecology, due to limited scope and more “isolated” ecosystem to narrow down the inspection to.

Ayres & Ayres support the view of Industrial Ecology as an imitation of biological concepts and analogies, such as the concept of “Industrial Symbiosis” and symbiotic networks to create Eco-industrial parks. However, this does not only limit the concept alone to the applications that Eco Industrial Parks offer, but in fact view the concept as more universally applicable on ecosystem level, not only limiting to adjacent facilities and close clusters of facilities. (Ayres & Ayres, 2002 c. 1) According to Ayres & Ayres, the ecosystems may therefore also differ on the relation in the sense how they are related to the outside inputs and feeds of resource flows and the linearity of said flows, along with the release of waste to the external environment in the end. Examining the model of clustering of potentially synergic activities will help also understand how to mitigate these risks and costs through finding common synergies and clustering of activities. (Ayres & Ayres 2002)

The following chart by Ayres & Ayres (2002) from Industrial Ecology Handbook illustrates three types of flows in Industrial ecology. The first and the most simplistic illustration displays a model that has the highest reliability to external resources and waste sinks, as opposed to the “type 3”, which is the other end of the spectrum, where resources are minimal, or limited barely to energy, whereas waste is utilized completely for production. This is a concept very similar to circular economics concept of close cycle. It could be argued therefore, that most clusters and ecosystems in the forms of Eco-Industrial Parks work in the between of these models, aspiring to be as cyclic as possible in nature, in order to achieve maximum effectiveness and minimum, or no waste.

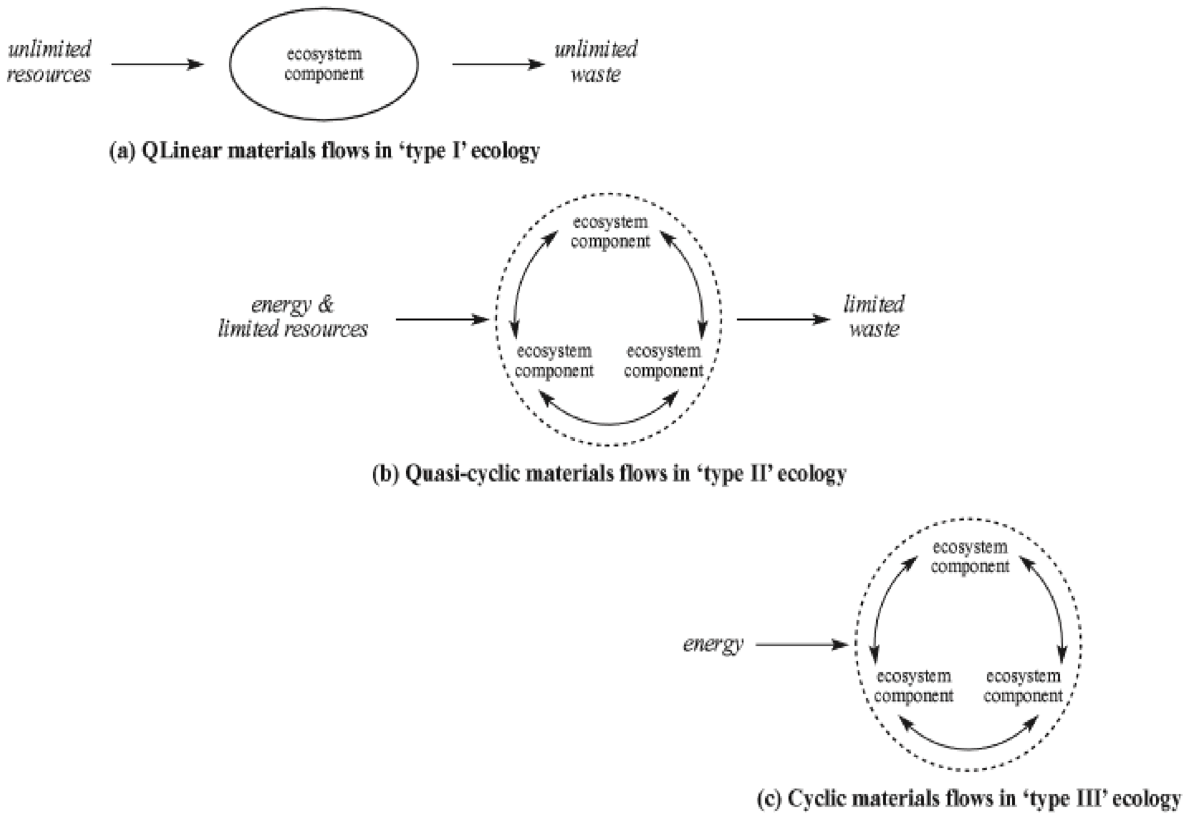

Figure 1. Material flows in three types of ecologies and their linearity (Ayres & Ayres, 2002)

The concept of Industrial ecology appears to be highly relevant to be applied to the study, as it provides the context, the working principle to the eco-industrial parks as well as a link to circular economic models. Due to the system-based nature of the theory, applying it on a case of an industrial park, platform or a cluster of actors in symbiotic or synergic case makes it easily applicable. However, recent studies have been going to the direction of Circular Economics more, rather than Industrial Ecology to explain ecosystems and material flows. In addition, the theory of industrial ecology is very wide, making it a broad tool to understand the benefits and needs of synergized industrial clusters. However, the theory is very closely related to ecological industrial parks, and the concept of ecological industrial park appears to be the main example of an ecological environment which the industrial ecology seeks to explain. Therefore, the theory will provide excellent understanding of systems level thinking applied to industry, sustainability and material flows.

The research in the field of industrial ecology shares also much of the theory with circular economics. (Saavedra & al. 2018) However the study will more focus on synergies and partial circulation of flows, due to the unlikeliness of achieving full circular economy in practical setting. (Ayres & Ayres, 2002) This focuses the research on finding and utilizing synergies between key actors, mapping value acting factors and the key needs of said actors in order to form an eco-industrial. In addition the actors challenges and difficulties will be taken in account in the research, in order to find a solution from eco-industrial cluster based solutions.

2.1.2 Industrial symbiosis

The concept of Industrial symbiosis is very closely related to the concept of industrial ecology and is used to explain the mutually beneficial process of material, energy and / or waste flows between different actors, creating mutually beneficial result. As in for industrial ecology itself, the industrial symbiosis uses biological terminology to define itself, as symbiosis is defined as *"The living together in more or less intimate association or close union of two dissimilar organisms (as in parasitism or commensalism) …"*(Merriam-Webster, 2017). However, in the context of industrial ecology, the symbiosis is regarded overwhelmingly positive co-operation and mutual benefit between actors and companies, such as the definition of industrial symbiosis: *"… instead of being thrown away or destroyed, surplus resources generated by an industrial process are captured then* *redirected for use as a 'new' input into another process by one or more other companies, providing a mutual benefit or symbiosis."*(International Synergies, 2017)

Indeed, Gérald Hess (2010: 275) defines the concept of industrial activity as an ecosystem, that is comparable to a more familiar background; biology and ecology. Hess describes this association more in a philosophical perspective, that to understand complex relations and material flows, businesses and industries can be described with terminology familiar from nature and biology. As there is circularity in the natural ecosystems, industrial ecology deals with understanding the element of circularity in industries and businesses material and waste flows. Symbiosis can be recognized as a metaphor for common and shared benefit.

Hess furthermore adds, that despite similarities in descriptions, concepts and terminology, this doesn't make the concepts identical, nor is the perceived circularity and benefits, but rather acknowledging the resemblance of the two systems, in order to create a viewpoint and a context. Hess states, that ecological metaphors in industrial ecology is something that has not existed before, thus making it difficult to make clear definitions. Indeed, this could explain the wide range of terminology used in sustainability related literature and, ranging from terminology, such as circular economics, industrial ecology, symbiosis etc. Hess' questions in general, whether the ecosystem is an actual concept or plainly a metaphor, and discusses the possibility of confusing metaphor and model (Hess 2010: 280). However, despite the variety of definitions, the main concepts appear to be similar, with circularity and waste minimization as a core concept. By defining these more complex, usually wide system related concepts in more familiar terms, it is easier to understand the larger picture and possibilities of industrial symbiosis as a metaphor for mutual benefit through interrelatedness between entities.

According to Ehrenfeld & Gertler (1997) Industrial symbiosis is heavily affiliated concept to Industrial Ecology. The concept involves of creating links between actors or companies in order to achieve and create efficiency between each other that can be seen on systems level scale. (Ehrenfeld & Gertler 1997: 68) These flows are material and energy flows through the whole cluster of activities and processes. Even though if a single company would be taken away from the system and inspected traditionally could be ineffective. Thus, the symbiosis creates benefit and minimizes waste as a whole. The materials, that would otherwise would be directly acquired “fresh” materials, can be therefore taken from byproducts of other companies in the cluster and used as feed inputs to others. The use, cascade and flow of by-products is a core of this concept. (Ehrenfeld & Gertler 1997)

There are various definitions of industrial ecology and symbiosis, which are based on similar terms from biology, adapted in to the field of economics, ecology and industry (Hess, 2010). Therefore, for the sake of clarity, terminology such as Eco-industrial cluster will be referred to operations that are geographically situated together and have a degree of synergy and mutual benefit between each other. Flows and side flows will refer to either primary and secondary in or output of an actor.

Industrial symbiosis and industrial ecology go therefore hand in hand in theory, as they both seek to explain complex industrial systems and environments with natural terms. Industrial symbiosis deals with mutually beneficial linkages and relationships. Industrial ecology on the other hand deals with industries as complex and wide ecologies all together.

2.1.2. Eco industrial park

Eco industrial park can be defined as a cluster of actors, organizations and entities that utilize the principle of industrial ecology and symbiosis, in order to benefit from each other’s actions, input, output and material flows. According to Kuznetsova & al. (2016) *“EIP can be created around the specific industrial sector to increase the production activity density in the same geographical area, to diversify the end products portfolio and optimize production chains”* This definition supports the systems thinking view, that the whole is more than sum of its parts. By clustering together geographically, the actors of a geographical area can gain larger product portfolio and more efficient means of production. This could lead to reduced costs, potential for larger amounts of production and wider ranges of production, along with benefits of utilizing and building a shared infrastructure, leading in to less need of investment from separate entities, cost savings and overall efficiency between actors.

Such sharing of activities and clustering could potentially yield benefits in cost saving, along with providing a more sustainable business model, where extra logistics expenditure can be decreased and the companies can benefit from the local inputs and outputs in the existing cluster. This could be used as leverage for product marketing and company image, in order to attract environmental minded customers and increase value of both corporate image and product portfolio, through sustainable development. Other potential benefits in such systems, can be shared product development, R&D as well as socio-economical aspects, such as creating large employers and industrial districts to centralized areas, contributing to national economy.

The topic of Eco-industrial park can be considered as a manifestation of the industrial symbiotic thinking, where multiple actors benefit the existence of others. An example of this beneficial symbiosis and system planning will be further analyzed under the next section through an example of Kalundborg Eco Industrial Park.

2.2.Clustering & Inter-connectedness

As described in previous section, the different flows of material and waste are essential in terms of inter-connectedness. The interconnectedness in a symbiotic relation is significant, due to the mutually beneficial nature of the flows. One actor will gain from the presence of others.

In order to define the actors in a system, a modular approach can be taken. Each actor is a piece in the system, which contributes to the whole. Inputs, outputs and waste are generated and utilized these actors. The actors are the pieces between links that operate in the cluster and seek to generate profit for themselves by using the other actors. In this case an actor can be in example the energy provider; a power plant and the company or companies running it.

Tsvetkova and Gustafsson take a modular approach explaining the industrial ecosystems, inspecting the ecosystem on system level with smaller interrelated parts (Tsvetkova & Gustafsson 2012), much to the likeness of systems thinking and eco industrial park theory. An example of biogas manufacturing is used as an example to demonstrate the modular approach of inter-connectedness. The illustration demonstrates the benefits of having actors with applicable material flows in a same system. Each actor provides a product and service in exchange for a cash flow, utilizing each other’s material steams, in order to create an interconnected network of actors.

The center core business of biogas production is indicated with a red boundary, indicating the core actor which the cluster is centered around. The other actors are units are interrelated to this main actor directly or inderictly. An example of direct relation is the farming, waste management or biogas distributor, whereas local transport operations, sellers of gas driven vehicles and local population are indirect, as they exchange cash flow or a product / service to a direct actor.

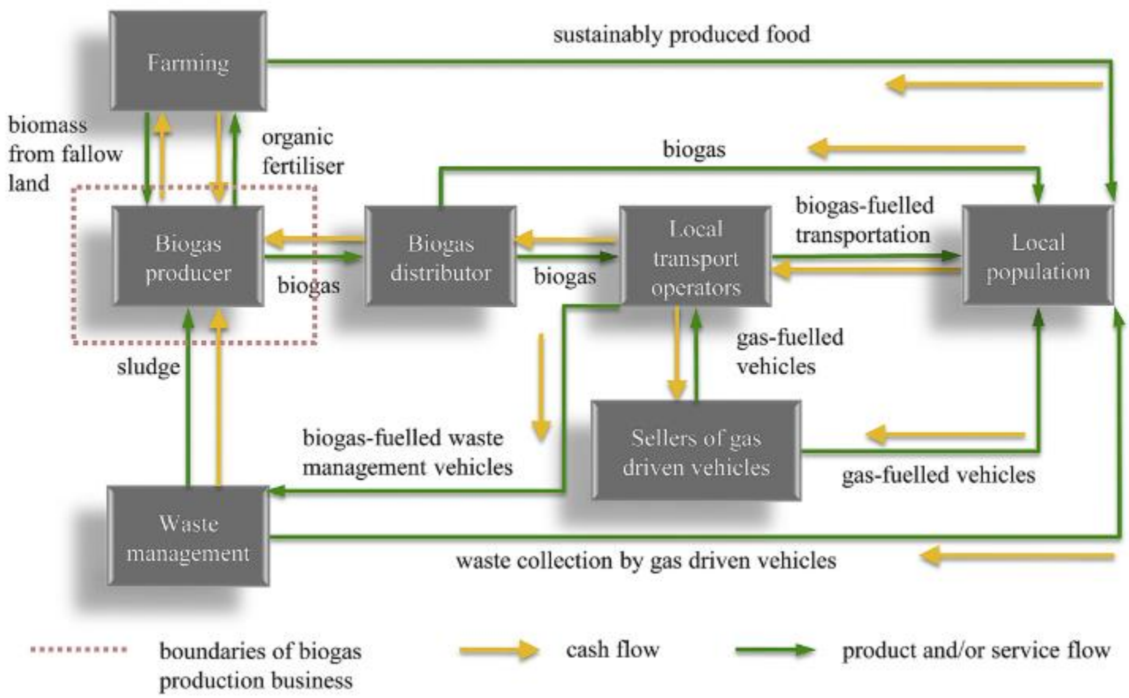

Figure 2. Biogas production system configuration for transport (Tsvetkova & Gustafsson 2012)

This view provides more business utilization, rather than waste minimization. However, it should be noted that the nature of the industry, the biogas industry, used in example is a prime example of an industry that can utilize waste sinks of other industries and outputs. This model provides a good understanding for businesses aspiring to enter in to an industrial ecological model or a cluster of waste / feed links to utilize for their benefit.

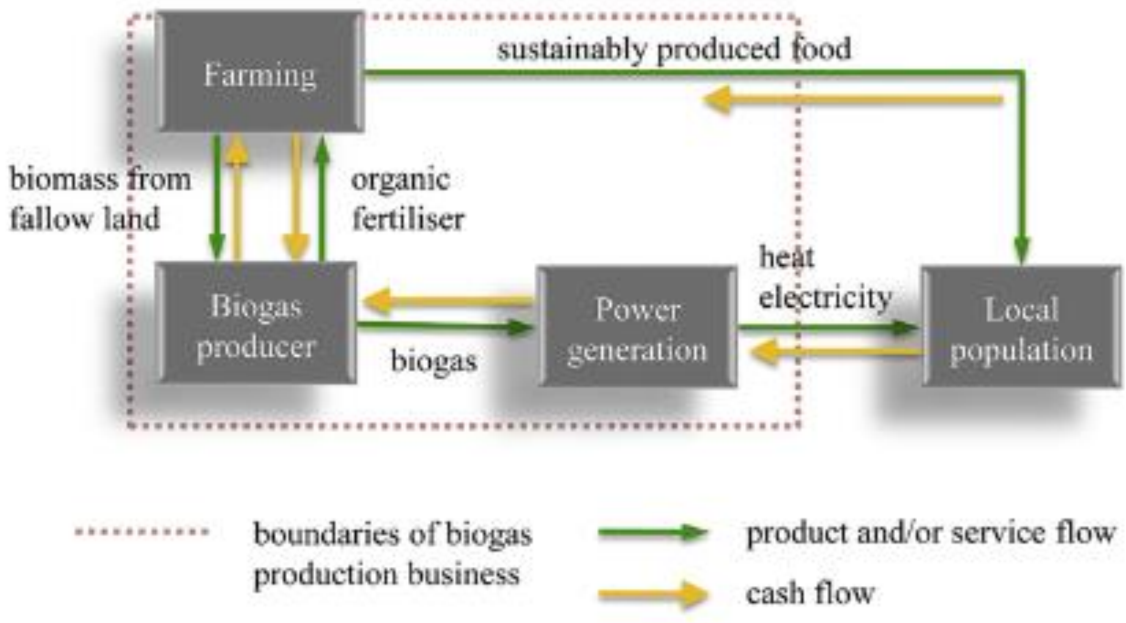

Figure 3. Biogas production system configuration for heat and power production (Tsvetkova & Gustafsson 2012)

The figure by Tsvetkova & Gustafsson gives an example of cash flow as a form of a flow between actors in a cluster. This implies, that not only materials or waste can be a stream, but also cash. In addition, the business can have components outside of it that are part of the circularity process.

Furthermore, this model gives flexible approach for the industry to view their possible business model to be utilized in different ways, as figures 2 and 3 (Tsvetkova & Gustafsson, 2012) represent. With different boundaries and flows, the business can define its model in various ways, making the industrial ecology system a viable option for companies that are willing to build their operations around the model. The conventional and rigid supply, demand and co-operation contexts can be instead defined by interchangeable modules which can be rearranged to meet the businesses needs in different contexts, environments and areas, giving a decent amount of flexibility.

The Kalundborg industrial symbiosis is among one of the known functioning example of symbiosis within the context of industrial ecology, which demonstrates in detail interconnectedness of actors. The cluster has developed over time, starting as a co-operation of Kalundborg municipality supplying water for the Statoil's production, from which it has developed to currently over 30 exchange links of water, by products and energy (Ellen Mac Arthur Foundation, 2017)

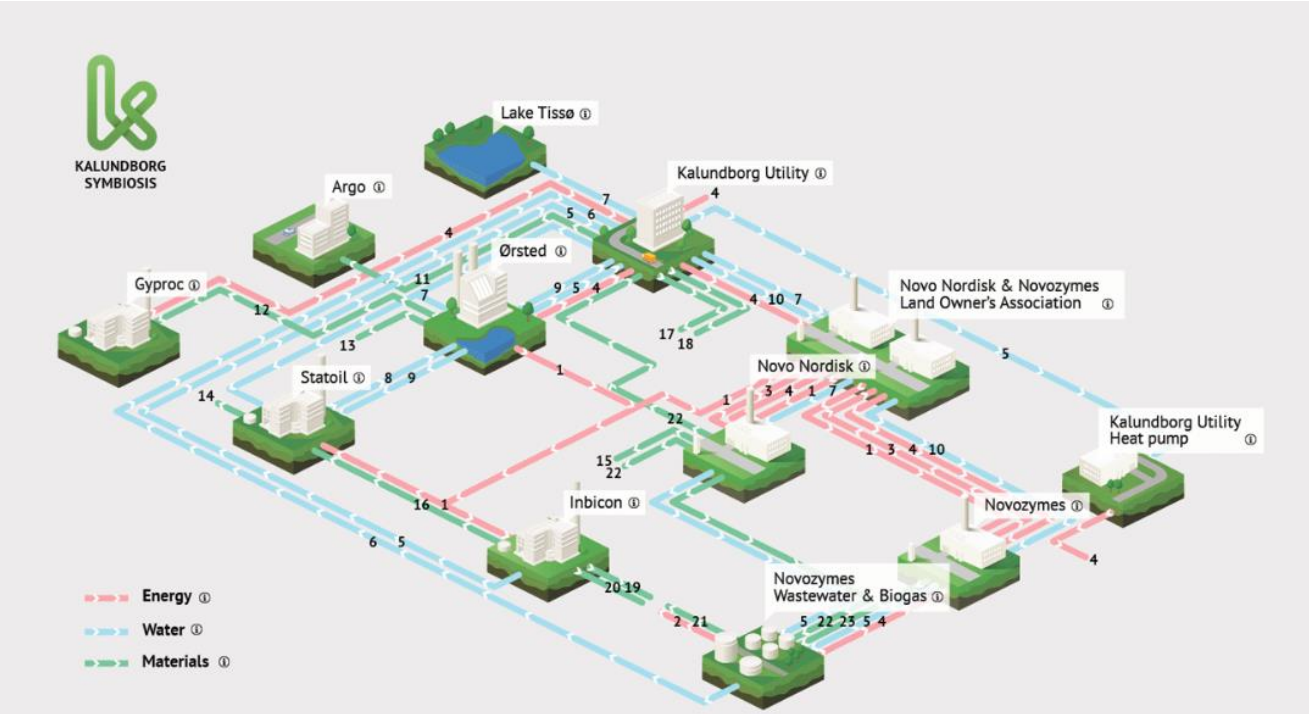

Figure 4. Flows in Kalundborg Symbiosis (Kalundborg Symbiosis, 2018)

The figure illustrates simplified schematic of the Kalundborg symbiosis, pointing out the various energy, water and material connections between actions.

The three flows are categorized by the Kalundborg Symbiosis as:

Energy
Such as: Steam, power to grid, heating and warm condensate
Water
Such as: Waste & cleaned water, surface water & cleaned surface water and purified water
Material
Such as: Waste, Industrial residual products, ethanol waste and biomass

Therefore, the more links and actors are present, the more flows there are to utilize by the other actors. The nature of the flows determine the usability, but basic flows, such as energy and water, could be easier to utilize, hence the large amount of such flows.

The prominence of energy and water transfer can be seen with the most links between the actors. Therefore, it can be seen, that the role of water and energy distribution can be pointed out as most crucial and numerous links between the actors within the cluster. In addition, the historical development of the cluster was backed by the water exchange of the two first actors. This would indicate, that the "waste flows" or material flows of actors would not have to be implemented right from the beginning, and that the more basic flows are indeed enough to build on to create an industrial symbiosis in the first stages. The back and forth flows also illustrate the symbiotic nature of the arrangement in the cluster, hence the links and distributions are mutual, rather than one sided.

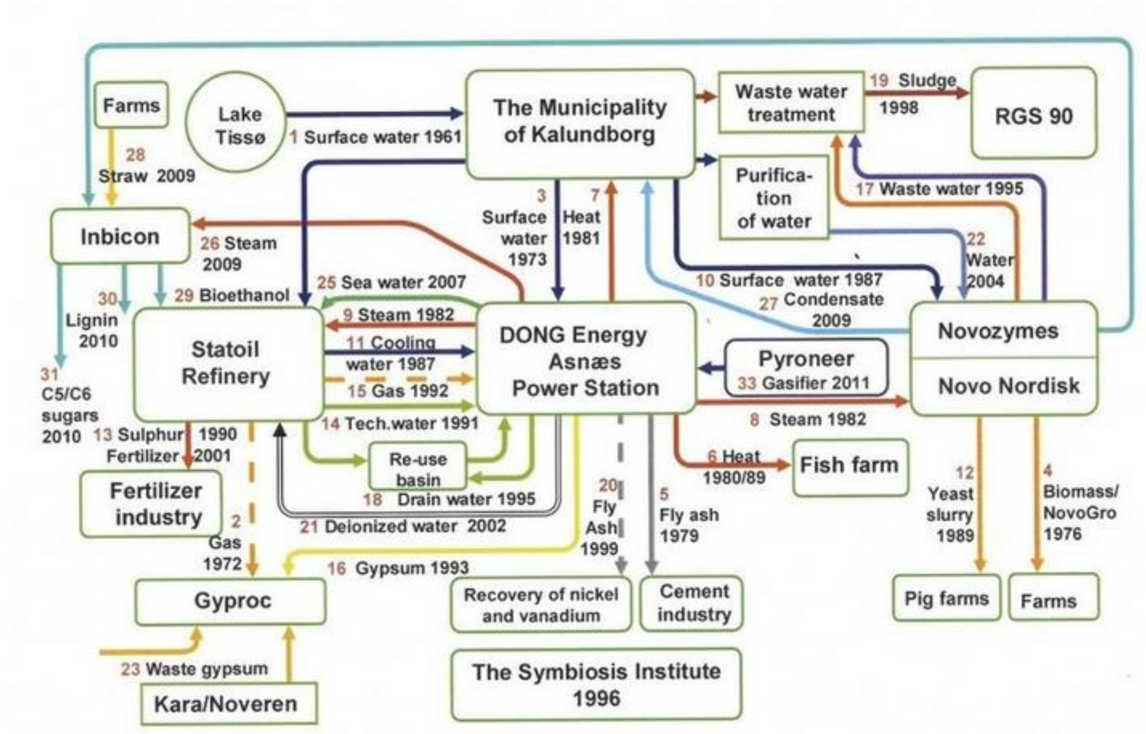

Figure 5. The Kalundborg network (Ellen MacArthur Foundation, 2017)

The network shows further details of the flows in Kaldundborg symbiosis, allowing to pinpoint the concentration of activities around four major actors - DONG Energy Ansaes Power station, Statoil Refinery, Municipality of Kalundborg and Novozymes / Novo Nordisk. This would indicate dependence to these four actors as the most prominent players and most important units, the other actors would be dependent on. The historical development of the symbiosis around the two – Municipality of Kalundborg and Statoil refinery can explain the operations building on top of these actors, as well as the abundant flows and inter-connectedness of rest of the actors.

While this symbiosis and link structure does not fit in to the previously discussed Type III ecology (System with only energy entering it, with no waste coming from the eco-system), described by Ayres & Ayres (2002), it does show circular nature of material and energy flows. In this sense, this would fit in to the category of Type II Ecology (Energy and limited resources enter the system, creating only limited waste) in Ayres & Ayer's description, not to mention that the Type III ecology can be debated to be impossible to achieve in such a setting. The benefits for the actors are however quite evident and the concept shows possibility to generate symbiotic structures growing around central actors, such as municipalities, power plants and large utilizers of water and energy. It also shows the possibility of growing around of linkages of simple flows, such as energy and water, without the need of having waste flows utilized, until later stages of development.

Therefore the added value from such an arrangement is the synergies between actors. The prominence of such cluster itself can centralize industries and actors together, in hopes of mitigating costs, sharing infrastructure and having relevant functions for their core business nearby.

2.3.Added Value and Challenges

In order to understand the potential benefits and applications of industrial ecological systems as well as their implications, the concept of Added Value will be defined. The definition will be done from both general, resource based view standpoint, as well as from more specific point of clusters, both industrial and eco-industrial. The goal of the chapter is to understand, what are the factors that bring additional value to the actor level and to the systems level. The actor level can be viewed as single businesses within a cluster, whereas the system level is the more general macro level of the whole industrial cluster.

Lepak & al. (2007) state that due to the multidisciplinary nature of management field, the view of value and creators of value can be wide. Each field from strategic management, human resource management to marketing can have different perception of value. Therefore value creation and perception can be seen to affect a wide variety of groups from investors, and stakeholders to customers. Lepak & al. (2007) argue that value creation can be seen from universal perspective, or contingency based perspective where the value is seen through the eyes of a single actor.

Furthermore, in order to compare the efficiency and viability of eco-industrial clustering challenges and potential barriers has to be taken in account. This creates a possibility of comparing negatives to positives and outweighing challenges and potential risks from added value and benefits.

2.3.1. Added value

Bowman & Ambrosini (2000) categorizes value in use value and exchange value. The use value is seen as a subjective value by customers. The exchange value is realized in the point of the sale. The use value is defined by Bowman & Ambrosini (2000) as follows: *"Use value refers to the specific qualities of the product perceived by customers in relation to their needs; e.g. the acceleration and styling of the car, the taste and texture of the apple, etc."* Therefore the value is perceived by the consumer in the sense of use value. This means, that use value is highly subjective, therefore a matter of perception by the customer. On the other hand, exchange value can be defined as price and the monetary value of a product. (Bowman & Ambrosini: 2-3, 2000)

While these definitions explain value associated with a product, the general principle can be applied in to the case of industrial clusters. Value can be split in to perception and actual monetary cost of a product or an item. In this sense the value of product can be increased due positive perception by consumer, due to sustainable nature of the production. On the other hand, the value can be seen in lower costs and higher profits.

The added value in an industrial cluster is explained as grouping together various kinds of industry activities to a single geographical area, in order to create benefit. These benefits range from economies of scale through land development, construction and shared facilities. (Geng & al. 2014) Therefore, the added value in this case can be seen as mitigated investment costs and sharing of in place infrastructure.

Existing industrial clusters have the potential to be developed to eco-industrial clusters through key drivers such as regulatory systems, guidance of local government and similarity of industry or geographic and technical requirements (Taddeo & al, 2017). Environmental cases in industrial clusters can be a typical issue, due to the proximity of similar actors, which consume similar resources, produce similar waste and require similar infrastructure. (Yoon & Nadvi 2018: 161), indicating that added value can be obtained through mitigating costs through shared infrastructure, logistics as well as material inputs and waste outputs. These waste outputs can be a previously unrealized source of an input to an actor in a cluster, thus adding value. Other unrealized opportunity for added value of activities, could be also environmentally friendly image of a company, through synergies of operations to minimize waste.

The added value in eco-industrial clusters can be seen as possibilities of strategies, that add in to the value of participants through "Economies of systems integration". (Geng & Zhao: 1293, 2009) This meaning, that the actors can utilize economies of scale within the system itself and contribute together in to more efficient environment to conduct business. Geng & Zhao (2009) further describe the added value, by partners sharing mutual service, transport and infrastructure based costs, leading to multiple benefits. It is furthermore elaborated, that the added value in this sort of system is a result of minimizing pollution, thus further enhancing operational efficiency. In the perspective of a singular actor inside an eco-industrial cluster, Geng & Zhao (2009) describe the added value as follows: *"For business, value is added as waste byproducts, water, and energy are cycled back into the overall production stream of the industrial park or region. This closing of the loop results in the conservation of natural resources and lower disposal and production costs."*

Therefore, two important factors of added value can be recognized:

Environmental: Less use of natural resources, decreased waste and pollution

Economical: Lowered costs in variable factors such as waste management and production as well as mitigated fixed costs in investing to infrastructure

As discussed in the previous section of Eco-industrial park, Kuznetsova & al. (2016) explains the eco-industrial park to create benefits of efficiency and sustainability through systems level by having actors contributing to each other. The view of added value can therefore be seen mutual with eco-industrial parks and explain the existence and founding of such systems. The added value can therefore be the synergetic operations, resulting in less waste, increased production capabilities, and creating commonly beneficial symbiosis (Ehrenfeld & Gertler 1997), (Ehrenfeld, 1994). It is however important to understand, that the symbiotic setting has its limitations, and no self-sufficient system with full circularity would be viable (Ayres & Ayres, 2002), thus not seeking to create a full self-sufficient and circular system, but one that is efficient enough for the stakeholders and actors included.

2.3.2. Barriers and challenges

A study based on an Eco-industrial park in Daven’s Massachusetts, USA identified three largest sustainability challenges being reducing the cost of energy, reducing the cost of materials as well as waste management as main challenges. (Veleva & al. 2015) In the terms of energy and material cost, no significant statement was made from utilizing side flows or waste flows of other companies, but rather the governance of the Eco-Industrial Park offering employment outreach, benchmarking and auditing in order to control costs.

The challenges of waste generation stemmed mainly from lack of tracking of waste generation and recycling of the associated companies, resulting of having no reliable information available in order to coordinate cost savings. (Veleva & al. 2015: 380) This would indicate a strong need of common practices and guidelines in an eco-industrial cluster, in order to co-ordinate activities in order to create synergies.

Furthermore factors such as unwillingness to co-operate with actors competing in same market segment as well as lack of previous inter-firm collaboration in the same industry can be a challenge for eco-industrial clustering. (Mirata, 2004: 979) In addition to unwillingness to co-operate technological limitations, in form of bottlenecks may cause limitations in efficient synergies along with having inefficient management bodies with not enough industrial contacts to attract relevant industries. (Mirata, 2004: 980) This would suggest, that the technology has to be compatible and applicable to the needs of the companies operating in cluster, in order to create value, rather than cause challenges. In addition, the presence of crucial industries for synergies is important. This would be of course a situational and dependent on the nature of the cluster, but a strong central actor would be crucial.

For challenges in Eco-Industrial Park in Tianjing, China Yu & al. (2014) state two main difficulties: large amount of companies, with wide variety of waste as well as lack of legislative and policy-based pressure on companies to reduce waste. The problem of large variety of fragmented companies within the cluster creates a difficulty to connect the companies together, to create chains of supply and waste between each other. The other problem regarding waste manifests in inefficient reclamation of waste, due to lack of standardized instructions of recycling on country level. (Yu & al. 2014: 472) This legislative difficulty is also addressed by Horvath & Harazin (2012). They argue, that EU's environmental policies steer the direction of companies, which are involved in sustainability in their businesses.

The difficulty of finding synergies between companies could be solved through careful planning of the cluster, including only core companies, crucial for the efficiency of the cluster. The legislative issues are harder for single actors to overcome and is country based challenge, however joint efforts for waste utilization and aligning of industries which benefit from other's waste flows would overcome issues with waste management.

2.4.Theoretical framework

The research will follow a flow of three basic guidelines to study – Clustering and inter-connectedness, risks and challenges and added value. All these combined will seek to answer both research questions and provide in the end, a summarization about the possibilities, as well as risk, for businesses to operate in cluster. The following figure illustrates the flow of the research and guideline for empirical study, along with current findings through theory.

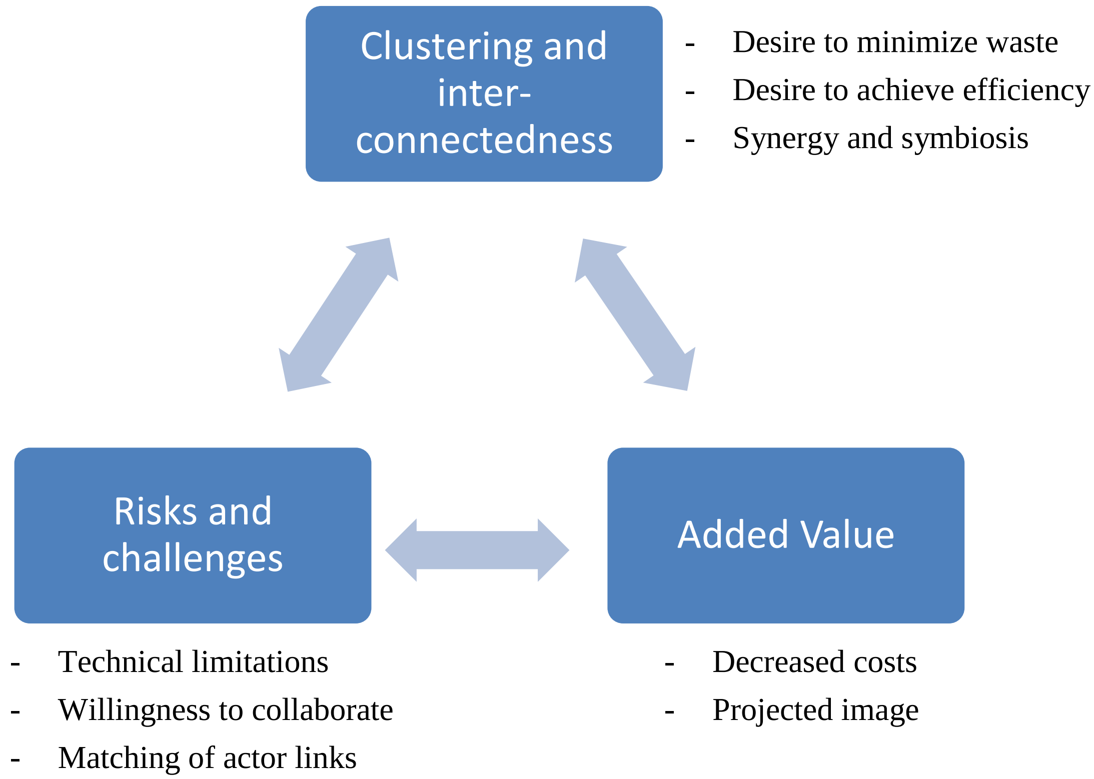

Figure 6. Theoretical framework

By understanding the related "why's" and how's" it can be understood in which conditions the clustering of activities in single geographical area, or around a unit could be beneficial and whether the benefit is actor level or system level, or both, hence being truly a symbiotic relationship. In addition, this allows the research to pinpoint better factors related to single actors and how to gain benefits of synergy in a larger system.

Clustering and interconnectedness

The Interconnectedness of factors in a clustered system can be analyzed both on the system level, as it has been analyzed previously in the paper, as well as on actor level, which will be carried out by interviewing relevant actors in the field. The system level examination provides a general, more strategic overview about the factors involved in eco-industrial symbioses and the explanation why actors should seek synergies amongst each other. The actor level examination provides understanding of the needs, benefits, risks and challenges and added value of single units in the ecosystem in order to answer the research questions. The importance of interconnectedness and good linkages and synergies can be observed in the examination of Kalundborg Eco-Industrial park. Therefore, the clustering and interconnectedness will be the central block to build the empirical research on.

In the theory of industrial ecology and eco industrial parks, central findings have been in the desire of creating synergies and efficiencies, from which stems minimized waste and increased efficiency. This leads in to understanding the risks and challenges associated with such arrangement as well as what are the added values in eco-industrial cluster.

Risks and challenges

The current challenges based on literature review in eco-industrial concept appear to be related in utilizing effectively synergies, attracting right companies to create right links, waste management challenges as well as general challenges regarding efficiency, both in materials and energy. (Veleva & al. 2015) Most of these challenges were explained by inappropriate planning from beginning, either by transitioning from a diverse industrial cluster to an eco-industrial cluster, (Yu & al. 2014) or by not attracting actors, which can utilize each other effectively through insufficient governance. (Mirata, 2004) All in all, these challenges add up as risks, due to unrealized efficiency, cost savings, heavy investments and possible loss of profits

The risks and challenges creates an important segment in the theoretical framework, in order to give understanding of the inner workings of a symbiotic structure. This framework will be used later on in data gathering as a guiding factor for the study. This seeks to answer the question what are risks a single actor can face, how this translates to the larger system, what are the challenges for the actor to exist in a symbiotic cluster as well as understanding the barriers of single actors to enter in such cluster. The goal will be to have an understanding of risks in a symbiotic cluster, in order to answer, whether these risks are outweighing the added value. Furthermore the risks already associated within the inspected field will be assessed, and whether the clustering can mitigate them or not.

Added value

The final piece of the research framework seeks to understand the benefits a business or an organization may realize by clustering together. Whether this out weights the risks and challenges, and to determine the benefits and profits to be made in such arrangement. This can be inspected both in the system and actor level, by categorizing the benefits on the system level: how the cluster benefits from co-existence and on the actor level: how does a single actor benefit from the cluster and co-existence, compared on operating on its own. Emphasis will be on the actor level from a business perspective, based to the assumption that businesses would prefer to maximize profit.

Due to the subjective nature of the value across fields and actors (Lepak & al. 2007) the value must be assessed on case basis across fields. However, basic assumptions of added value can be made based on the theory, such as decreased cost of operations, increased value and shared infrastructure and investments. The subjective terms of added value have to be looked in on case basis on the later stages of the studies in empirical context. For example, whether markets, consumers or producers see sustainably produced goods as an added value itself.

Based on the theoretical framework model, the focus in the empirical study will be on the identification on the central players and the inter-connectedness between them, the added value as well as risks and challenges associated with a clustering in to an eco-industrial entity. The chapter has mapped out these critical aspects, and seeks to apply them later on in the research. The synergies gained from symbiotic relations between businesses and actors have a large potential for value creation, but are as well complex to apply.

Most evident value benefits involved in eco-industrial cluster are the shared costs, increased efficiency and prominence of similar actors. The existence of in place infrastructure can also decrease the need of investments as well as work as an incentive for new businesses and actors to join in to an existing cluster. This can be seen in the example of Kalundborg Eco Industrial Park, which has over time developed around few central factors, of which local community of Kalundborg has been a significant stakeholder. This prominence of public interests on government side could be a significant incentive for actors to cluster around, due to possible incentives and favorable policies pushed by the governing bodies. Risks and challenges in the field of Eco-industrial clusters are often associated in difficulties to create synergies, due to poor planning or lack of actors within the cluster. Certain system level factors, such as cluster governance and legislations or lack of them can also cause challenges in the clusters.

Mapping out the current conditions and the possibilities of existing interconnectedness as well as increasing interconnectedness to form symbiotic relations, is therefore extremely important. The study will try to find these interconnecting factors and see potential to utilize them in a mutually beneficial way. In addition, challenges and risks will be identified and weighted, will these barriers and risks out weight the added value, that a eco-industrial cluster could provide. Understanding the added values and mapping them out from actors is therefore crucial. From theory, these added values can be generalized as cut costs and positive image. The study will observe how these added values apply to the studied actors, and if there are other added values from inter-connectedness.

3. METHODOLOGY

This section will describe the selected method of research, as well as give information how the method aligns with the research framework (figure 6) and the research questions. Along with is explained the methodologies and the stages of empirical research. The usage of research methodology is explained and backed up in the chapter.

3.1.Research Method

The research method used is case study, due to the research questions seeking to answer a contemporary event's effect on organizations or companies, by asking how and why-questions. (Yin, 2009: 9) By analyzing important actors and organizations in the field, gives understanding of the current, already existing clustering and inter-connectedness of the actors as well as potential future synergies gained from moving in to an eco-industrial cluster. In addition, risks and challenges are also analyzed from the same perspectives among with added value. The method is sought to give insight about the current and future value driving factors, as well as crucial components and key factors to success.

Research consists of six stages of planning, designing, preparing, collecting, analyzing and sharing. (Yin 2009: 24) The research is planned first with relevant theory gathered from the literature review and existing case studies and works. Designing of the research is based on preliminary meetings with relevant stakeholders and experts in the field of regional development and relevant industries to the research. After initial information had been gathered and the crucial components for study had been found a general interview form had been laid out. This interview form would have similar structure of three key elements: sustainability, challenges and key success factors. These topics would have a group of questions tailored for each interviewee, depending on the field the interviewee operates in.

The strategy is divided in three broader stages based on data collection methods, in order to guide the research. These stages will be elaborated further in the chapter.

3.2.Case context

In order to understand symbiotic relations and clustering of activities for benefit, the subject will be approached from the direction of agriculture in form of Aquaponics. Aquaponics is described as *“a system of growing plants in the water that has been used to cultivate aquatic organisms”* (Merriam Webster, 2018) Due to this, the viewpoint is already symbiotic in nature. To simplify this concept, the research limits itself to observing in general terms greenhouse growing and fish growing along with their benefits and decrees of symbiosis between each other. Goddek & al. describe the aquaponics as follows: *“Aquaponics is an integrated multi-trophic system that combines elements of recirculating aquaculture and hydroponics, wherein the water from the fish tanks that is enriched in nutrients is used for plant growth. It is a soil-free down-sized natural process that can be found in lakes, ponds and rivers.”* (Goddek & al. 2015). Simply put the aquaponics system utilizes nutrient recycling and efficient use of water between growing of plants and aquatic organisms (for example fish).

Aquaponics development and implementation in farming can have various benefits. The close loop system of aquaponics could lead to solving problems with climate change, soil degradation, water shortage and generally securing food production (Goddek & al. 2015). The benefits therefore can be seen as very topical issue with much of the attention being placed on sustainable production of food without causing extensive environmental problems. Furthermore, utilizing symbiotic relations with acrtors related to the process can also bring cost savings in form of utilizing by products as resources that would otherwise go to waste.

As already established, the aquaponics type of solution could be an ecologically and environmentally sustainable solution for growing plants and fish, the economically sustainable aspect is important in order to make it profitable and sustainable for businesses. Indeed Goddek & al. recognizes the challenge of profitability and places importance on the study of commercial implementation of aquaponics systems.

The commercial viability and profitability is studied by Adler & al (2000) with the conclusions, that the recycle of aquaculture and plant growing can be economically feasible. However, implementation of such system requires larger amounts of capital as in conventional way of growing plants. However, it is notable that Adler & al. state, that there are benefits that are non-monetary benefitting the society. These benefits come in form of environmentally sustainability, through saving of water and in general having more efficient and waste free system as the conventional one.

The combination of food production with energy production can be justified by the symbiotic nature of the input and output flows they provide. Waste generated by greenhouse growing can be utilized in biogas production, incinerated waste-to-energy as well as utilization of in place infrastructures such as vicinity of heating pipelines. Waste flows from energy production, such as excess heat and CO2 emission can be utilized in food growing.

Due to the ever increasing and accelerating need of energy and the ever-accelerating exhaustion of natural resources the case of studying a concept of eco-industrial concept in a local setting gives an interesting framework. Although being only a concept it is valuable due to the potential practical applications of sustainable and efficient production methods and systems. Furthermore, the legislative pressures and interests by local and EU-level authorities pushes businesses to adapt more environmentally friendly, sustainable and efficient solutions in production (Horvath & Harazin, 2012).

The merits of such development can be seen as sustainability and ensured continuity and decreased dependency on raw materials, as well as value adding activity. This is especially true in the region where the study is implemented in, with already large proportion of greenhouses, compared to the rest of the country. This coupled with interests of local development, energy providing and waste management companies to develop their activities in more efficient and sustainable direction. In addition to companies' presence and interest of development, the sustainable development of production can be seen as a public and governmental agenda. This makes the study of aquaponics solution for food production as well as energy utilization from waste very important and interesting, due to the feasibility of symbiotic relation between them, along with relative geographical proximity of the actors.

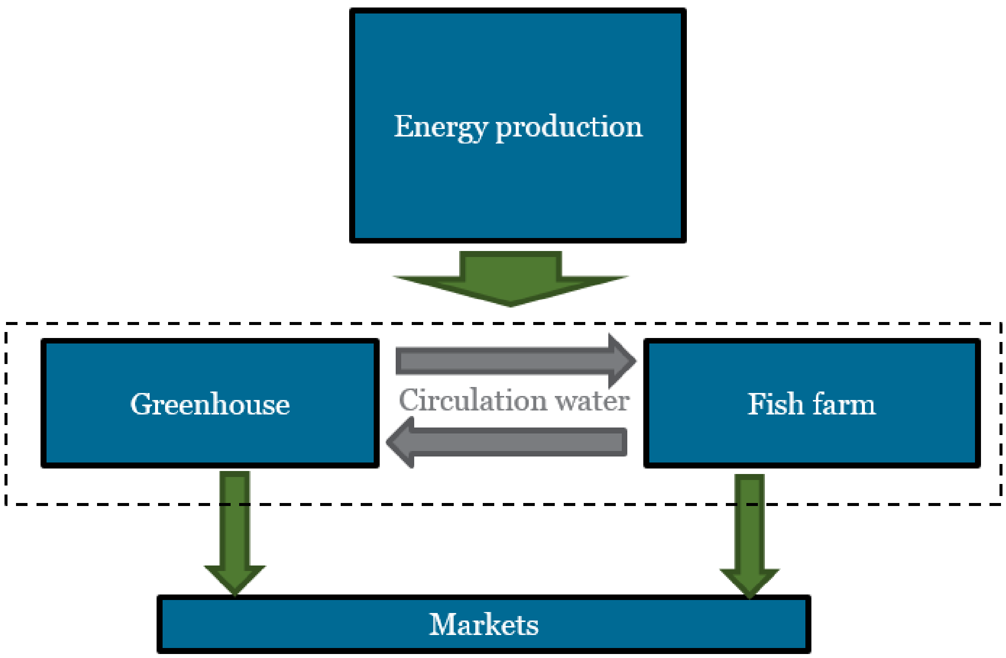

Figure 7. Mapping of actors for interviews

The figure illustrates the actors which the empirical research is focused, and from which the selection of interviewees is based on. The central point will be the aquaponics operations –

greenhouse and fish farm symbiotic operations. Due to the symbiotic nature of the aquaponics activities, this will serve as the central point of the eco-industrial cluster.

The actors related to aquaponics will be inspected how they add value to the core operations and how the actors related to aquaponics can gain value. Experts in sustainable development, as well as the field of greenhouse experts will be source of preliminary data, in order to understand whether the symbiotic activities can add value, what are the risks and challenges currently as well as being situated in an eco-industrial cluster.

In order to understand this further, interviews have to be conducted on greenhouse farmers, as well as fish farmers within the context of aquaponics. In addition, energy providers will be looked as another crucial component for the operations, due to the need of heat and electricity, both in greenhouse and fish farming operations. The data concerning markets and the general situation in the field of greenhouse and fish farming will be gathered through both experts and consultants. Therefore, two main groups can be selected for interview: Experts, consultants and producers in the field of greenhouse operations and fish farming, as well as managers or directors in local energy providing companies, with possible symbiotic integration possibilities with food production.

From these actors, the study seeks to understand the possibilities to operate in an eco-industrial cluster environment, understand their current risks and challenges, how those risks and challenges transfer or are mitigated in eco-industrial cluster and last; how can the eco-industrial cluster add value for the actors.

Since food producing in a greenhouse, fish farming or aquaponic setting has demand and supply in material, as well as waste flows which are related to waste management and energy production, makes the inspection of the topic relevant from their point of view. Waste management can utilize both standard and bio-waste coming from food production facilities, utilize it to biogas, heat or electricity. This gives a possibility for the waste to energy utilizers to gain direct benefit from waste being supplied to them from a same system, as well as providing heat and electricity to an actor within the system. Products not needed within the system can be sold to outside market. However, the symbiotic relation with matching material and waste flows to create mutually beneficial system is the desired outcome.

3.3. Data collection

The process of data collection is divided in three stages. The stages are built on previous stages and overlap partly. The development and content of each stage is therefore related to the data and information collected from previous stages. The stages can be divided in to different methods of data collection. Stage one relying on discussions and meetings of experts and consultants. Stage two gathers data through selection of interviewees and stage three is information gathering through a strategy workshop, involving presentation of current data and findings to stakeholders and actors within waste management and energy providing company. The information from stage 3 is used to rehearse findings and validate them from the perspective of energy and waste management providers.

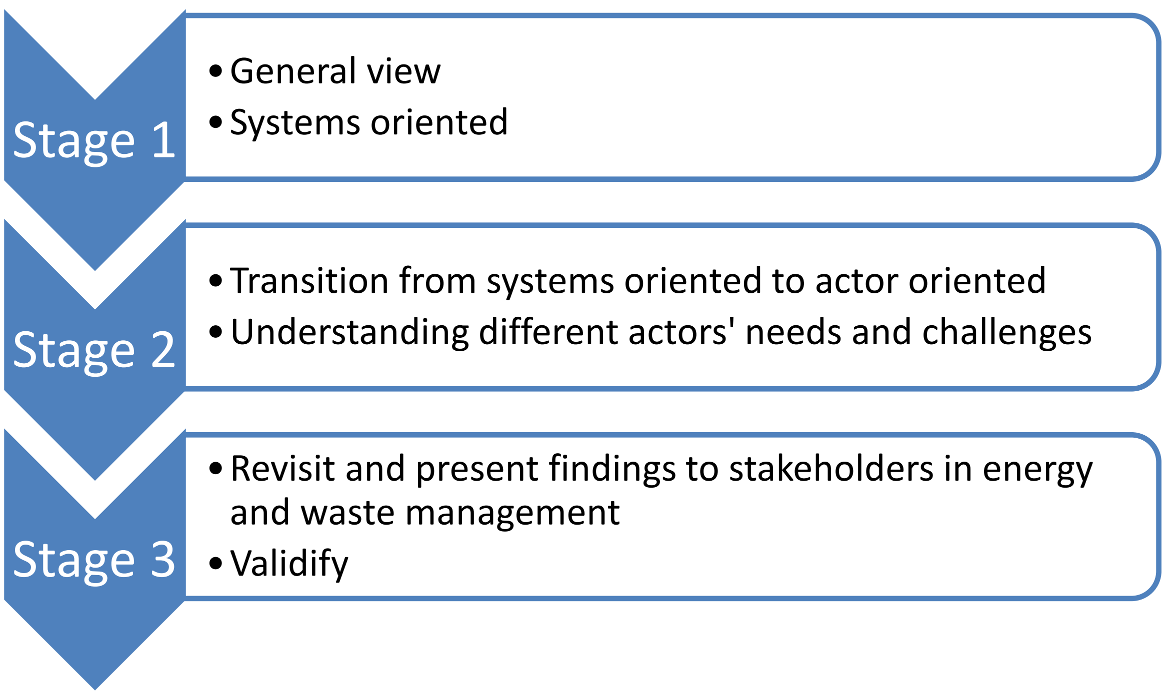

Figure 8. Stages of research

Stage 1

First stage is to arrange a meeting and discussion with experts in the field of regional development, sustainability and greenhouse farming. The concept and research is presented to experts of the field, in order to familiarize them to the topic. This leads to finding actors that fit in to the concept of eco-industrial cluster. Further general information about the field is gathered from relevant actors and current directions of development through discussion with experts. Interview groups and categories are based on this stage's information and contacts gathered. General interview questionnaire is constructed based on the information and understanding gained from meetings.

Stage 2

The sample of interviewees is collected together with relevant and available interviewees. During this phase, stage 1's contacts are utilized and more contacts are being gathered based on demand of gathered information from ongoing interviews and the availability of interviewees. Phone and skype interviews commence and questionnaires are slightly tailored per interviewee. Interview questions remain open ended, in order to specify to fill in gaps in the research.

Stage 3

Gathered information and understanding is reviewed and compressed in to a brief presentation. The findings are published and presented in a strategy workshop as a part of a larger project. The workshop involves stakeholders, associates and directors from the waste management companies. Managers and directors are interviewed, along with other stakeholders in the general field of waste management. Informal discussion related to circular economics and waste management during the workshop serves as further input to confirm and reinforce assumptions and findings from waste management perspective, as well as to understand future trends of the industry.

These stages are generally linear, apart from slight overlap of stage 1 and 2. This is due to the reason of having an interview as precursor to a meeting (Interview 1 & meeting 3). It is acknowledgeable, that reverse order (meeting first, followed by an interview) would have produced more specific and focused questions, leading to more pinpointed information. However pragmatism in arranging both simultaneously, worked in the favor of having said order. The meeting however gave a possibility to have informal conversation around the topics, reinforcing claims in the recorded interview. In addition, the interview being on the field of fish farming through circular means, meant that the findings gave way for understanding in both fish farming as well as support activities from waste management, greenhouse operations as well as energy production. In a sense, the interview gave understanding of an eco-cluster that is in-housed and maintained by one actor.

After data had been gathered, the analysis of data would be made comparing the found data between other actors, finding linkages and possibilities of synergies through comparing benefits and key success factors to challenges and risks, along with feasibility of clustering together. The final stage would consist of sharing the information to stakeholders from one field, validating the information from their point of view.

	Form	Organization / Actor	Position
Stage 1	Meeting 1	Local region development company	Project Manager
	Meeting 2	Regional growers association	Project Manager
	Meeting 3	Greenhouse consultants	Consultants & professionals in the area of greenhouse agriculture
Stage 2	Interview 1	Biotus OY	Greenhouse consultants - 8 varying professionals related in the field of greenhouse agriculture
		Närpes Grönsaker	
		ProAgria ÖFL	
		Kekkilä	
		Österbottens NTM	
		Österbottens Svenska producentförbund	
		Berner OY	
		YA i Österbotten	
	Interview 2	Circularity based aquaponics cluster	Product and Development Director
	Interview 3	Regional growers association	Consultant
	Interview 4	Regional waste management company	Managing director
	Interview 5	Regional waste management, incineration and energy providing company	Managing director
Stage 3	Workshop 1	Waste management & energy companies	Board members & associates

Table 1 Stages of research and actor details.

The table gathers together the sources of data gathered during the research. The table can be roughly divided in two sections; actor level and system level research. Due to the nature of interview 2 being a circular based aquaponics facility, it gave valuable information from both the perspective of fish farming, as well as implementing a circular solution. However, this circular solution being in-house limits the study more to an actor level, with possible implementations in system level. The meetings and first interview give idea about the general field with implications to single actors, but focus more on how the markets are in the industry and what are the challenges and risks in current environment. The data gathered from the macro perspective gave way to narrow down to more specific studying and interviewing. Furthermore, two groups of actors can be recognized based on the interview selection: **Experts in the field of greenhouse and fish farming –** including consultants, directors and experts in the field. The other group can be distinguished as **directors and stakeholders in energy production and waste management**. These two groups of people are significant, as they are the actors, which have the possibility to participate in a symbiotic cluster operation.

Interviews are carried out in Finnish and vary from personal interview of a stakeholder or an expert in a relevant organization as well as focus group interview. Four of the interviews are carried out on the personal basis and one as group interview. It is noteworthy, that one of the actors is in food production with in-house waste management capabilities utilizing side flows, thus representing a systems level view of already existing undertaking in the field.

The following section will give rationalization for the selected interviewees and groups, in relevance to the study. Brief summary and description of the actor, their relevance to the case as well as goal for each interview will be defined. In general, each interview seeks to understand the general current aspects of each actor's field currently, as well as how they perceive possible clustering of actions.

3.3.1. Interview 1 – Greenhouse consultants

The interview was conducted in a focus group-type of a setting, in a group format. The group consisted of wide variety of experts, consultants and practicing professionals in the field of greenhouse farming and farming related companies, including purchasers, distributors and chemical companies. The positions of the interviewees ranged from regional representatives and area sales managers of chemical, fertilizer and pesticide companies, experts and consultants in the field of greenhouse farming, local vegetable producer companies representatives, greenhouse farming instructor from the regional vocational school as well as various farmers and representatives of local greenhouse farmer's organizations.

Primary goal of the interview was, to understand the current situation of greenhouse farmers, the field the industry they operate in and the local region's operations in greenhouse farming. In addition to this, secondary goal of the interview, was to understand the trends and possible future direction of greenhouse farming. The interview followed set of four general guidelines, constructed around following categories to align the interview questions to fit in with the research questions:

1. Sustainability and profitability
2. Challenges
3. Factors for success
4. Factors that steer activities and development

3.3.2. Interview 2 – Circularity based aquaponics company

Interviewee is a product & development director in a closed loop cycle based aquaponics based company, located in South-West Finland. The company produces fish and greenhouse products with circular water system, linked with power plant, bio-gas plant and a greenhouse. In addition, the company utilizes the additional waste flows of the main actions to their other functions within the cluster. Stated values of the company are ecological sustainability of the closed loop system. The company utilizes assets, which reflect to the actor's function in figure 7, thus providing valuable information about interconnectedness of actors and their possible added value, challenges and risk.

The interview consists of the same four leading question themes: 1. Sustainability and profitability, 2. Challenges, 3. Factors for success and 4. Possible future trends. The interview has a goal of understanding clustered eco-industrial solutions and close loop systems in the context of fish and agricultural products. Furthermore, the importance of different actors and their interrelatedness is inquired, as well as paying attention to profitability and sustainability.

3.3.3. Interview 3 – Greenhouse consultant

The interviewee is a consultant for greenhouse farmers in the Pohjanmaa area, and is an associate of a Finnish bio-economy research organization. Prior to the meeting with the interviewee, a discussion have been had in the stage 1, mapping out the field of greenhouse farmers. The interviewee contributes to success of the regional greenhouse farmers through consulting and associating with them.

The goals of the interview are to understand the previously mentioned four main points, aligned to the research, as in interview 1 & 2. Main goals are to understand the greenhouse farmer’s perspective as well as the more complex aspects of greenhouse farming, markets and sustainability. Aspects which interview 1 looked on general level from wider stakeholder group, as opposed to this interview going deeper in to understanding of challenges and the field where a greenhouse farmer operates in.

3.3.4. Interview 4 – Managing director of waste management company

The interviewee is a managing director of a Finnish based waste management company. The company operates in six different municipalities within it’s region, of which hold shared ownership of the company. The company operates in waste management and recycling. Main activities are conversion of generally household based wastes to utilizable solutions. Examples are bio-waste to bio-fuel and composed soil along with recycling activities. The significance of the interview for the research, is the capabilities of the company to convert bio-degradable wastes to usable products, making it a possible stakeholder to utilize waste in aquaponics activities, and to create mutual added value.

Due to the nature of the company operating in waste management and recycling, the input from a waste management and utilization company gives a significant perspective to study value adding factors through utilizing waste flows. The company states sense of responsibility, profitable renewal and co-operation as its core values, giving an optimal case to study. Emphasis is based on the waste management company’s view, understanding key needs, resources, success factors, added value factors as well as difficulties.

3.3.5. Interview 5 – Managing director of waste to energy company

The interviewee is a managing director of a Finnish waste incineration and utilization company. The company states, that it has a non-profit policy, and seeks to maintain its operation on self-sustaining principle. Five waste utilization related organizations own the company, of which one is the company related to interview 4. The company’s operations span multiple administrative regions and a few cities in Finland.

The interview seeks to understand the core aspects of the research questions: sustainability, value adding factors and challenges in the perspective of a waste incineration and utilization. What makes the interviewed company noteworthy, is that the company is operating on self-sustaining cost structure, without a goal to make profit, but to secure equal price waste treatment options throughout the region for its customers.

3.4.Data analysis

The analysis of interviews is carried out in the fourth chapter. The data is compared between comparable actors, for example food producers between food producers etc. Analysis will try to find recurring factors in the interviews. The starting point of the analysis is; how can the actors cluster together their activities. Correlations between possible synergies cross – industry will be focus of analysis. Analysis aims to align itself with the three points of theoretical framework, thus answering the actor’s relation to Clustering and interconnectedness, risks and challenges as well as value adding factors. Challenges and difficulties in technical and environmental context will be paid attention to on system’s level as well as on actor level. Summarizations of the interviews and the key factors will be listed in the final chapter, in order to either address them, or to find synergies between actors for added value in eco-industrial clusters. The goal in the end is a crystalized framework to address the research questions, having value added factors for each actor and the challenges involved within each field, within and without clustering.

3.5.Validity and reliability

The study of greenhouse farming is focused on one singular area and region in Finland. While this is an area that has high centralization of greenhouse farming, the data gathered from it may give a regional view, rather than a national level view of the matter. Therefore understanding the underlying factors of centralization will have to be taken in account, to understand the conditions. Due to this restriction, the volume of interviewees is limited to a small amount, potentially affecting the reliability if to generalized the results to whole industry.

Due to the nature of waste management companies being generally sole actors in given markets through being contracted by tendering processes, the study of waste utilization is limited to two companies that operate in the area. The data gathered from these companies is therefore from multiple channels, in order to give an objective view. These channels include direct interviews, and workshop data gathering. The interviews have the same basic structure, which is modified to each field (Greenhouse farming, fish farming and waste management) to provide interviewees uniform interview process with minimal deviation and confirmation bias, to avoid compromising the reliability of the findings. In order to maximize reliability of data, different interview methods were used to gather data, ranging from group interview to single interviews. Results in these were compared to each other, and no significant deviation was found within the groups compared (food producers & energy business).

In terms of fish farming and studies of complex circular systems the actors in Finland are limited as well. Therefore, the data gathering of fish farming is conducted on a circular system project, which gives both data about already existing circular system, as well as fish farming.

Due to mixed research strategy, using interviews, group interviews and workshop type data gathering methods, it was taken in account, that the data gathered was done in different ways. The data gathered and analyzed corresponded with each other and yielded uniform results and interpenetrations regardless of data gathering method. The validity of the study was later enforced by a workshop to present the findings to stakeholders of waste management companies, which were part of previous interview process. This lead in to validating the previous data, gathering of new data and also recapping as well as giving an overview of the process and validity of data.

4. EMPIRICAL FINDINGS

The chapter consists of analysis and mapping of a conceptualized cluster, which is based on the first stage of data gathering, and on which the following interview's context is based on. Actors identified in this concept are analyzed by their current conditions, challenges and benefits related to the concept. Each actor is systematically analyzed for these three aspects as well as the system in whole, to understand the system level and interconnectedness of actors.

4.1.Mapping and conceptualizing the cluster – analysis on inter-connectedness

The following section will be focused to inspecting the actors in and their roles in an ecosystem and to inspect how they can benefit the most from the co-existence of each other. Eco-industrial clusters could be an answer to push forward co-operation between different actors, both public and private to create more efficiency and cost savings. (Horvath & Harazin, 2015: 214) Efficiency and cost saving in itself can be therefore seen as a value enhancing factor, as well as involvement of the public sector to acquire funding or to gain favorable policies.

The aim of the systems level analysis is to answer the questions how the cluster should be structure and how extensive does the system have to be, in order to yield benefits. The theory inspected in earlier sections will be applied in to a local conceptualized cluster in Finland Pohjanmaa region, with local companies and organizations as stakeholders and participants, in order to map out and conceptualize a possible cluster operation in a symbiotic setting. In this concept, the central production will be fish and greenhouse agriculture, utilizing each other's material streams, in conjunction with a local waste management and power supplier.

The following figure represents the central actors of the conceptualized cluster with flows of material, water and energy between central actors. The visualization helps to realize the first research question's crucial components and needs in an eco-industrial, as well as guiding towards realizing the success factors, by inspecting the streams between actors, and their significance or the lack of it. After realizing the actors, their streams, and the relevance of streams, can the added value to actors be inspected further, to accommodate to the second research question. The central element of the study is the linkage of food production and energy production's synergies.

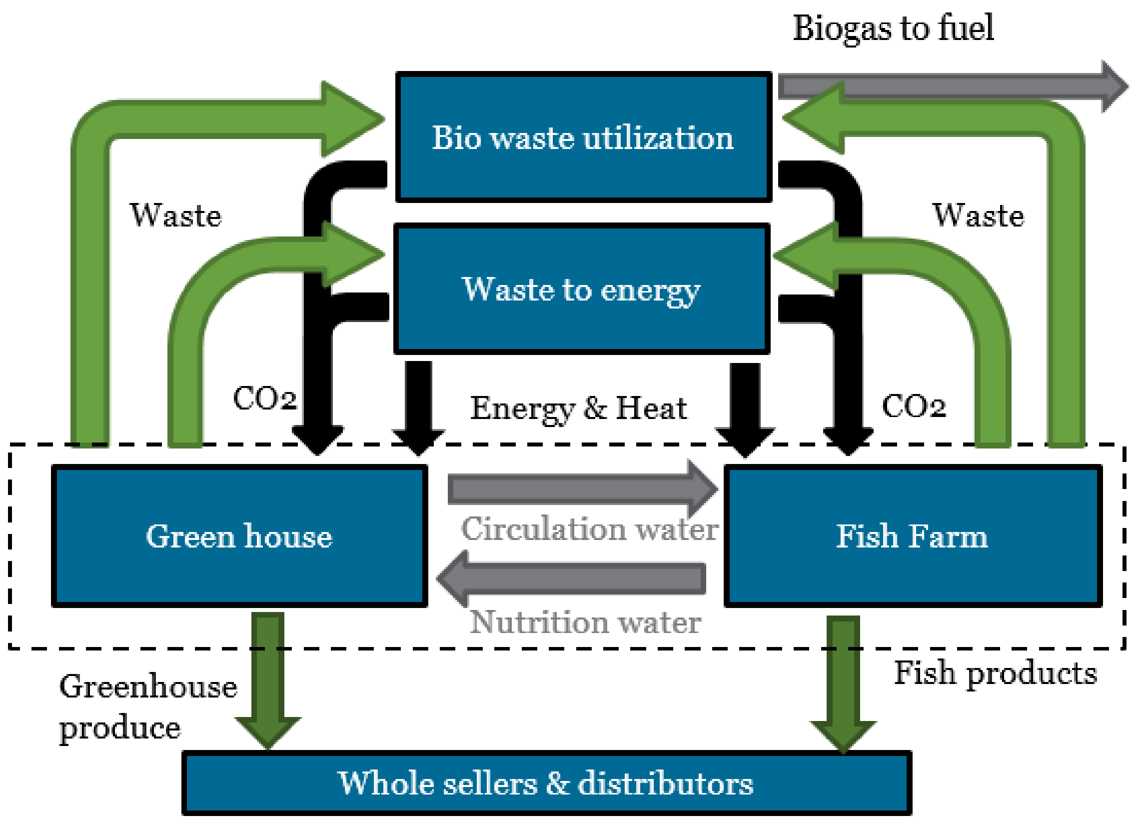

Figure 9. Industrial symbiosis cluster conceptualization

The figure represents the conceptualized eco-industrial cluster-The interconnectedness is represented in material flows, such as waste, water, carbon dioxide, food products as well as energy and heat. The figure 9 is based on the findings from stage one, from mapping out crucial elements and actors. Therefore, the figure works as a basis for interviews as well, familiarizing the interviewee with the concept, in order to gather data from actor level perspective. In this illustration, the energy provider works also as a waste manager, due to the capability of the actors to either incinerate waste, or to compose bio-degradable waste. This fits well in to the eco-industrial narrative of minimizing waste, as both of the energy / waste management companies already are utilizing waste as a resource.

The central piece of the figure is the aquaponics operations Greenhouse and Fish farm with shared infrastructure. The potential side flows of the aquaponics operations are bio-degradable waste or gutting scraps from fish. The main flows of the aquaponics on the other hand are the crops of fish products. The possibility of the energy companies of using these side flows are illustrated as arrows. The possible by-products of incineration and composting are indicated with arrows, which the aquaponics facilities may be able to utilize. It is notable also, that the waste to energy companies may utilize the side flows of aquaponics operations for biogas, which can be sold out of the loop, creating additional markets. In addition, the added value can be indeed tapping in to unrealized markets, but as well projecting an image towards wholesalers and distributors, as a product that is created through sustainable methods, creating a value perception, possibly through marketing.

Summary of actors in figure 9 and their flows:

Greenhouse

The greenhouse produces vegetables and crops as main products. By products of main process is waste in form of bio and conventional waste. This waste goes either to bio processing to decompose or to incinerator for energy. Has in addition to utilize the emission CO2 gasses produced by the powerplant. The greenhouse is linked in to a fish farming facility, benefiting from shared, close circulated water. This water can contain nutrition from fish farming facility, giving possible benefits in farming and cutting costs of acquiring fresh water.

Fish farm

Produces fish as a main product. By-products are similar to the greenhouse; bio and conventional waste, used by same facilities as the greenhouse. Utilizes the energy; heat and electricity to power and warm the facility the same way as greenhouse does. Due to linkage to shared water source, the water used to cultivate fishes in, can be used in greenhouses, creating cost saving opportunities and sharing of costs.

Waste to heat power plant

The facility provides electricity and heat from burnt waste to the fish farm and greenhouse. Waste produced in vicinity of the plant can be utilized with less needs of infrastructural investment as well as logistic costs. Having a facility nearby in a symbiotic relationship would provide a steady partner and a customer.

Bio waste utilization plant

Handles organic waste by decomposing and utilizing it for example as biogas or soil. The byproducts of decomposing (CO2 gasses or soil) can be utilized by the greenhouse and fish farm. Biogas can be sold to outside markets.

Whole sellers and distributors

Distributors can benefit from the centralization of their suppliers in to one specific cluster, by having decreased logistic costs, as transportation efficiency rises. Furthermore more significantly the distributor can use the sustainably and efficiently grown crops and fish as a large leverage in marketing to utilize the megatrend of environmentally friendly produced food and green values. While this is not an actor itself to be studied in the form of circular cluster, but an entity for final products .

4.2. Actor level analysis

The following section inspects the interviews and data gathered from interviewees of the research, in order to summarize and find the most crucial elements regarding the research questions. The analysis takes an actor level view on majority of the cases. Summarization of the crucial actor level points are made after each analysis: Added value through clustering, risks and challenges, both currently and in eco-industrial cluster. The theoretical framework (figure 6) is used as a basis for the analysis.

4.2.1. Greenhouse growers

There is a large centralization of greenhouse growing operations in the area of the interviewees. The input is significant on a national level due to favorable conditions including optimal sunlight levels, good distribution channels and centralization of many growers to one area. This has created good conditions for the business in this area. However, the current market conditions for vegetables are very saturated and the competition is harsh. Successful greenhouse growers have to either specialize in their crops / vegetables or to ramp up their operations to create economies of scale. This building up of operations is tying a lot of money of the farmers, increasing their level of risk.

In addition EU-farming policies are playing a large role in the sustainability of the business. This creates additional layers of bureaucracy and demands for the farmers, limiting the methods they can utilize to farm. This is a notable finding and a potential threat to the industry and clustering of activities in to less conventional way.

The main risks and challenges in the terms of greenhouse and fish farming in an eco-cluster setting were the already made geographical commitment, based on discussions and interviews with greenhouse consultants. The commitment and already in place investments would mean in practice, that the farmer would be more hesitant to leave and build again operations in order to support circular activities, as illustrated in figure 9. In addition, skepticism was voiced in the discussions about the reality of such operations. These are all challenges that deal with already in place infrastructure, operations, and sink costs in general. It was noted, that for new farmers and new operations to be built, the symbiotic based structure could be potential. Other challenges that were voiced, was the hesitancy of working with competitors. It was mentioned by a participant in the discussion involving greenhouse farmers: *"I am sure that there are those people who would pay hundred (Euros) to make a neighbor lose a fifty"* This sort of mentality would be a large barrier, due to the nature of shared infrastructure and services.

Notable challenges and especially risks, were the added burden of investment on already investment heavy environment. This was commonplace challenge and risk across all interviewees. The uncertain profits and entry to possible new markets due to clustering is an uncertainty seen as a risk. For energy and waste management companies, the risk of utilizing waste and the volume of waste to be profitable was a factor of uncertainty, suggesting that economies of scale and existing markets have to be in place to benefit. For farmers, risks were more in the already existing investments and large debt in existing operations. However, a risk mitigating effect was also voiced, due to shared power provider, without having to invest in to an in house power plant, which as it is, could be a burden to upkeep and has a risk of creating downtime or loss of production due to failure.

Added value from the perspective of greenhouse farmers was largely cost based. Secondary findings were mitigation of risks, easy access to energy, water, employees and markets. Added value from sustainable product image recurred as well. The risk mitigation was obvious through shared utilities, such as heating system acquired through means of joint investment and co-operation. Other significant value adding factors were stated to be scaling up of production to create more in bulk and to utilize economies of scale

Based on the interviewees there is a lot of variance in terms of sustainability and profitability of greenhouse farming throughout Finland. This variance is caused according to the interviewees mainly by volume and variance. Producers can therefore utilize economies of scale by producing large volumes of produce and cut down in cost through standardization and efficiency. On the other hand, differentiating in the crop affects the profitability as well. This does not close out the fact, that smaller greenhouses could be profitable, this would however mean, that the produced crop would be differentiated and that the intensity, control and commitment from the farmer would be greater. The interviewees stated the largest costs in the greenhouse farming activity as electricity, heating, salary and in seasonal farming, the planted crops.

It is important to note, that the largest costs perceived by the interviewees, are variable costs, as well as two of these costs; electricity and heating, being the sort of costs, that are possible to share between actors. This reinforces the idea of synergies through clustering, by sharing infrastructure and investments.

As challenges was stated the costs in general – both heavy investments as well as high running costs. In addition, the challenges based on geographical location were voiced, limiting operations and requiring larger amounts investments and running costs, especially in heating and lighting. The preference of greenhouse farming over a conventional open-ground farming was also stated due to differentiation and higher yields of crops in greenhouse compared to open ground farming. As an example certain species would not yield profitable amounts of harvest, or would be at risk of not producing at all. In addition to this, logistical costs and side flow (bio-waste and water waste) were stated as challenges. Fluctuating energy costs and market for vegetables was stated as a threat, along with bargaining power of distributers[1].

The focus group indicated positive view on recycling, as well as on circular model. This was based on a fact, that greenhouse farming has a large energy use, which was seen by the focus group as something they would desire to utilize, along with bio-residue. In addition,

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[1] Finnish retail market is dominated by two dominant groups S-Group and Kesko, holding a market share of 45,9% and 35,8% of the total retail market in 2017. (Päivittäistavarakauppa RY, 2018)

the desire to project a more environmentally friendly image towards consumers and public in general was voiced. The interviewees stated that the consumer is more environmentally aware, and acknowledges the need to project an environmentally friendly image to them. They state, that image is a very important factor, and that marketing is utilized as a tool to promote environmentally friendly values. However skepticism was voiced about the effect of clustering together activities, seeing and utilizing the side and waste flows difficult as well as mitigating costs being unrealistic in current environment.

For the visions for future, the interviewees stated the increase of size in greenhouse and agricultural operations, as well as decrease in number of entrepreneurs / farmers, as a result. This is a consequence of cost savings and utilizing economies of scale. For another upcoming issue, the ethical questions in food producing were stated. The importance of producing food near rather than far, and the environmentally conscious consumer were stated as important factors for the future.

It was added as well, that the foreign competitors were currently more competitive, than domestic growers. Certain species of plants are not imported, giving the local producers better market position, compared to their cross-border rivals. However, the cost structures of the foreign competitors were stated to be better, compared to the Finnish producers. Efficiency by square meter was claimed to be better, as well as tax benefits, better subsidy structure and investment subsidies in other European Countries, such as Spain and Netherlands was used as an example. All in all, the subsidies were stated to be better in overall in other parts of European Union for the industry. The entry of foreign substitutes in the domestic market, can therefore be seen as a future threat for the greenhouse agriculture industry in Finland.

The success factors were stated to be dependent on which way the farmer wants to operate, choosing from small operations, retaining flexibility, or to mitigate costs and do large scale operations. This comes down therefore to utilization economies of scale through large yield mass production, or to differentiate with flexibility on production and quick response to markets. Factors that were not dependent on strategy, and which were applicable in general, was low risk aversion and ability to continue investments.

Most concerns were related on costs and risk related to equipment and infrastructure. For example, the risk associated with having a single boiler for each farm to provide heating, would mean that the farmer would be dependent on one piece of machinery, of which failure or increased cost would halt or destroy production. However, the interviewees stated doubts on the clustering concept on the basis of having more risks in more complicated systems, and by adding more unknown factors as well as making more additional investments. The interviewees however acknowledged the benefit of sharing infrastructure in order to cut costs and further profits. Furthermore, the interviewees stated, that there are many benefits of centralizing operations in to one area, due to shared logistics, infrastructure and costs in general. It is also notable to acknowledge, that according to the interviewees, it is possible and beneficial in the industry, to work together with possible competitors.

This would indicate, that the main concerns are not in competition, and that co-opetition, is indeed seen as beneficial. However, the risk aversion in the industry, companied with high investments and entry barriers, make the further investments in infrastructure and clustering together, seem as an added risk, rather than a benefit. It is however acknowledged by the focus group, that the industry would benefit from new farmers / entrepreneurs, who would be more risk tolerant and aggressive in investing and expanding.

It was stated, that the business of greenhouse farming is not very profitable in general currently. This applies generally to the whole country, having the interviewee's area doing slightly better, due to benefits caused by centralization of farmers, natural conditions and easy accessibility to markets due to prominent purchasers. The larger actors and companies are doing well, which the interviewee states to be due to benefits gained through economies of scale. The interviewees state it is clear, that there is a clustering of large companies in the area and that the small companies are constantly going under. For other reasons of profitability, it was stated that there seems to be a correlation between companies using artificial lighting for growing crops and yield. This enforces the findings that farmers that dare to make investments in to new technologies and technologies have an edge over others. However, the interviewee states, that small growers can still be profitable, if the flexibility of small operations is utilized and finding a niche market position. In general, the area favors large companies due to easy access to markets with bulk production, due to the prominence of large packaging companies. The interviewees stated that largest costs are energy (electricity & heating) and workforce – which seem to be agreed upon in other interviews and findings.

It was agreed, that clustering together is a way to mitigate costs, and gives an example of mitigating costs through farmers banding together to negotiate percentage discounts from the purchasers and packagers. In other forms, such as eco-industry related clustering, the interviewee agrees strongly on the possibility of sharing streams between actors and utilizing waste as a resource. Energy costs are a significant incitement for actors to cluster together for benefit. An example was given from local actors to make joint investment to power plant, to provide mutual energy. These findings and attitudes would indicate an opportunity for industrial-symbiosis based eco systems in the field, in conjunction with the profitability of actors, which are cost minded and less risk aversive in investments.

In addition to cost savings perspective, the importance of decreasing carbon blueprint due to legislative pressure was stressed. This is especially important on the energy consumption per square meter. Therefore, it would seem, that the economic pressure is not the only driving factor to increase efficiency in the farming. Problems however are related with environmentally friendly solutions and technologies being very costly to invest to, having them very risky for a farmer to allocate funds to. This would indicate more incentives for the farmers to mitigate investment costs through joint-investment and industrial symbiosis based solutions.

Key factors were stated for the greenhouse farming industry to be steady accessibility to irrigation water, lowering of energy costs, utilization of economies of the scale as well as farmer's having more entrepreneurial perspective on the work (delegating, risk aversion and managing farm as a business). Challenges for the industry are the prioritizing of irrigation water for communal facilities (hospitals, schools etc.) as well as households over greenhouses. This would indicate furthermore the need of cluster based shared infrastructure. Further challenges are meeting demand in generally satirized market and cost of energy.

The current factors that steers development was listed the following; markets and farmer's positioning in them, energy costs, workforce (cost and accessibility), as well as possible solutions to mitigate the risks and costs. These solutions are technology based, such as investment in more efficient lighting systems. It is notable, that an interviewee states very positive outlook on the possibilities of industrial symbiosis through clustering together the various actors, to utilize side streams. This is notable, due to the findings in the focus group interview being skeptical to clustering together in possible joint-operations. In general, the importance of cost mitigation, economies of scale, infrastructure development as well as trends in environmentally friendly values are similar in the interviews. The interviewee furthermore stresses, that the key action for future in order to be successful would be addressing energy intensity and saturated markets.

Notable amount of interviewees indicated a very positive outlook for eco-industrial clusters dealing in food and energy symbiosis. The current market is saturated with bulk produced products, indicating that the current farmers have to either ramp up operations or differentiate. The image benefit of sustainable eco-cluster could provide the differentiation over bulk produce based farmers. The significance of costs is stressed throughout the interview, suggesting that cost mitigation and efficient operations are key to the future development. Current geographical clustering has already made markets more accessible for producers. Therefore, co-opetition in the field is already familiar. The increased investment needs are a notable problem however, due to the risk aversive mindset of the farmers.

In summary:

Added value in clustering together can be summarized in:

- Decrease of costs to share infrastructure and logistics
- Minimization of risks to share crucial operations, such as energy production
- Adding value through marketing a sustainably produced product
- Creating profit from previously unrealized side flows, such as water circulation and waste.

The current difficulties in the field can be summarized in:

- Saturated domestic markets
- Difficulties through demanding legislation
- Dependency on subsidies
- High risk aversion due to already substantial investments
- Prominence of large producers utilizing economies of scale, making smaller operations go under
- Dependence of infrastructure; water, electricity, heating
- Changing customer preferences

Concerns about clustering can be summarized in:

- Geographical commitment already in place
- Risk aversion due to already substantial investments
- Suspicious attitude towards working with competition
- Lack of seeing a circular ecosystem as concrete feasible solution (too abstract or complicated)

The difficulties could be outcome through clustering, by differentiating a product from bulk to specialization, finding a niche market from marketing a sustainable solution for customers. This gives an alternative to the production in high quantities and utilizing massive economies of scale, possibly giving a lower cost alternative. Risk aversion can be partially mitigated by sharing infrastructure and large investments, such as power plants and heaters. The currently financially stressing environment can also be eased, by sharing the costs of investments in to eco-industrial cluster. By having the infrastructure nearby, would also ease the cost of attaching the greenhouse to a district heating network, provided one is present to begin with, or to invest in to a heating plant. The largest problem would however be policies, legislation and subsidies around farming, due to subsidies being tied to compliance of policies.

4.2.2. Fish farming

The current conditions in fish farming is also suffering from market saturation. Competition is not only coming from domestic markets, but from imports. Largest competitors are foreign, most notably Norwegian fish farms, which are producing large quantities of salmon to the Finnish markets.

The fish farming operations have their own challenges today, most of them being investment related. The systems needed for fish farming operations are expensive both in fixed and running costs. The infrastructure and systems needed for fish farming are as well complex and require extensive amount of attention, in order to keep things running smoothly. This is another aspect that ties up resources as well as creates need for extensive and sophisticated planning and engineering to build up operations that run smoothly. This can be seen as a large barrier to entry for new businesses, making it favorable for the existing businesses. In general, the conditions in the fish farming business seem to be harsh due to high requirement of know-how of systems, large investments as well as harsh market conditions.

Challenges in the perspective of fish farming were similar to greenhouse farmers. An interview with a fish farm, utilizing circularity based solution emphasized the risk of system failure and creating bottlenecks. This would suggest, that the system level has to be mutually beneficial, rather than creating additional risks. This could be overcome by large enough investments to create power supply of large capacity and a backup system. Therefore, the technical aspects, especially limitations of technology, create a challenge and risk in investments.

The fish farming operations director also stated, that the problem of an extensive and complicated infrastructure is costly, which causes problems in profitability. This profitability problem would have to be solved in order to make the operations sustainable. The interviewee stated, that there is already an expensive and complex system in place, but the consumer is not aware of this. Making the consumer and markets aware of the differentiating factor, in this case, the sustainability and ecological effect of the product compared to the competitor would be an important factor. Indeed it was stated that the markets are currently quite saturated in terms of fish, however this was not reflected in missed sales, but competitive environment and lower prices. Communication to the customer about the origin of the product could therefore be the competitive edge.

On the view of fish farming, the cost reduction was not seen to be a crucial factor acquired through the means of circularity system. This was due to the financially unsustainable system the fish farming company had utilized. However, it was stated that increased investments and scaling up of operations would make the system profitable and financially sustainable through economies of scale. Main added value was stated to be the ecological sustainability of the product, stating that this should be utilized in marketing to create value. Side stream utilization was mentioned in form of fish gutting wastes to bio-gas through biogas plant.

In general, the fish breeding and farming is profitable in Finland. The markets are quite saturated and dominated by foreign products, especially Norwegian, but the trade is still profitable with right products. There are some categories which are better suited for mass production and some market niches to fit in with more specialized. Profitability and sustainability is different depending on scale of operations and the way of farming – larger facilities can utilize economies of scale and the smaller have trouble in general. In addition, the water circulated farming of fishes requires larger investment and capital to drive up production and is more necessary to have large scale benefits, in order to be profitable. Currently there are policy based cuts in educating new operators to the field, meaning a decrease of farmers is foreseeable when older farmers (both fish and vegetable) retire or exit the business. For new farmers, the barriers of entry are high, due to the high investment need, especially in water circulation based farming (greenhouse – fish farm water linkage).

Largest costs are in setting up the facilities and the infrastructure. This requires a significant capital and large amount of risk for a new actor. In addition, finding the technology and human resource capabilities to operate and run the facility is a challenge in the more complex systems. The interviewee states as well, that economic sustainability is hard to come by, and the concept is currently working with “trial and error” basis. Currently the project is six years in and not economically sustainable, but moving towards the right direction.

It was stated as well, that the clustering of activities can indeed mitigate costs and give benefits, but there are also another side of the coin. If not properly engineered, the system can also hinder at times other activities, when one component is not working. This bottlenecking can be a serious threat to sustainability of activities. The interviewee stated, that the key factor of success, is to have the system working together in synergy and not to hinder other modules, when one is not working properly. The best synergies in this sort of system however, come in energy savings and waste management.

For added value; the waste that is produced can be used as an additional revenue through the biogas plant, by selling excess heat and gas to municipal heating grid. In addition, this provides heating and other benefits, for example cut costs from waste management, logistics and energy to the cluster. In addition, the possibility of marketing the product by using sustainable means, was mentioned to be a significant selling point for the added value, due to the current high costs of production and upkeep.

The centralization of this industry is mainly on the South-Western seaside of Finland, due to most favorable environmental conditions. There is no significant clustering together or sharing of activities between farmers however. There are also limitations on fresh water farming and artificial pools, meaning the seaside is the most optimal for this sort of operations. It was stated, that similar actors could indeed (theoretically) work in the same cluster, provided the entrepreneurs could find a way to co-operate and share responsibility of upkeep of facilities. Largest problems however, would be to allocate a fair structure of costs for usage, and everyone "pulling their load".

For key success factors was stated: clean circulation water, easy accessibility to energy from an electric grid along with a backup power supply. In addition, it was stressed, that waste management and biogas plant is crucial for mitigating costs and making revenue. This could be arranged either by own investment, or having waste management company involved with waste treatment to biogas. Furthermore, having good (short) service distances between modules and actors is very important. For facilities; fish farm, water circulation system, power plant, biogas plant and a greenhouse are key facilities. For these factors to work in order to provide added value, no single module should be hindering others unreasonably in case of breakdown or failure. In general; a good, reliable and efficient infrastructure along with key facilities is needed. This all brings investment costs up significantly, if operated by one company or actor, suggesting that there is value to be added, by cutting costs by bundling together actors in a cluster.

For additional non- concrete success factors, the interviewee stated a large capital base to ramp up production and operations as quickly as possible. The importance of economies of scale were stated again, to overcome the burden of large fixed costs of facilities, technology and equipment. For market situation, it was stated, that the markets will always take the product, but the constant production is far more important along with not making the problems of one-unit cascading down to another.

In general, it would seem, that the clustering of activities, utilizing the side flows and to generate additional value from by-products is viable business solution. This is of course provided, that the actors understand the importance of good infrastructure and the interdependence of actors and possible risks and high costs of the symbiotic solutions. As mentioned by the interviewee, it is important to then find and actually realize the value adding factors (sustainable product image in marketing etc.) to mitigate costs to make the business profitable.

In summary:
Added value in clustering together can be summarized in:

- Decrease of costs to share infrastructure and logistics
- Control over operations, less dependency on outside factors
- Giving possibilities to add value through image of sustainability
- Possibility to sell side products, such as biogas for extra income

The current difficulties can be summarized in

- Need of substantial investments to build up operations
- Need of ramping up production and minimize downtime
- Saturated domestic markets in fish

Concerns about clustering can be summarized in:

- Requires careful engineering to build synergies without system failure's cascading to other components of the system.
- Profitability – need to utilize economies of scale more to cover large investments
- Possibility of cascading problems, halting operations if one system fails

The problems of the profitability in the cluster could be explained by operational scale, as interviewee stated *"Given enough investment money, all problems with long term profitability could be solved."* This would indicate, that running all operations of a cluster in house takes away the possible efficiency. Another explanation could be, that the production is not ramped up to high enough levels to cover the investment costs, meaning that such large scale investments should indeed be a joint effort of different actors, or to have sufficient economies of scale in house. In addition, the reliability of operations is stressed a lot. This would suggest, that a company specialized in one core activity, could lead in to more efficient operation of one field of an eco-industrial cluster. In a sense, this would be contradicting the added value of having less dependency on outside factors, if the core operations are too wide and unreliable.

4.2.3. Waste utilization companies

The two studied waste utilization companies are operating in similar fields and are associated with each other. One of the companies collects and utilizes organic waste and the other conventional waste. The other company deals in conventional waste, which is recycled or incinerated depending on the usability of the waste. The incinerated waste provides energy in the form of heat and electricity, which is sold to the local grid. The organic waste is utilized as biogas through decomposing process.

These companies have an extensive region wide collection area of waste. Their current challenges are cost structure in collection of waste (a flat fee for each collection area), changing regulations in waste collection and utilization as well as changes and pressure through environmental politics.

The waste utilization companies would not require extensive investments to utilize waste that greenhouses or fish farms provide, due to the nature of the waste being organic. The risks and challenges for the waste utilization companies would be to create an infrastructure, where they could distribute heat or electricity to the growing facilities. In fact the infrastructure would be so costly, that the near vicinity of the growing facilities would be necessary. It was stated by the waste to energy -company, that these sort of infrastructure investments are large social undertakings by the community / government, rather than something a company would do. This limits the geographical location of growing facilities close to the waste utilization facilities. However, having the food growers centralize their activities around the waste utilization plants, would limit the risk of waste utilization companies. This in turn creates dependency on the growers to waste utilization plant, increasing their risks.

The energy and waste management companies saw added value in additional streams of waste, utilized as revenue, increase of markets as well as positive company image. It was stated by an interviewee, that the first energy companies to utilize circularity, will be the ones who steer development in the future. The image reasons therefore would seem to be incentives for developing in to circular and eco-industrial based system. In addition it was stated, that the legal and policy based restrictions in waste management shrink the current means of gathering household waste and making revenue. This would mean, that the energy and waste providers would need to supplement their previous main flows of waste to other ones. This would therefore be a risk mitigating factor as well, due to decreased input from a main flow.

Waste management company

The largest customers of the company are currently households. However, there are potential difficulties in the near future due to changes in legislation, limiting household waste gathered by single companies. This could be seen as threat for the core business as well as an initiative for the company to find new sources of income from other sources. In addition to households, benefactors of the services are generally local companies as well as other waste management companies, in form of horizontal co-operation. The co-operation is based on the interviewee trading of capacities and knowledge. This would indicate already existing synergic relationship with other actors, as well as possibility to integrate in to an eco-industrial cluster.

The interviewee states, that the largest difficulties in utilizing waste are related to markets and technology. Certain materials, such as plastics are not recyclable due to insufficient technology and equipment. On the other hand, some materials simply do not have a demand in the markets. The interviewee states, that there is still however an opportunity to utilize unrealized side flows, partly through clustering together and creating the markets by positioning. However, technical constraints and simple lack of demand is a notable problem to be overcome. This finding is significant, due to the fact that the greenhouse and fish farming operations produce utilizable waste.

For key factors to success, one of the interviewee stated the importance of streamlining the process and having a working system together, with functioning chain from customer to waste management working, before making large implementations. As an example having both an infrastructure and the critical mass of biogas cars, to create large enough markets, is crucial. This is both a large risk and opportunity to time together supply and demand - infrastructure and customer basis. For gaining basis for customers, the interviewee stated marketing to be a key actor. Indeed marketing and playing on the environmental aspects and sustainability seems to be one of the key factors stressed by interviewees. An eco-industrial cluster would further boost therefore the marketing potential, due to its possible reflection of positive image on sustainability.

The most important resources were stated to be capital, in order to invest further in order to gain economies of scale, due to the low price of end products. Second crucial resources are the human resources and know how. The importance of human resources comes in understanding and exploiting variety of different waste inputs and turning them to profitable material. This requires a wide array of experts and people working.

The interviewee stated, that from current wastes metals are the most profitable, while plastics the least profitable, but however with tremendous potential, provided the technology of utilizing them are in place, along with sufficient demand on market. There are positive views on clustering together with waste flow (side flow) providers in order to acquire both supply and possible markets for end products. In addition, it was stated, that there are still a wide range of products that cannot be utilized. However in the case of aquaponics and agriculture, the waste and end products of the company seem to be very well aligned, most significantly bio-waste and its possible end products: soil, energy and gas.

Due to the changing legislation affecting the core business of the company, the clustering can create flows, which are from other sources than households. This gives new streams of income to compensate lost ones. The large investment needs can be negated by decrease in cost and acquisition of new markets. The waste management company has a clear benefit from clustering with agriculture and fish farming, due to potential inputs of bio-waste as well as market for decomposed products, such as soil.

Waste to energy utilizer

According to interview, the largest factors that affect the profitability – or in the waste management company's case; self-sustainability, is price of electricity, price of district heating, the price of the trash, as well as running costs along with financing costs. The interviewee stresses, that good placement has a significant effect of sustainability in order to have a link to municipal district heating, as well as having the waste input within decent vicinity. The importance of infrastructure is also voiced, having importance on being able to position the operations in a point, where a district heating linkage allows the company to produce heat to the network around the year. Urban density and municipal centers on the other hand are crucial for decent yields for waste to handle. The investment costs to build and infrastructure and a waste management plant are high, therefore stressing the importance of having a good access to create value from municipal waste, and an output (heating pipeline), to mitigate costs to expand infrastructure. The benefits of clustering activities together with other actors would therefore be a value adding factor through cost savings.

The company utilizes side flows of waste as well, for example side products from incineration including ash, slag, metals and minerals. This indicates, that the side flows of the material, are coming from the core activities of the business – incineration of trash, rather than finding additional outside flows to compensate. This would also indicate, that the company is striving to gain high amount of efficiency by using as much of the input, as they are getting now. The interviewee states however, that in excess heat, they do not have any solutions to utilize. However there are projects involving of finding out ways to utilize waste heat. This would indicate, that clustering greenhouses and fish farming together within a power plant, would create mutual value in a symbiosis sort of a setting, due to both having significant dependency on heating.

The interviewee states, that clustering together activities in an industrial symbiotic setting is an opportunity to attract companies and customers. Currently the company is gathering household waste from a wide area, from which not all is currently utilizable. Solutions are being sought to both utilize more trash, as well as finding markets to end products, which no longer have demand. As an example recycled plastic and it’s importing to China, until recently, was given. According to the interviewee, a solution, where the producer thinks about the final product is an optimal situation – using products, which are utilizable by the waste treatment in the end. This can be achieved through legislative changes, or through increasing consumer awareness.

Legislation, subsidiaries and policies are a large factor, which steers the field currently. This limits and also gives other opportunities for the company. The interviewee states, that favorable legislation up in the value chain (producing of goods) would have a very beneficial effect for the industry. This would be through utilizing materials that would be easy to re-use at the end of the products life cycle. The environmental awareness is also important on consumer level. The interviewee states, that there are obvious benefits to be realized, by having an environmentally and economically sustainable business, through image reasons.

More concrete benefits from clustering, side flow utilization and industrial symbiosis, it was stated, that the companies that manage to do co-operation and utilize circular economics early on, will be significant drivers for the field in the future. Interviewee states also, that the company is interested finding solutions in utilizing side-flows in agriculture and fish farming, making the clustering of aquaponics facilities together with waste management operations seem feasible and concrete. In addition to this, the core business of the company has to be sustainable, having a certain volume of material coming in, in order to maintain running and investment costs of large plants and operations.

All in all, the interview shows potential in the mindset of waste management company being positive in eco-industrial cluster for synergy. The benefits for the waste management company can be in more input of materials, previously unrealized side-flows of materials / waste, previously unrealized end products and markets, as well as benefits in company image.

In summary:

Added value in clustering together can be summarized in:

- Company's desire of co-operation
- Positive company image
- Sharing of infrastructure and investment
- Mutual value creation through cutting costs
- New markets for side flows, such as excess heat
- Utilizing unrealized side flows, due to legislation restricting core operations
- Situating waste flows closer
- Decreased logistic costs
- Positive company image

The current difficulties can be summarized in:

- Extreme costs of building infrastructure – seen as a social undertaking
- Legislation issues
- Investment needs

Concerns about clustering can be summarized in:

- Investment needs in to new operations and systems
- Lack of seeing concrete outcomes yet in such systems
- Risk of expanding to new markets
- Uncertain demand of end products, such as bio fuel

The findings are similar to the previous interview with the municipal waste management company, due to the similar industry of the companies. Differentiation has to be made however, that the interviewee's represented company deals more in the energy sector, thus is more affected by energy markets. However, the waste incineration process gives a potential for the company to make profits from waste heat and connect agriculture and fish farming to a district heading grid with larger ease, easing on investment needs and infrastructure building cost. This can also be a risk mitigating factor, due to changing legislations making waste utilization from households more difficult.

4.3 Summary of findings

The following table is the concluding points for the research questions for creating added value in eco-industrial cluster from the stakeholder's point of view, as well as the challenges they are facing. It is notable, that the challenges that they face currently can be mitigated by clustering of activities. On the other hand, the challenges of clustering together were, based on the interviews, more related with manager's mindsets, risk aversion and further investments. The main concerns lay on costs and investments, along with risks associated with them across the board.

Actor	Added value	Notable challenges in cluster
Municipal waste company 1 (Decomposing & utilization)	Positive image - eco friendliness	Investment costs
	Additional venues of income. Utilization of side flows - compostable bio-waste	Legislative issues limiting household waste
	Local inputs - decrease in logistics cost	Sufficient input to cover costs
	Shared infrastructure	
	Increased volume of input (waste)	
	Easy access to bio-waste	
Municipal waste company 2 (incineration & energy)	Positive image - eco friendliness	Investment costs
	Additional venues of income. Utilization of side flows -waste to energy	Volume of burnable waste
	Local inputs - decrease in logistics cost	Legislative issues limiting household waste
	Shared infrastructure	Sufficient input to cover costs
	Increased volume of input (waste)	
Greenhouse farmers	Decreased waste management costs	Risk of technical failures (heating, electricity and irrigation)
	Shared infrastructure	Investment costs
	Near access to heating network	Operating with competitors
	Decreased risk due to vicinity to a power plant	Marketing the product as unique
	Shared water circulation	
	Sustainable image	
Fish Farms	Decreased waste management costs	Risk of technical failures (heating, electricity and irrigation)
	Shared infrastructure	Investment costs
	Near access to heating network	Operating with competitors
	Decreased risk due to vicinity to a power plant	Marketing the product as unique
	Shared water circulation	
	Sustainable image	

Table 2 Added value and challenges across the fields.

The table summarizes the added value which the different actors perceive and which can be achieved through clustering together. The concerns and difficulties are collected from the current difficulties in the field, along with the concerns that the interviewees have stated. Some problems which are on the field in generally, such as already saturated markets, have been added to the list, due to the clustering solution not closing them out, even if the actor would participate in an eco-industrial cluster.

In total five interviews were conducted using Industrial Symbiosis cluster figure (see figure 9, p. 50) as a basis selection of the interviewees. Majority of the interviewees were based around a specific region in Finland, with an exception of one interview being geographically isolated from the others. The general goal of the interviews was to map out each section of the conceptual figure (figure 9), in order to understand the challenges, benefits and value creation opportunities of eco-industrial cluster, by examining each unit and understanding their challenges, opportunities and general field they operate in.

The benefit of clustering was seen in general as an obvious asset and a system to be strived for. Reasons for positive views were utilizing an already existing greenhouse cluster furthermore, increasing cost savings as well as positive image for customers. The greenhouse farmers agreed, that clustering was the way to go in order to develop the industry, due to having distributor center near the location, saving possible costs with other farmers, having organizations in place for common interest as well as having the possibility to share costs in infrastructure.

Studying another circular project related to aquaponics which was already in place with a working system yielded interesting points for and against such system as well. The representative for the circular system would state the following: *"In order to gain the full benefits of such system, the system alone is not enough. It needs to be marketed and to be made known (for the consumer)"* The problem is therefore, that the business running the project is aware of the benefits, but these benefits are not transferred to the potential customer basis.

The benefits of such system are obvious in form of cost savings, centralizing of activities in one spot to make savings by creating supply and demand locally, due to clustering together facilities that use waste and byproduct as “food” for a final product. In addition, the public relations impact of such activity can be seen overwhelmingly positive, due to practicing sustainable business model by consuming as little as possible virgin materials, but using the waste and by-products of others in the cluster.

The way different actors see the cluster varies a lot as well. The core of the cluster is the aquaponics facilities: fish farm and greenhouse. These actors benefit from the proximity of others due to sharing of water, cutting cost in waste management, participating in environmentally efficient and friendly way of producing. The latter can be leveraged in way of marketing the end product for consumers or distributors to command higher prices or wider target market.

The waste management companies see the cluster as an input for their demanded product – waste, which they either turn in to power or biogas. For these companies the benefits come in as an available supplier of their needed product to fuel their core business. Benefits in the cluster include possibility to gain customers to distribute electricity / heat and more input to produce end product. Due to close proximity of actors, savings in transportation costs are possible, as well as positive PR image to utilize waste as a resource, rather than a landfill deposit.

On systems level the technical limitations, planning and utilizing economies of scale are a key to successful operations. With too limiting design and scale, financial sustainability becomes an issue. In addition, bottlenecks in technical solutions can cause cascading problem throughout the system, causing harm in the whole cluster. A backup and contingency solution would have to be taken in account therefore, increasing need of investments. A challenge exists also in planning a properly working eco-industrial cluster. This would have to be a trial and error based system, increasing overall risk of such undertaking, if there are no examples to design the system from.

On actor level, the risks and challenges are largely dependent on the actor's current status. It can be noted that building an eco-industrial setting from the beginning would be easier than to integrate already existing operations in to one, due to geographical factors. Therefore the system would have to be built ground up, or to centralize around the most important actor. In addition, risk aversion brings a challenge, due to new investments, making the actor less hesitant to adapt in to eco-industrial cluster

However, the benefits in a cluster could reduce significantly costs due to utilization of other actors by products. This could be the competitive edge that the fish farmers and greenhouse growers are seeking right now. Indeed many are struggling in saturated markets, being forced to either specialize or ramp up capacity to achieve economies of scale. Participation in a cluster will provide that specialization, as well as the economies of scale. The economies of scale steps in, that the costs are being already shared between how many participants there are in a cluster. Larger amount of joint investments to infrastructure will cost savings to everyone through dividing the costs between each other. In addition, building operations around a waste utilization company will provide savings in waste management, heating and electricity costs, due partnership and in place infrastructure. For the waste utilization companies, this creates increased opportunities of extra income, through more inputs of waste as well as customers and business partners.

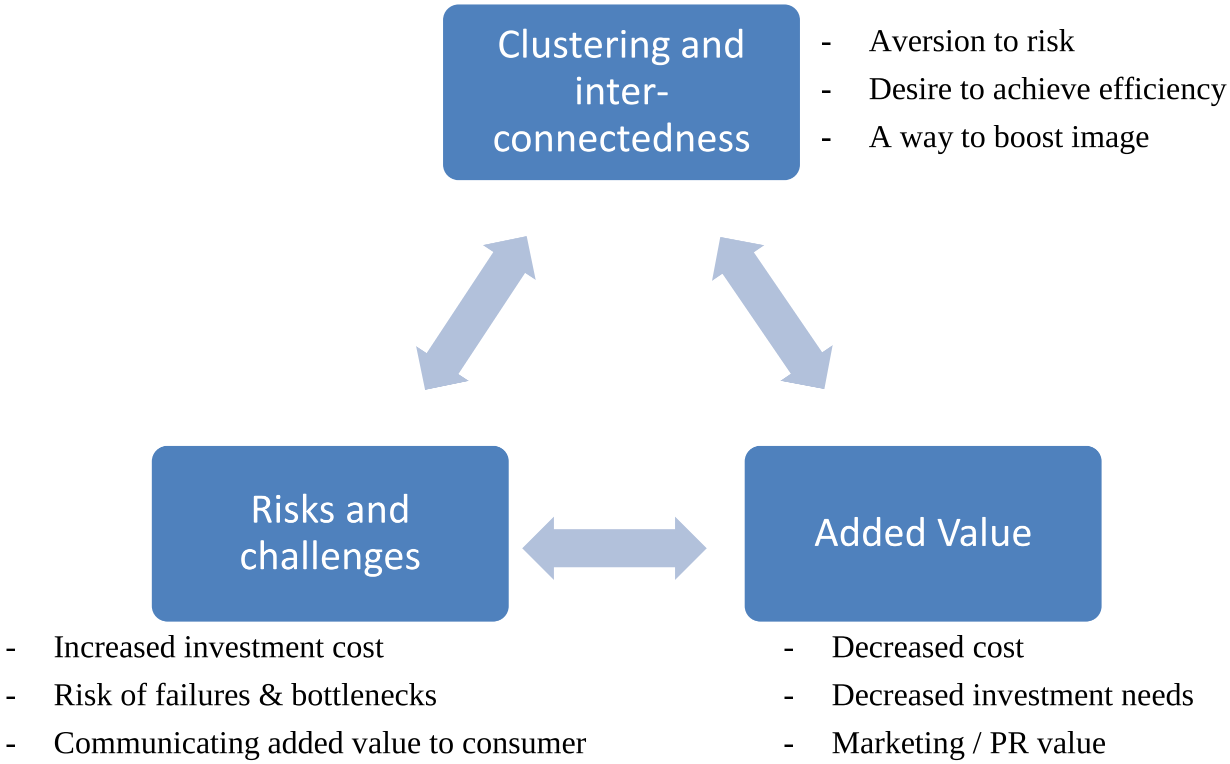

Figure 10. Updated theoretical framework

Reflecting to research framework, the following findings can be made:

Clustering and interconnectedness:

The different actors have large potential to benefit from each other's existence in a same cluster. Decreased costs are possible to be made on behalf of every actor through shared infrastructure is considered as an added value among positive public image. Investment needs are a concern however, when dealing with clustering, which is evident on every actor. In general, the shared infrastructure and presence of other actors works also as a way to decrease risks that would otherwise appear by acting separately. This risk decreasing aspect is different throughout actors however. The waste to energy companies see the clustering as an addition to supply chain and access to customers, whereas food growers see this as a securing of vital utilities.

When compared to the theoretical framework (figure 6), majority of the aspects found from theoretical study have manifested through the research. Clustering and inter-connectedness has been seen across the board to minimize waste, increase efficiency and create mutually beneficial arrangements – symbioses. The waste decreasing sentiment has been captured from the interviews as a positive PR or marketing boost. Some concerns were voiced from greenhouse growers in the clustering, due to being on proximity of competitors however. This can however be mitigated and negated properly by specialization within the cluster.

Risk and challenges:

The risks and challenges from interconnectedness are increased investment costs in to a new system and the need of careful engineering and planning, in order to avoid cascading problems or bottlenecks in the system. In addition, investing in to a large and complex system has to be communicated to the end consumer in order to justify the existence of the heavy investments

In comparison to figure 6, it was found indeed, that technical limitations are indeed one of the major challenges. The willingness to collaborate manifested as well, but in much lesser content. The matching of actors with links however did not manifest as strongly as expected. This is due every actor having a secure and strong core business already. Indeed, it would make little sense to enter in to an eco-industrial cluster with a model that is not viable to begin with. Therefore, this raises a point, that clustering of activities should be based on already working and existing industries, rather than building artificially from “green field” perspective.

Added value

Most notable added value comes in form of shared infrastructure and mitigated costs. Joint investments in to an infrastructure decrease the investment costs and shares risks between actors. In addition shared infrastructure brings savings in form of logistic costs, energy and water costs, which are most notable for the greenhouse and fish growers. In addition, the energy companies have access to their material needed flows from nearby. Sustainable system, which minimizes waste and utilizes majority of it to create new products has a significant marketing potential to leverage the image of the company or a product, bringing in an added value.

Compared to figure 6, the added value was most notable in the form of cost savings and projected image. It is notable however, that the projection of image should take conscious marketing effort to project to consumers, as the benefits of clustering may not be evident to a consumer.

5. CONCLUSION

The industrial ecology and industrial symbiosis has wide range of implementations in to aquaponics based farming and energy production's combination. Due to the customer behavior shifting in to more environmentally oriented mindset, ecological implementations to companies and industries may bring significant added value. Implementation of these systems are however risky through high investment costs and risk aversion to new technologies. The risks however can be outweighed by the potentially great added values, through cost savings and marketing potential of sustainable production.

5.1. Key findings

The research was able to answer the initial research questions, stating that there is tangible benefit and interest in utilization and implementation of cluster like symbiotic solutions in food production.

> **Research question 1:**
> How to create an eco-industrial cluster, utilize crucial components and needs in order to create successful symbiosis.

Findings:

Success factors for a symbiotic food production system have been identified to be profitability, skilled labor force, and entrepreneurial interest in the concept as well as having the right components in place for the infrastructure. Most important actor has been identified to be the energy provider. The other crucial components are the production facilities; both plant and fish production facilities, an infrastructure for water circulation, as well as heating and electricity infrastructure. The heating and electricity should be localized near the production. Symbiosis can be furthermore enhanced by having power plants utilizing waste, which uses the side products of food production as fuel. The by products can be used to create products such as biogas for fuel, heating, electricity and CO_2 gas for plant growing. By connecting otherwise separate actors locally together, can all actors within the cluster benefit. This form of interconnectedness can be called a symbiosis. In optimal situation, waste is minimized and the actors are able to utilize each other's waste and inputs for their production. In optimal setting, circular linkage can be formed, minimizing waste and external output to the system.

Research question 2:
How can businesses and actors create and perceive value from their activities through clustering together and utilizing their inputs and out-puts?

Findings:
The symbiotic nature of the cluster creates a resource sustainable solution with less needed input for a final product, than the conventional way. This sustainability in resources is ecologically and environmentally friendly, and can thus be utilized in marketing of the end product. In addition companies and facilities associated with the cluster can use this fact as a public relation boost to promote their business as environmentally friendly business. Furthermore, as discussed by Adler & al. (2000) a resource saving system has both economic benefits through cost savings as well as societal benefits through saving resources, such as water and fertilizer, providing a less ecologically intensive way of cultivating plants and fish. Cost savings can be achieved in form of water, electricity and heating costs. As mentioned previously, the more self-sustaining and circular the system is, the less external output is needed and the less waste in produced.

5.2.Theoretical contribution

The study contributes in two notable ways. The systems level studying of a greenhouse / aquaponics symbiosis cluster gives an insight about not only the requirements and key components within the aquaponics operations, but in the larger picture. The systems level study contributes to the research by making it clear, that the theories of industrial ecology and symbiosis can be implemented on smaller, local levels in food producing – waste to energy symbiosis, through interviews mapping the key factors and attitudes of businesses operating in the field. These system level researches have been conducted previously through heavy industry in relation to Kalundborg and other eco-industrial clusters by contributors such as Ehrenfelt & Gertler, Yong and Raffaella, but not so much in the form of food production on smaller scale.

By understanding the concepts of industrial ecology and symbiosis and implementing it on smaller scale, the paper aims to make the matter more approachable to businesses that seek to mitigate their own risk, leverage their environmental image as well as lowering their barriers of entry to circular based solutions, by mapping out key factors and risks. The research contributes also to municipal waste to energy managing companies to find additional ways to utilize their already existing infrastructures, as well as mapping the field for future partnerships in symbiotic settings.

Furthermore the study delves in deeper to the possibilities of commercializing the eco-industrial cluster activities in food production, studying the current conditions in the conventional greenhouse farming and studying already in place circular cluster. These findings help to understand the challenges and key factors related in such systems, as well as the attitudes and mindsets of different actors in such a cluster.

5.3. Managerial implications

Based on the empirical research, the current environment for food production in Finland is largely based on EU-based subsidies coupled with high investment need. This coupled with saturated markets, imports from other EU countries as well as high investment needs create a difficult environment for the growers. Fish farming is under similar conditions, but the market saturation is not as adverse to the business, as on the greenhouse farming sector. The outlook for both of the industries is larger scale operations with heavy leverage of economies of scale, resulting in bulk production, further causing market saturation. Both in fish farming and greenhouse farming running costs, especially heating and electricity are seen as a key factor for profit and continued operations. Ways of mitigating costs and decreasing the investment need of equipment are therefore very valuable in the industry.

From this a conclusion can be drawn, that industrial symbiosis and eco-industrial clustering can be a solution to add value to fish and greenhouse farming operations. High risk aversion can work together with join invested infrastructure, shared utility providing as well as general mitigation of costs. The importance of environmentally friendly and sustainable image was prominent in all meetings and interviews. This can be a powerful marketing tool for the actors in a cluster that want to add value to their product through image. Secondary needs for greenhouse and fish farming operations, along with waste management are concerns of proficient workforce on hand. A clustering of actors can be an incentive to draw sufficient workforce to an area to provide suitable employees.

In waste management perspective, current legislations are fracturing the current core business of gathering and utilizing household waste to end products and energy. Eco-clusters can therefore provide a supplementary flows to the waste management companies, shifting the core business of which profitability might be at stake, to another direction. In addition, the vicinity of new flows of waste to be utilized can also cut costs and make operations more profitable. The prominence of proficient workforce can also help cross-function operations to work in better efficiency. As discovered from interviews with waste companies, human capital with knowledge to utilize different flows of waste is important. In general waste management companies see value in clustering together activities for side flows. Furthermore, they indicate the need of leading the change and being sustainability minded, seeing this is the new trend for the future, having the companies who go this direction early flourishing and driving change in the future. Same sort of development can be drawn a conclusion from the sector of greenhouse farming and fish farming; indicating that possible added value can be found from marketing to consumers with sustainability and ecology as their value.

The role of governance, both on EU and national level is also an important factor that steers development, or in some cases hinders it. (Horvath & Harazin, 2016) Therefore it is important, that the government and public is encouraging and subsidizing actors, who steer their activities towards sustainable practices.

The main value adding factors on the other hand lay in the shared infrastructure and cut costs. This would indicate the further need of analyzing the costs involved with eco-cluster based investments and the return on capital, indicating financial sustainability of such undertakings. However, the study proves almost overwhelmingly positive mindsets and views on the eco-industrial based clusters in the field of waste management, greenhouse farming and fish farming.

5.4.Limitations and future research

The research is conducted in a limited geographic area, due to being centralized in Finland. Due to this the market, economical, legislative and social factors can be limiting the findings. It is noted also, that due to harsher climate and larger costs of upkeep due to the natural conditions, either the benefit or need of symbiotic and eco-industrial clusters in greenhouse, fish farming and aquaponics can be different to location with other environmental conditions.

Due to the fact of researching majority of the existing greenhouse facilities without fully implemented aquaponics solutions, the implementation of aquaponics is theoretical. An implementation and piloting would have to take in place to provide a fuller picture of the feasibility, as only one of the interviewees had reached the point where they had implemented a circularity based system. However, the cluster systems and implementation of flows can be in fact utilized with greenhouses without needing a full aquaponics system (non-soil based growing). The research is rather revealing success driving factors, as well as challenges and barriers. Further research is therefore needed solely in the area of implementing circular system in to purely aquaponics facilities.

The research scope is limited to Finland, therefore future research in the area of food production in symbiotic way in to eco-industrial clusters in other parts of the EU and the globe in general is needed in order to give broader understanding of the subject in general. However, the research will provide information about the feasibility, key factors and challenges of aquaponics clusters.

The research lays a good groundwork for further studies in sustainable ways of producing food and utilizing waste, through providing data about businesses and growers interest of differentiating their businesses as well as implementing sustainable solutions in their businesses.

REFERENCES

Adler, P.r., et al. “Economic Analysis of an Aquaponic System for the Integrated Production of Rainbow Trout and Plants.” *International Journal of Recirculating Aquaculture*, vol. 1, no. 1, 2000, doi:10.21061/ijra.v1i1.1359.

Allenby, Brad. “The Ontologies of Industrial Ecology?” *Progress in Industrial Ecology, An International Journal*, vol. 3, no. 1/2, 2006, p. 28., cspo.org/legacy/library/110215F0XT_lib_AllenbyPIEontolo.pdf.

Arbolino, Roberta, et al. “Towards a Sustainable Industrial Ecology: Implementation of a Novel Approach in the Performance Evaluation of Italian Regions.” *Journal of Cleaner Production*, vol. 178, 2018, pp. 220–236., doi:10.1016/j.jclepro.2017.12.183.

Ayres, Robert U. Ayres Leslie W. (2002). “*Industrial ecology: goals and definitions. A handbook of industrial ecology.”* Retrieved November, 2017.

"Aquaponics." *Merriam-Webster*. Merriam-Webster, n.d. Web. 21 Oct. 2018. <https://www.merriam-webster.com/dictionary/aquaponics>.

Bellantuono, Nicola, et al. “The Organization of Eco-Industrial Parks and Their Sustainable Practices.” *Journal of Cleaner Production*, vol. 161, 2017, pp. 362–375., doi:10.1016/j.jclepro.2017.05.082.

Bowman, Cliff, and Veronique Ambrosini. “Value Creation Versus Value Capture: Towards a Coherent Definition of Value in Strategy.” *British Journal of Management*, vol. 11, no. 1, 2000, pp. 1–15., doi:10.1111/1467-8551.00147.

"Edunvalvonta" *Päivittäistavarakauppa Ry - Tilastot Ja Julkaisut- Tilastot*, 2018, www.pty.fi/julkaisut/tilastot/.

"Effective Industrial Symbiosis." *Ellen MacArthur Foundation*, 2017, www.ellenmacarthurfoundation.org/case-studies/effective-industrial-symbiosis.

Ehrenfeld, John R. "*Industrial Ecology: A Strategic Framework for Product Policy and Other Sustainable Practices"* (1994) The Second International Conference and Workshop on Product Oriented Policy msl1.mit.edu/classes/esd123/2002/jre_stockholm_1994.pdf.

Ehrenfeld, John, and Nicholas Gertler. "Industrial Ecology in Practice: The Evolution of Interdependence at Kalundborg." *Journal of Industrial Ecology* 1.1 (1997): 67-79. Web. <http://www.johnehrenfeld.com/Kalundborg.pdf>.

Erkman, S. (1997). Industrial ecology: an historical view. Journal of Cleaner Production, 5(1-2), 1-10. Retrieved November 6, 2017, from https://ac.els-cdn.com/S0959652697000036/1-s2.0-S0959652697000036-main.pdf?_tid=bb530d5c-cb9b-11e7-8edc-00000aacb360&acdnat=1510925718_8c86fe1252686b4db3e2f442c2d8980b

"Explore the Kalundborg Symbiose." *Kalundborg Symbiose*, 2018, www.symbiosis.dk/en/.

Goddek, Simon, et al. "Challenges of Sustainable and Commercial Aquaponics." *Sustainability*, vol. 7, no. 4, 2015, pp. 4199–4224., doi:10.3390/su7044199.

Horvath, György, and Piroska Harazin. “A Framework for an Industrial Ecological Decision Support System to Foster Partnerships between Businesses and Governments for Sustainable Development.” *Journal of Cleaner Production*, vol. 114, 2016, pp. 214–223., doi:10.1016/j.jclepro.2015.05.018.

Hess, Gérald. “The Ecosystem: Model or Metaphor?” *Journal of Industrial Ecology*, vol. 14, no. 2, 2010, pp. 270–285.

Frosch, Robert A., and Nicholas E. Gallopoulos. “Strategies for Manufacturing.” *Scientific American*, vol. 261, no. 3, 1989, pp. 144–152.

Geng, Yong, and Zhao Hengxin. “Industrial Park Management in the Chinese Environment.” *Journal of Cleaner Production*, vol. 17, no. 14, 2009, pp. 1289–1294., doi:10.1016/j.jclepro.2009.03.009.

Geng, Yong, et al. “Emergy-Based Assessment on Industrial Symbiosis: a Case of Shenyang Economic and Technological Development Zone.” *Environmental Science and Pollution Research*, vol. 21, no. 23, 2014, pp. 13572–13587., doi:10.1007/s11356-014-3287-8.

International Synergies "What Is Industrial Symbiosis." *International Synergies*. N.p., n.d. Web. 17 Nov. 2017. <http://www.international-synergies.com/our-approach/what-is-industrial-symbiosis/>.

Kuznetsova, E., et al. “A Methodological Framework for Eco-Industrial Park Design and Optimization.” *Journal of Cleaner Production*, vol. 126, 2016, pp. 308–324., doi:10.1016/j.jclepro.2016.03.025.

Lepak, D. P., et al. “Value Creation And Value Capture: A Multilevel Perspective.” *Academy of Management Review*, vol. 32, no. 1, 2007, pp. 180–194., doi:10.5465/amr.2007.23464011.

Mirata, Murat. “Experiences from Early Stages of a National Industrial Symbiosis Programme in the UK: Determinants and Coordination Challenges.” *Journal of Cleaner Production*, vol. 12, no. 8-10, 2004, pp. 967–983., doi:10.1016/j.jclepro.2004.02.031.

Official Statistics of Finland (OSF): Waste statistics [e-publication]. ISSN=2323-5314. 2015. Helsinki: Statistics Finland [referred: 19.11.2017]. Access method: http://www.stat.fi/til/jate/2015/jate_2015_2016-12-20_tie_001_en.html

Saavedra, Yovana, et al. “Theoretical Contribution of Industrial Ecology to Circular Economy.” *Journal of Cleaner Production*, Elsevier, Jan. 2018, www.sciencedirect.com/science/article/pii/S0959652617321728.

"Symbiosis." *Merriam-Webster*. Merriam-Webster, n.d. Web. 18 Nov. 2017. <https://www.merriam-webster.com/dictionary/symbiosis>.

Taddeo, Raffaella, et al. “Implementing Eco-Industrial Parks in Existing Clusters. Findings from a Historical Italian Chemical Site.” *Journal of Cleaner Production*, vol. 33, 2012, pp. 22–29., doi:10.1016/j.jclepro.2012.05.011

Tsvetkova, Anastasia, and Magnus Gustafsson. “Business Models for Industrial Ecosystems: a Modular Approach.” Journal of Cleaner Production, vol. 29-30, 2012, pp. 246–254., ac-els-cdn-com.proxy.uwasa.fi/S0959652612000297/1-s2.0-S0959652612000297-main.pdf?_tid=22a5cbde-cca5-11e7-a485-00000aacb35e&acdnat=1511039708_951cacb121d2c62622d5bcd12aeeeba0.

Veleva, Vesela, et al. “Understanding and Addressing Business Needs and Sustainability Challenges: Lessons from Devens Eco-Industrial Park.” *Journal of Cleaner Production*, vol. 87, 2015, pp. 375–384., doi:10.1016/j.jclepro.2014.09.014.

Yin, R. K. (2009). Case Study Research. Design and Methods. 4th ed. Los Angeles etc.: Sage Publications Inc.

Yoon, Sukjin, and Khalid Nadvi. “Industrial Clusters and Industrial Ecology: Building ‘Eco-Collective Efficiency’ in a South Korean Cluster.” *Geoforum*, vol. 90, 2018, pp. 159–173., doi:10.1016/j.geoforum.2018.01.013.

Yu, Chang, et al. “Process Analysis of Eco-Industrial Park Development the Case of Tianjin, China.” *Journal of Cleaner Production*, vol. 64, 2014, pp. 464–477., doi:10.1016/j.jclepro.2013.09.002.

APPENDICES

Appendix1. General interview structure

1. Sustainability: how sustainable are the current practices?
   a. Which are the key factors that affect the actors in the industry currently
   b. What is the effect on size and scale of operations?
   c. From what do the largest cost come from?
   d. What are the current market situation domestically?

2. Challenges & Risks
   a. How do you see clusters to alleviate challenges in costs?
   b. How do you see possibilities on investing in a cluster
   c. What are the challenges to market a sustainable product / service?
   d. What are the technical challenges?
   e. How is the competition inside the industry?
   f. What are the greatest current threats in the industry?
   g. What are the future trends you see now?

3. Key success factors – What are the most important factors for success in the field?
   a. How do you utilize these factors?
   b. How important is geographical location
   c. How do you see co-operation between the industry?
   d. What is the importance / how large are investments in the industry?
   e. What are the factors that steer development?
   f. What are the most notable changes in the industry in the recent times?