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Controlled environmental agriculture & the need for innovations networks

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Abstract

This thesis explores which innovation systems that facilitates growth for Controlled Environment Agriculture (CEA) companies and to successfully operate within the food industry. This was done by interviewing several companies within the CEA industry as well as relevant governmental organizations. The theoretical framework was constructed to support the analysis and was based on several innovation systems theories as well as the Multi Level Perspective (MLP). The research found that the CEA companies to a great extent rely on several important actors within their different innovation systems to successfully grow their business over time . Investors emerged as the single most important actor for CEA firms, especially during the startup phase when funding was crucial for scaling up their operations and achieving profitability. Collaboration with governmental institutions and universities are also very important for CEA companies, both when it comes to financial and research support but also as a platform for future working competence. Additionally, the study identified a trend where younger companies rely on local and regional innovation systems, while more mature companies seek engagement in larger global systems for increased funding, knowledge, and support. In conclusion, the success of CEA companies is closely tied to the involvement of the relevant actors within their innovation systems to overcome the obstacles that the companies are facing where financial partners and universities proved to be the most important actors in the startup phase, but where laws and regulations were an important indirect factor for the companies .

Key words

Controlled Environmental Agriculture (CEA), Food Production, Innovation Networks, Multi Level Perspective, Sustainability

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1. Introduction

1.1 Background

Never before have the global discussion been so active as today on how we need to change our society, from being a carbon intensive society to being a more sustainable one. If this is not to happen anytime soon the consequences are projected to be seen globally according to IPCC (Intergovernmental Panel of Climate change). The IPCC which is an intergovernmental body of the UN and one of the leading organizations when it comes to assessing and addressing the potential impacts of the rise in global temperature are stating there is an urgent need to transform the society to mitigate some of the future risks. (Australian Government, 2023).

IPCC (2022) did in their 2022 report say that the result of continuing on our current trajectory and not conducting the necessary transformation of our society, to a more sustainable one, will have devastating impacts on the planet. The organization further emphasizes that rising sea levels, loss in biodiversity, increased droughts and increased extreme weather are just a few realities this behavior could result in and would most probably affect us all, independently of where one lives, (IPCC, 2022).

A parallel phenomenon to climate change is the globalization in the world that has resulted in a massive growth of the global food supplies and its interconnection. But, as a response to the globalization and the corresponding climate impact, local alternatives have started to emerge that, in contrast to the global supply chain, favors locally produced food (Dickens, 2015). Originally these consumer groups represented a niche group favoring locally produced food due to its sustainable, healthy and not sprayed characteristics and also advocated a re-shoring of food production due to those benefits. They were requiring a “re-localization” of the production in order to provide sustainable products and where local ecosystems are not exploited beyond their ability and a reality where the products are not transported thousands of miles (ibid). This movement has created an increased share of farmers choosing to farm in a sustainable practice, which indicates that this is a growing trend and increased public awareness. However, this ecological food production has mainly, up until now, been a sustainable substitution to traditional food where both use quite similar growing technology instead of any radical production innovation (FAO, 2013).

It is not only a change in consumer behavior described previously by Dickens (2015) that is asked for. The World Bank is also raising a warning that future food supply possibly could be heavily affected , by the projected population growth globally and the climate change.

According to the OECD there is a need to find and develop a sustainable way of producing enough food for the future population that is projected to reach 9,6 billion by 2050 (OECD, 2023a). Food production is also a major contributor to the climate change that we are seeing today (UN,2023). The UN are therefore at the same time addressing the need to improve the global food production and implement a sustainable practice in the industry. The UN is emphasizing that the transition will have to be done through improved resource management but also by developing and implementing new innovation which can reduce the total emission (ibid). Possibly could the niche group, described by Dickens (2015), constitute an inspiration for a desired and needed development within the food industry

There are several initiatives from both the UN and the EU that promote innovation and development to hopefully result in the implementation of new technology within the industry. Where the EU for example are promoting innovations within the industry via FOOD 2023 that later can be granted to member states and their innovative companies (European Commission 2023b). The implementation of new technology and innovation within food production and other related industries are projected to have an important role and many developmental opportunities within the industry. The goal set by the EU is to offer a sustainable product and to mitigate some of the climate emissions and other issues within the industry. The FOOD 2023 project will be launched under the broader Horizon 2023 project and strives to promote innovation with fundings and help to overcome the many difficulties and obstacles new innovations may suffer from (ibid).

IPCC states in one of their climate reports that continuing on the same trajectory as we are currently going is predicted to significantly reduce the total arable land in the world. The report further stated that this effect most likely will be disproportionate between the world's population where the most vulnerable people are likely to get affected the most (UN, 2019).

The World Bank stated in a report from November 2022 that approximately 345 million people globally suffered acute food scarcity and according to The World Bank the food shortages will be even worse in the future due to climate change as climate change alone could add as many as 45 million people to that score, from the African continent alone (Worldbank, 2022). This is stressed by several scientists to be alarming since a majority of the arable land is already used for food production. It would also imply that forest areas were ravaged in order to be replaced with food production (ERFM, 2013). Due to the fear of food shortages and greater climate impact the need for finding new and innovative ways of producing more food have accelerated (UN, 2012).

One of the many possible technologies that has been given a lot of attention as a possible solution is the Controlled Environment Agriculture, which several different global companies have begun to explore the possibilities to commercialize and make economically viable. Controlled Environmental Agriculture, henceforth CEA, is a highly advanced farming technology where various forms of cultivation is performed in a closed and controlled environment thus the name: CEA. The most common form is hydroponically based agriculture but other systems such as aquaponic and aeroponic systems exist.
The plants are cultivated in a controlled process where the goal is to maximize horticultural practice (Cornell University, 2023). Horticulture is the science and assembly name for several academic practices and includes amongst other things development, marketing, sustainable production and cultivation of food. The scientific practice is wide in its scope since it for instance touches on fruits and vegetables, landscape flowers as well as traditional crops (Michigan State University, 2023). As of today CEA techniques is a knowledge intensive practice since it requires skilled workforce within several different practices such as engineering, plant pathology, and computer science in order to make a viable production system (Cornell University, 2023). The most common form of CEA systems is the vertical farming practice which just as the name indicates, means that the production is conducted in layers above each other and thus increases the output per sqm significantly (Edengreen technology, 2023).

New and emerging industries like the CEA industry can often experience a miss match with the preexisting landscape and regulations. This can be explained by the Multi Level Perspective (MLP).

The multi-level perspective is a framework that explores the interaction and challenges that arise across various levels, including technology, organizations, and society, when introducing new innovations or technologies to society. It recognizes factors like technological complexity, existing systems and regulations, cognitive barriers, power dynamics, and scale implications (Geels, 2002). New industries often require a support system in order to facilitate these challenges.

These support systems are often described as Innovation Systems and can be defined as interconnected networks of actors, organizations, institutions, and processes that collaborate and interact to generate, diffuse, and apply knowledge, technologies, and innovations (Chaminade et al,. 2018). The innovation networks facilitate knowledge sharing among industry participants, as well as encourage collaboration and partnerships, allowing companies to combine resources, expertise, and capabilities to tackle complex industry challenges together. Further on innovation networks provide access to resources and funding, since they connect industry players with potential investors and shared infrastructure, and offer valuable market and customer insights. To summarize it, innovation networks create an environment that promotes innovation, cooperation, and the growth and sustainability of new industries (Chaminade et al,. 2018).

1.2 Problem discussion

As mentioned in the previous subchapter, the prognosticate population growth in combination with climate change are on their own expected to change the way we view food production. The University of Minnesota states in their report that to provide the future global population with food there is a need to increase the annual food production between 60-100 % until the end of 2050 (ERFM, 2013). In this calculation made by the university the increase in the annual yield is only considering the growing population and not necessarily the climate effects which may affect the food production. The United Nations have in several reports stated possible effects that the climate changes can have on the global food production depending on which scenarios were to occur. In one report published back in 2019, by the UN organ IPCC, a possible scenario would significantly reduce the total arable land globally, primarily due to heat but also other extreme conditions (UN,2019).

It does not take much to understand the fact that we need to develop a technique that can address both these problems (climate change and population growth) in a way that doesn't compromise the progress of the other. A possible suggestion from someone without the precise knowledge could be: can we increase food production within the same area of arable land? A quick answer would simply be no. Meanwhile a longer answer could include the negative long term effects that fertilizer has on agriculture. As IISD states the longtime use of fertilizer is in some aspects environmentally harmful (IISD, 2022). Instead new technologies like CEA- controlled environment agriculture have emerged as a new technology that possibly could address both increased food yield as well as addressing the environmental problems affecting traditional food production. Unfortunately, the emerging CEA industry and the companies within it are affected by the same problems as many other new technologies, the problem with proof of concept and economy of scale. Today some of the problems that hampers the roll-out of the CEA technology are that it is too expensive to invest in, and that the final products have a high price tag that is too high for the local market to pay (Vertical farming planet, 2023). One problem that contributes to the higher price is that the CEA technology is a very energy intensive farming method that requires several times more electricity compared to conventional farming (Global CEA census report,2021). This sets demands on the farming sites to be able to deliver enough electricity which is an expensive infrastructure to build. Apart from the electricity supply per se, it is also important to have a stable price on the commodity itself and a predictable operational cost. Both of these issues are something that has been given more attention recently due to the escalated price of electricity that especially Europe has been experiencing, partially due to the Russian invasion of Ukraine but also because of the increased demand of electricity from society as a whole (European council, 2023).

In similarities with many other emerging industries the need for a supportive infrastructure and to belong to an innovation network is often crucial in order to successfully commercialize the idea. Lundvall et al,. (2019) are emphasizing the need for emerging industries to belong to a network where many different stakeholders are participating in order to successfully transform, from being a niche to becoming a regime in the market. This type of innovation networks are often characterized by governmental organizations that support the industry with soft funding’s (economic support), universities to support with R&D and business partners willing to invest in this new technology (Lundvall et al,. 2019).

The CEA industry and its technology might very well be a possible solution to the problems emphasized in the beginning, regarding increasing food production without compromising the environment. But before that can happen, the CEA industry needs to mature in the global and local markets.

It is therefore of great importance to investigate and understand which type of innovation systems that are important for the CEA companies to be involved with in order to succeed. It is also important to investigate which actors within these types of networks are crucial for the CEA companies to collaborate with in order to accelerate their acceptance in the global market.

Because even if the CEA technology might be a possible solution to the future food challenge, the technology needs to mature significantly from being a niche to a more standardized product in order to address these issues. The road to being a standardized product can be long and challenging, and it is therefore crucial to understand how innovation systems can facilitate the growth needed for the CEA companies. To understand the challenges that new innovations like CEA companies are facing, the Multi Level Perspective (MLP) is used. The MLP is a framework that is used to understand how technology changes and spreads. It looks at three different levels: the technology itself, the organizations involved, and the wider society. Through this MLP helps to see how these levels interact and influence each other and from there identify what factors that can either help or hinder the adoption of new technologies (Geels, 2002). By using MLP in this thesis, we can better understand the challenges, why they exist and how they can be solved.

1.3 Research question

How can innovation systems facilitate growth for CEA companies through a Multilevel perspective?

1.4 Delimitations

For this research, only new innovative companies that operate within the CEA industry have been interviewed and thus have all the traditional food producers been excluded from participation. This was done due to the fact that it was our belief that these companies had the best experience and understanding for the barriers and possibilities within an innovation system and the industry. To this selection of company, it should be added that a clear majority are only selling salad and various herbs and are as of now lacking protein-based products as commercially viable, which could further affect the scope of the thesis. Due to the limited time that was given for this thesis only governmental organizations from Sweden have been interviewed while the companies are from different countries.
It shall also be mentioned that the companies which have been selected for participation are all established in a close geographical proximity of each other, all from the northern/west part of Europe.

1.5 Structure of the thesis

Theoretical Framework In this chapter the theories that create the theoretical framework are presented. There are primarily two different theories that are used, various theories within innovation networks and the multi level perspective (MLP) which later are combined into one conceptual framework.

Methodology In this chapter the methodology that was used in order to answer the research question is presented and motivated. This chapter includes data collection, triangulation, analysis of data, criticism, ethical aspects and a presentation of the interviewed companies and organizations.

Empirical Findings In this chapter the selected empirical findings that were found during the interviews are presented, the empirical findings are divided into 7 different categories that were identified. These were investments, important actors, competences, market perception, sustainability and internationalization.

Analysis & Discussion In this chapter the theoretical framework and empirical findings are combined in order to analyze the findings from the interviews together with the theoretical framework in order to try to find a possible explanation to the empirical findings that enable an answer to the research questions to be presented.

Conclusion In this chapter the main findings and along with the answer to the research question are presented. Also theoretical contributions, implications and recommendations and ideas for future research are presented.

2. Theoretical Framework

2.1 Innovation systems

Innovation systems refers to the networks of individuals, organizations, and connections that participate in the creation and dissemination of knowledge, concepts, and technology. This includes businesses, colleges, research centers, governmental organizations, and other organizations, as well as the networks and connections that bind them together.
Innovation systems are dynamic and interactive in their nature, with system actors constantly adapting to and reacting to changes in the external environment. In recent times, academic study and policy analysis have increasingly centered on innovation systems because they provide a framework for comprehending how innovation occurs and how it may be encouraged and supported. In addition to the significance of cooperation and knowledge exchange among various players in the innovation system, this research has also highlighted the significance of institutions and policy in determining the incentives and possibilities for innovation. In general, the study of innovation systems offers a useful way of comprehending the dynamic and complex character of innovation as well as for determining the strategies and policies that will promote its future growth. Innovation systems can be divided into different types where they can be all from global systems that are outspread all over the world to small regional innovation systems. In this thesis both global-, national- and regional innovation systems will be used as a part of the theoretical framework (Chaminade et al 2018,Asheim et al 2019).

There has historically not been much connection between sustainability and innovations systems, but during recent years more research has been made on these connections. Altenburg & Pegels (2012) defined the concept of Sustainability Oriented Innovation Systems (SoIS) as "*the networks of institutions which create, import, modify and diffuse new technologies that help to reduce environmental impacts and resource intensity to a level commensurate with the earth's carrying capacity".* Altenburg & Pegels (2012) concept emphasizes a new thinking model for governments and new agendas that facilitate internalizing the environmental costs and help new technologies that promote sustainability. The starting point for SoIS is that there is a need for environmental sustainable technologies to be developed at a more rapid pace but to adapt and develop this can be hard in an environment that is influenced by market regulations and short term thinking. Therefore in many situations governmental and national incentives are necessary. The incentives can both support or subsidize technologie as well as change in policies in a more favorable way. The SoIS concept focuses mostly on technological development as the main factor for sustainable development Altenburg & Pegels (2012). Chaminade at al (2018) believes that the transitions are as much related to the diffusion as of the development of technological solution and propose the following definition of sustainable innovation systems "*An open, evolving and complex system that encompasses relationships within and between organizations, institutions and socioeconomic structures which enables the generation and diffusion of innovations reducing the environmental impact of human activities to levels compatible with the planetary boundaries and with adequate levels of global economic and inclusive development."*

Chaminade et al (2018) means that even if it is true that the transformation that is needed within environmental sustainability would benefit from cooperating at a global level, it is also true that some countries need to take on the leading positions and build up these networks, and therefore they expect a movement towards more sustainable national innovation systems.

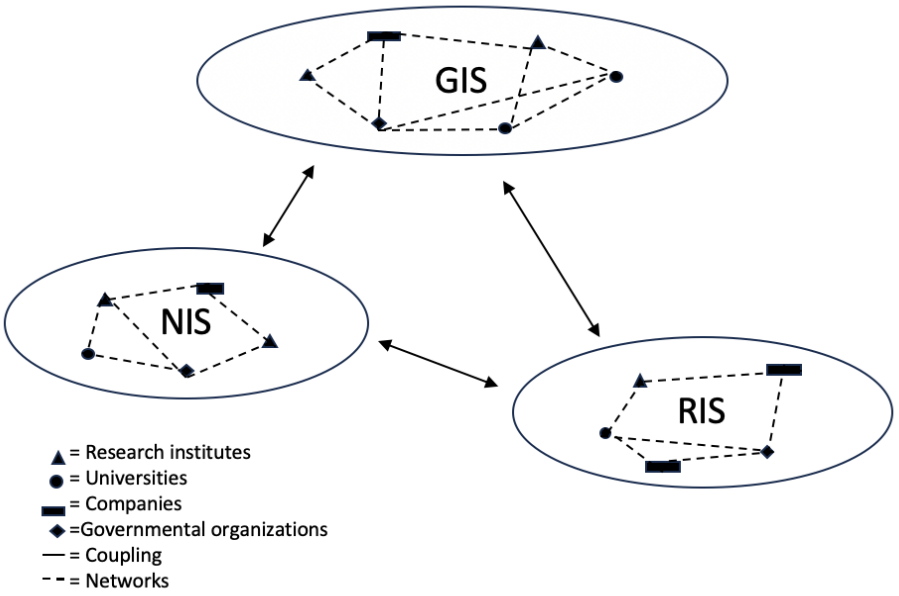


Figure A example of the structure a Global innovation system could have

2.1.1 Regional Innovations Systems (RIS)

Regional Innovation Systems (RIS) are networks of organizations, businesses, universities and other stakeholders that collaborate to promote and spread innovation within a close particular geographic proximity to each other and not necessarily within a country's national borders (Asheim et al., 2019). The RIS can make us understand how regional factors can affect the innovation capabilities of firms. The concept of RIS is pretty new and was first introduced in the early 1990s by Philip Cooke (Cooke., 1992). Regional innovation systems mainly consist of three core entities 1) Networks, including relationships between organizations as well as providing R&D, knowledge flows and cooperation. 2) Actors, who are the different organizations like universities, firms and governmental functions. 3) Institutions, which are the norms, culture and laws that exist within a region (Asheim et al., 2019). Most RIS are located within a country but they do not have to be limited to just one country. The Öresund region in southern Sweden and Denmark is one example of an RIS that exists across country borders, where both Danish and Swedish municipalities, organizations etc collaborate (Asheim et al,. 2019). Depending on how the RIS is constructed the need for external knowledge can differ. Diverse and organizationally thick RISs often have less need for external knowledge while thinner and more specialized ones have a stronger need for external knowledge to complement the specialized knowledge (Martin et al., 2018).

The external knowledge can come from many different ways including personal relationships, international collaborations, labor mobility, FDI and more. (Martin et al., 2018) As mentioned earlier, an RIS consists of Universities and research institutes, companies , government agencies, and other entities participating in the innovation process, such as non-profit organizations and industry associations. These different actors are linked together by both formal and informal networks, including supply chains, clusters, and networks for information sharing. By utilizing the skills and assets of the several parties engaged, a RIS seeks to promote innovation and economic growth within that specific region (Asheim et al,. 2019).

This is frequently achieved through the creation of new products or services, the development of new technologies, and the sharing of knowledge and expertise between firms and actors. These procedures may help boost the local economy and strengthen their competitiveness. RISs are frequently linked to regional innovation and entrepreneurial support programs like funding for research and development, the building of specialized infrastructure, and the encouragement of cross-organizational cooperation (Asheim et al,. 2019).

However the theory is not exclusively positive towards the regional innovation systems, Martin et al (2018) describe how small RISs with few actors are bad at identifying what kind of knowledge that they need. Furthermore they also explain how regions sometimes can be too specialized and locked in to their knowledge and therefore have a hard time to absorb and use external knowledge.

2.1.2 National Innovations Systems (NIS)

Just as RIS, National Innovation Systems (NIS) builds on the concept that communication and interaction between organizations facilitate innovation. Previous research has shown that companies through interaction with other actors such as users, suppliers, universities, competitors absorb ideas and therefore promote the innovation process through involving several different actors (Chaminade,. et al 2018). Similar to other innovation systems, an NIS includes all the organizations that are a part of the innovation process but the NIS gives extra attention to the companies or organizations that are rooted or located within the national borders.

However the system is not closed contrariwise its open and one of the main characteristics of an NIS is the ability to absorb and take advantage of the knowledge that is developed abroad (Chaminade,. et al 2018).

Lundvall et al. (2009) define National Innovation Systems (NIS) as:

> "*an open, evolving and complex system that encompasses relationships within and between organizations, institutions and socio-economic structures which determine the rate and direction of innovation and competence-building emanating from processes of science-based and experience-based learning"*

There are two different views on national innovation systems, the narrow and the broad one. The narrow view focuses mainly on the relationships between R&D and innovation, while the broad definitions of national innovation system assumes that the innovations process include the diffusion and use of new technologies and also the introduction of new technologies as well as formation of new ideas. Given that the broader definition includes more actors, both national institutions and different organizations that shape the learning processes and human resources. Some organizations are formally engaged in education and training and the aim for them is to shape new competence while others are more informal and consist of different frameworks for experience based learning (Chaminade., et al 2018). This could for example be the dynamics of the labor market where it could promote organizational learning which in the longer run shape people competences, interactive learning which helps the innovation process (Chaminade., et al 2018).

Different NIS can be more or less open when it comes to absorbing and adopting new technologies. The reasons for it are often different but one explanation can be that the success of previous established systems can explain the lack of new systems since there exists a resistance to open up for new technologies. This trend has been seen in the energy sector where systems that are heavily dependent on coal based energy systems often lack greener energy systems. The resistance can both come from the behavior of single actors but it can also be of a more systematic character and rooted in the innovation system in forms of collaboration and the independence that exists within the NIS or in the institutions (Chaminade et al 2018). National innovation systems also play an important role in sustainable development.

In today's society where rapid climate change is one of the most pressing issues one big question remains: how and if we can increase our social and economic development without risking the future sustainability of our planet. To address this pressing issue it is crucial to drive technological innovations both within products and also within processes (Chaminade et al 2018). In addition to this, new technological innovations, like social-, organizational and institutional change are necessary. Both of these require national innovations systems that can enable the necessary radical and incremental innovations to ensure a sustainable development (Chaminade et al 2018).

2.1.3 Global Innovation Systems (GIS)

In the globalized economy that we are seeing today the boundaries between what's global, national and regional become more and more blurry. With greater complexity in the innovation process the so-called Global Innovation Systems (GIS) perspective has gained more importance recently. International networks can take various forms, ranging from formal hierarchical organizations to virtual communities that are loosely connected based on shared knowledge. Examples could be found in the field of software development for example where the structure is very loose. These networks are the result of diverse geographic and non-geographic proximities that can be institutionalized to varying degrees. They can last just for a short time like international conferences or they can span for a long time such as international associations (Binz & Truffer (2017). Binz & Truffer (2017) are in their research paper analyzing the increased importance that GIS are having in the international business environment. This is because the traditional innovation system theories which are based on RIS and NIS are harder to apply since today's business are more internationally interlinked than before. The GIS should not be viewed as a replacement for either RIS or NIS but rather as a compliment for better understanding the international context which has played a more prominent role the last year (ibid). Carlsson (2006) emphasizes the fact that innovation systems are becoming more internationalized even though some institutions which previously supported the national innovation systems remain within country specific regions. Binz & Truffer (2017) refer to the important role that RIS and NIS plays as they could either play a contributing part of the GIS, a functioning GIS could consist of several NIS and RIS systems.

Through the GIS, these innovative systems could be interconnected with each other and benefit from the different competence the different networks inherent and thus benefit from international presence (Binz & Truffer (2017). Another challenge that historically has hindered new innovation to grow internationally is the lack of international legitimacy since they constitute the niche of the market where they need to challenge the existing market. Some of these hindrances can be eased by participating in a GIS and thus gain legitimacy and gradually become standardized (Binz et al, 2016).
The wind turbine industry was used as an example where the industry competence historically and still today is strongly concentrated within a national context but where participating in the global innovation system has led to global presence. On the other hand, the solar photovoltaic industry was, according to Binz & Truffer (2017) used as a contradictory example. As the industry and its actors in the innovation system all could be found on a global level and could therefore not be directly linked to a geographical region like the wind farm industry could to Denmark (Ibid). Actors like R&D, companies, consumers, institutions and investors were considered. It is important to emphasize that the GIS system and the role within the network is a dynamic process which is a constantly changing environment that is also highlighted by Binz & Truffer (2017). This indicates that an immature industry like CEA could have a greater need of participating in the regional or national innovation systems in the early phase of commercialization since a region or nation is driving the innovative industry, as in the case of wind turbines in Denmark. But as the industry matures and international competence is needed in the sense of skilled workforce, investors or R&D the structural belonging can change as a result of the changed business environment (Ibid).

2.2 Multi level perspective

The multi level perspective (MLP) analyzes technical transitions from a multi dimensional perspective and combines both the actual technical change but also the change in the society from user practices, industrial networks, regulations, culture and infrastructures. The MLP focuses on three particular mechanisms: Niche-cumulation, Technological add-on and hybridisation and riding along with market growth (Geels, 2002).
The MLP perspective of technical transitions stems from sociology of technology and in this perspective the technology itself has no real power when it comes to transitions, instead it needs to be in association with the social structures, human agency and organizations.

Only if these boxes are ticked then does technology fulfill its functions. Radical new technologies often face a mismatch with the current regulations, infrastructure or user practices and therefore often have a hard time to break through immediately but these socio technological configurations do not remain closed for good and can be undone (Geels, 2002).

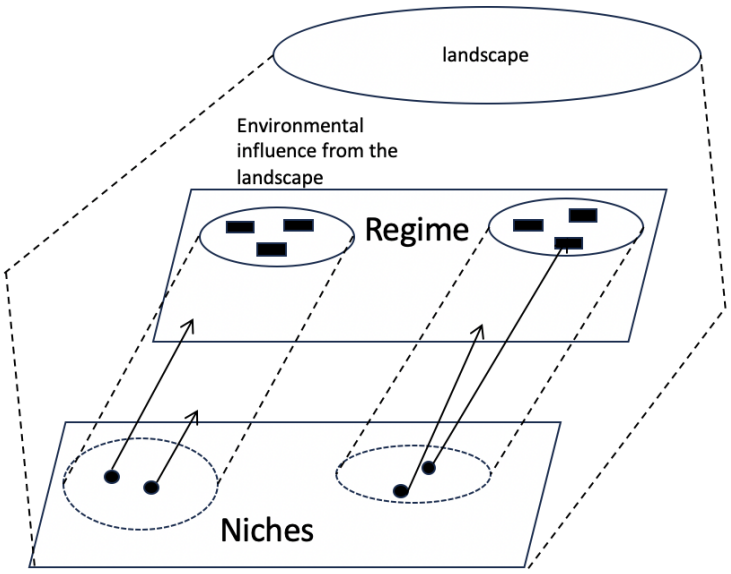


Figure B, example of the MLP configuration, inspired by (Geels, 2002).

Geel divides the environment in three levels with the socio-technical landscape on top which is divided into different socio-technical regimes which in turn are divided into niches. The socio-technical landscape (STL) consists of deep structural trends and it contains a set of heterogeneous factors e.g. economic growth, immigration, wars, political coalitions, commodities, prices, general values etc. The STL is viscous and it takes a long time for changes to occur.

Technical regimes are described by Rip and Kemp (1998):
"A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures".

While incremental innovations normally are generated in the broader technical regimes, radical innovations are generated in niches, these niches are protected and insulated from the so-called normal market which offers them a protected environment to grow. This is often necessary since they tend to have a low economic performance in the beginning since they are inflexible and expensive. The multi level perspective highlights the importance of the new technologies to break into the existing regimes and landscapes and not only develop within the niche for the future success of the new technology. Change in the landscape can put pressure on the regime who in turn can open doors for the new technology. Geels means that the general patterns when radical innovations go from niche to regime level is that they follow trajectories of niche cumulation (Geels, 2002).
This development doesn't happen in one step instead this transformation occurs gradually. There are several mechanisms involved in the breakthrough of radical innovations, one is add-on and hybridisation, the meaning of this is that technologies in their early phase physically link up with already established technologies, this is often required to solve a lot of the bottlenecks that occur in early stages (Geels, 2002).

Another mechanism that Geels highlights is the fact that new technology breaks out of niches by following along with the growth in particular markets. To exemplify the authors mentions the situation for steamships where the development was highly aligned with the growth in the passenger transportation over the atlantic.
If the situation in the regimes are stable radical innovations has a hard time to break through but if the regimes experience problems the linkages in the configuration eases up which creates opportunities for the innovations to get out of the niche level and become an incorporated part of the socio-technical configuration and if these new elements are introduced within the regimes they can trigger further developments for the innovation.
The emergence of specialized actors that are directing their activities towards expanding and improving their elements are also a big driver for further change (Geels, 2002).

Innovation within existing systems and regimes tends to be incremental and path dependent because there exist a number of lock in mechanisms. The different lock in mechanisms are Techno-economic-, social and cognitive- and institutional and political lock in mechanisms. While radical innovations normally emerge in smaller niches at the periphery of existing systems, this happens through pioneering activities by entrepreneurs, activists, start-ups and more.

The interaction and development that occurs between existing socio technical systems and niche innovations are affected by the broader context and includes both external shocks like wars, financial crises etc but also slow changing developments like social concerns, geo politics, macro economic trends and more (Geels, 2002).

The MLP has received criticism for not acknowledging conflicts, culture or politics since it tends to focus on artifacts and technologies. Geels (2019) argues that this criticism is misleading because even though MLP uses innovations and technology as an entrance point for analyzing. The analytical strategy of following innovation trajectories draws attention to multiple different actors and struggles. According to Geels (2019) this technological transformations happens under a long time and can be divided into four different phases:

Phase 1: Is characterized with trial and error and experimentation while learning about the radical niche innovations. In this phase there are many uncertainties, high rates of failure and pioneer burn-out and competing promises and claims.

Phase 2: In the second phase the innovations are more established and enter more market niches which generates a greater flow of resources. The innovations often transform into a more dominant design. Sometimes though innovations can receive criticism from social groups who are experiencing negative side effects, which can result in controversies. This has for example been seen in the situation with wind power.

Phase 3: In this phase the previous radical innovations transforms into the mainstream markets where they are driven by both niche internal drivers like economies of scale, price and performance improvements but also from taking advantages of structural windows of opportunities that are created by landscape developments that are putting pressure on the regimes for a change that are leading to destabilization of the regimes. This phase is characterized with a lot of conflicts between the existing and new innovations both regarding economically, politically and the business aspects.

Phase 4: In the final phase will the new socio-technical systems replace the old ones and in these steps become institutionalized in the society. This includes user habits, regulatory programmes, professional standards and more.

2.3 Conceptual model

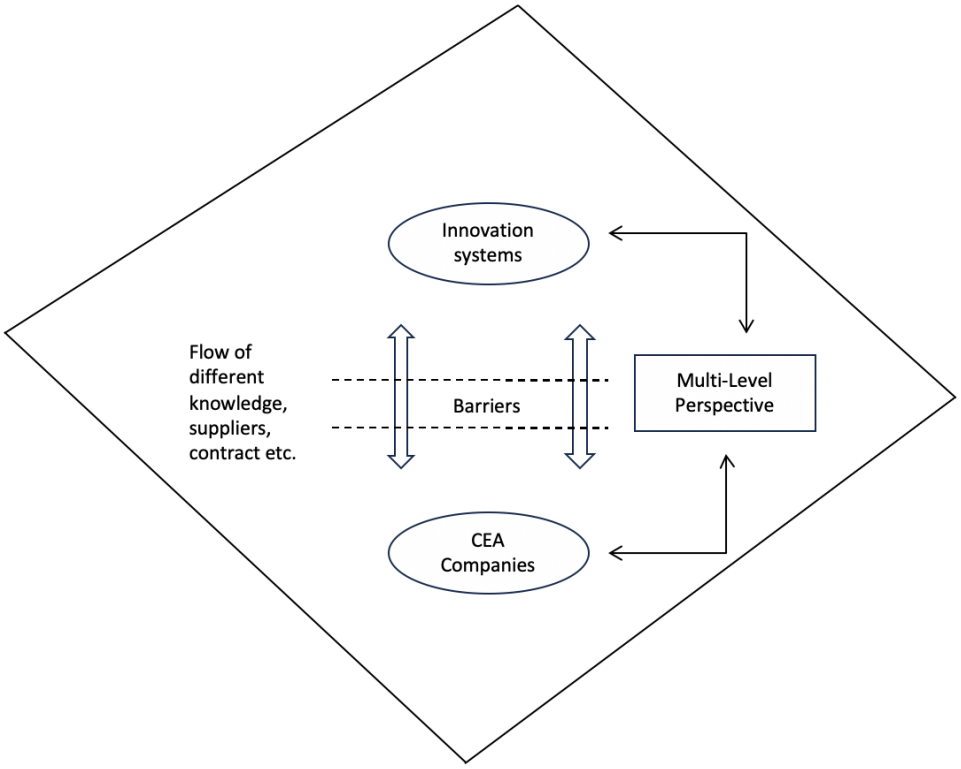


Figure C: The Model represents our conceptual theoretical model. The MLP and the arrows symbolize the interaction between the CEA companies and the Innovation Systems and how the process and the barriers that occur can be explained by the MLP. The model is also considering the influence which the landscape has on the relationship and how barriers can be understood, which is symbolized by the bigger arrows.

In this thesis the theoretical framework has mainly been constructed around two theories: theories about innovation systems and the MLP (Multi Level Perspective). The innovation system theories give relevant information regarding how the supporting systems are constructed, their functions and what qualities that are important to create a successful innovation system whilst the MLP theory enables an analysis of the dynamics of socio-technical transitions. This enables us to analyze the barriers and processes that the CEA companies are facing throughout their business journey since the theory includes the three dimensions: niche, regime and the landscape.

By combining these perspectives, the model will analyze how innovation systems in the CEA industry interact with the MLP and its dynamic process. It will further explore how actors, institutions, and policies within the innovation system contribute to the emergence and the spread of CEA technologies and practices, while also considering the broader landscape factors that enable for a system-level change in agriculture, towards an industry who uses controlled environment technologies to a further extent than before.

In this conceptual framework it is assumed that CEA and the interviewed companies are considered as “niche” actors in the food market and thus in the beginning of the MLP “cycle”, something which is further described in the section above regarding MLP. This assumption is made since vertical farming was first popularized in 1999 by Dickson Despommier and it took many years until small scale commercialization, when traditional food production has been ongoing for many 100 years (Cambridge consultants, 2018).
The established and traditional food producers are considered to belong to the “regime” and are thus representative of the market and its “norms”.

Since the research purpose for this thesis is to investigate how different innovations systems can facilitate growth for disruptive industries such as CEA. An important step in order to grow is to make the transitions from being niche to being part of the regime. It is important to incorporate the different innovation systems and understand the influence from the “landscape” emphasized in the MLP to understand what is needed to make the transition and also identify challenges.

By including various innovation systems, which could indicate the maturity phase of the company (see GIS paragraph), it can also help to identify what type of innovation systems the CEA companies need in order to transform from niche to regime. The MLP theory is considered to be a dynamic process where several environmental factors are considered such as politics, climate and public perception etc. These factors amongst many others are considered to constantly influence the market in a dynamic process.

As the MLP theory partially depends on environmental factors that are influencing the business climate it is also of value to analyze which innovation networks, partners and governmental regulations the CEA industry needs in order to start influencing the "environmental factors". It is vital for a CEA company to understand this dynamic to be able to make the transition from niche to a regime.

An additional feature with this conceptual framework is the theoretical knowledge to understand how established food producers (regime) also have made the transition which the CEA industry is keen to do and that the regime also is embedded in one or several different innovation systems. This is probably a developed network which has been constructed over several years and where the need to have various partners have changed throughout the years. By understanding this, it can deepen the understanding when analyzing these firms and it can facilitate for the CEA companies when they are trying to challenge the established regime. Another important knowledge due to the fact the regime belongs to an innovation network is that the niche and its innovation systems in a way also will challenge the established innovation network and stress for a structural change. This indicates that it can be mandatory to challenge several different actors and their perception and not only the traditional food producers but also the actors within the innovation networks which the food producer is embedded in. This theoretical framework is believed to extend the possibility to analyze and understand an existing market and to also understand the challenges a niche product like the CEA technology are facing in order to successfully change the market.

3. Methodology

3.1 Scientific approach

3.1.1 Research strategy

The purpose of this research was to investigate and answer: *How can innovation systems facilitate growth for CEA companies through a Multilevel perspective?* The research question constitutes the basis for the design of the research strategy that needed to be conducted to achieve the desired result. The strategy was to use and review existing literature within both innovation networks and MLP and to later apply those on the CEA industry together with the conceptual framework. In accordance with Bell et al., (2022) the theoretical findings were later used to formulate relevant qualitative questions used in the interviews with several different stakeholders within the CEA industry. Due to the complexity of the research question we found that a qualitative approach to be most suitable for the thesis This since the qualitative approach enables the researcher to gain a deeper understanding of the research subject, social context and other factors that might affect the outcome of the research topic (Ibid). Since our goal with the thesis has been to find how innovation systems can facilitate growth for CEA companies it was necessary to conduct a multicase study in order to try to make our empirical findings more generalizing to the whole industry and not a single case study where the empirical findings only can be tied to one company and their experience. To further nuance the findings in the thesis we have conducted interviews with several governmental organizations and research institutes, all active within the CEA industry, to give their view on the opportunities and challenges that the CEA companies are facing.

3.1.2 Research approach

In this thesis the use of both deductive and abductive approaches have been selected as the most suitable approach. By applying more than one research approach it enabled us to elaborate between different perspectives how existing theories, hypotheses and empirical findings are influencing each other depending on the approach you are applying (Patel & Davidson, 2011).

The initial step of the thesis creation was to generate a general knowledge about how the different innovation networks are affecting the emergence of new industries, potentially, such as the CEA industry the deductive approach was used due to its characteristics as a top-down structure were existing theories are formatting the research question which later will affect the selection of empirical data to the study (Patel & Davidson, 2011). The deductive approaches are symbolized by the fact that the existing theories are generating the hypothesis which later on will be tested through empirical data collection (Bell et al., 2022). The interview guide (see appendix 1) was generated from the chosen theories and the hypothesis in which the empirical findings strive to acknowledge or neglect the theories relevance, this was done in accordance with the deductive working methodology (Bell et al., 2022). explained by (Bell et al., 2022).

The abductive approach which is a combination of the deductive and inductive approach strives to generate a dynamic research approach whose goal also is to bridge the gap between the two methods and erase their limitations. The method is used to find explanations for empirical findings where the chosen theories lack the ability to explain the phenomena. The dynamic and ongoing interaction between empirical observations and theories is thus aiming to harmonize and further develop existing theories (Ibid). The abductive approach was therefore used when analyzing the empirical findings since some of the empirical observations were difficult to explain by only using the deductive approach and needed to be further complemented by the abductive approach. This was since existing theories did not have the ability to sufficiently account for the findings during the interviews. Since the abductive approach offers the possibility to move back and forth between empirical evidence and theories the possibility was also given to find a logical explanation to findings and further develop existing theories (Bell et al., 2022). The abductive approach also gave us the possibility to later revise the theoretical framework and create a new updated framework based on the new findings.

3.2 Data collection

The thesis has used both primary and secondary data in order to generate as reliable and trustworthy research as possible. The primary data represents the data generated by the interviews that were conducted with relevant stakeholders(Benedictine University, 2023).

The Primary source is also giving the researcher a direct insight in the event they are researching which often is characterized by interviews with high value people that are directly involved or can give first-hand experience of the problem and their viewpoint (ibid).

Primary data sources were the source most frequently used since it was important to get the perspective and experience from people who had extensive knowledge within the CEA industry. But also so they could express their personal opinions about the future need for the industry. Due to the early stage the CEA industry is considered to be in the need to access first hand sources and was considered to be of great usage due to its direct access to the area of research. Secondary data sampling has also been used throughout this thesis. The secondary data is characterized by the fact that it is generated in relation to another research or event that has happened previously in time and is not directly connected to this specific research which the primary sources are (Benedictine University, 2023). The secondary data which was used most frequently in this paper have been existing research considering CEA industry as well as several climate reports published by EU, UN or other relevant organizations. Secondary data does not offer the unique insight as the primary data does, instead it can be used as an effective method to find other arguments which can amplify the validity and argument and validity of findings from primary data (ibid). The secondary data used in this paper is partially research done by the UN regarding food production and future food security. Research done by other relevant stakeholders have also been used and was considered to contribute with useful insight and strengthen our findings as well as broadens the perception of the studied phenomenon.

3.3 Interview methods

The purpose with the interviews was to get as much valuable information as possible from each interviewee and try to interpret their experience from the industry, and later being able to compare the different companies with each other.
This was done to find similarities and deviation within the CEA Industry. To be able to interpret the experience from each company representative it was important to have semi-structured interview questions, giving the respondents the possibility to nuance their answers freely. Although the questions had a low degree of structure, they are still grounded in the theoretical framework used throughout the thesis.

It was yet important to have some degree of predetermined questions that were asked to all the company representatives in order to create some degree of homogeneity so a comparison would ensure validity in the analyzing chapters. A qualitative interview strategy is often characterized by this type of structure (Patel & Davidson, 2011). The predetermined questions constituted an interview guide (see Appendix A) and were asked to all companies. The respondents also got the questions in advance in order for them to prepare in the best way possible and to feel relaxed before the session. The method used was therefore best described as semi-structured where some questions were predetermined but room for individual interpretation of the questions were given(Patel & Davidson, 2011). The purpose with the interview method was to enlighten characteristics and experience from every individual, which naturally will differ within the group. It was therefore very difficult to predetermined all the questions before, since the interview and the interviewee together are creating the forum (ibid). Since the interviews were conducted with governmental organizations like Jordbruksverket (Swedish Board of Agriculture), Landbruks Universitetet (Swedish University of Agriculture Science) and Naturvårdsverket (Swedish Environmental Protection Agency) the questions were adjusted to match their profile better (See Appendix B), since they are not a profit driven organization and their perception regarding hinders and possibilities could differ significantly. However, the same interview techniques were also used during these sessions.

Since all companies selected for participation in this thesis were located either abroad or in a Swedish city far from our location (Gothenburg) every interview was conducted via the internet, either via Zoom or Microsoft teams. Using internet techniques was a way to increase the effectiveness and limit our environmental impact. All interviews were of essence, in case any additional question arose after the interviews supplementary emails with questions were sent out to the respondents.

3.4 Sampling criterias

3.4.1 Selection of companies

For this thesis the respondents have been selected to participate since they all represent a company or organization that was considered to have either deep knowledge about the CEA industry or employed at an organization that plays an important part in the innovation system. The governmental organizations that was interviewed was: Swedish Board of Agriculture (Jordbruksverket), Swedish Environmental Protection Agency (Naturskyddsverket) and Swedish University of Agricultural Science (Svenska lantbruksuniversitetet) (SLU), where the two former plays an important role in implementing laws and regulations in Sweden and act on behalf of the Swedish state. They are currently active within several different aspects which are needed in order to facilitate the growth of a new technique and technology like CEA and were therefore interviewed. The University was interviewed because of their involvement in both education and thus the supply of skilled workforce and the development of these new farming methods where they also have done studies, for this thesis a PhD student, which had done a lot of research within the CEA industry was, interviewed to further deepen the understanding of the research subject in question.

All companies interviewed for this thesis are currently active within the CEA industry either as a research institution, system deliverer or producer and they were chosen due to their expertise within the industry, and could therefore contribute with important information about the industry. Due to the limited size of the CEA market there are not many active actors in each country and therefore companies from different countries were included in the thesis. We choose to only include companies from countries within Europe since they are active in countries with similar regulations and economic situations. This was done so that the findings would be more generalizability and enable us to draw more conclusions.
The participating companies were from the Netherlands, Denmark, Sweden and Norway and were selected since we found relevant companies for the thesis in these countries. In the selected countries several active CEA companies could be located, many of them being able to contribute with answers that could help answering the research questions.

The fact that only governmental organizations were interviewed from Sweden meanwhile companies from multiple nations was since the focus of the thesis was on CEA companies and therefore considered enough to only include governmental organizations from one country. The complexity of organizing a meeting with foreign organizations proved to be difficult which also influenced the decision to only include Swedish organizations.

3.4.2 Selection of respondents

When implementing a qualitative research approach in a thesis the selection of respondents is crucial since they are supposed to contribute with the empirical data that is used to answer the research question of the thesis. It is therefore an important step in the thesis to select which respondents that could be of interest for the thesis. The research question acts as a guiding light in the selection process since the respondents should answer the questions and thus need some degree of knowledge about the subject chosen which is also the main reason why random samples were not applicable in the thesis (Bryman & Bell, 2013).
Since the main focus of the thesis is to investigate how innovation networks can facilitate the growth for the CEA industry, respondents within the CEA industry have therefore been specially selected for participating, as well as other strategically important actors to facilitate a well-functioning innovation network. Including respondents from universities, governmental organizations and consumers (Chaminade. et al, 2018).
In order for the respondents to be able to answer the research questions several sampling criterias needed to be fulfilled in order to participate. We made the assessment that the respondents needed to be part of the management group and have been involved in strategic management. The respondents also needed to have worked within the company since the beginning. This was considered to be important since they could retell challenges and opportunities they had faced since the beginning, but also retell which actors they had worked with over the years and how it had influenced the company's progress.
When it comes to the respondents from the organizations we were looking for people with good insight in the CEA industry as well within the traditionally agriculture industry. It was also a decisive factor to only select respondents that had worked or researched within the field in order to be able to contribute with relevant knowledge.

As a result of the sampling criterias the following interviews were conducted:

Respondent	Position	Company	Interview platfrom	Language of the interview	Lenght
1	COO & Founder	A	Zoom	English	41:51 Min
2	CEO & Founder	A	Zoom	English	43:37 Min
3	Project leader	B	Zoom	English	49:33 Min
4	R&D, Founder	C	Teams	Swedish	42:23 Min
5	Innovation supporter	Naturvårsverket	Zoom	Swedish	45:58 Min
6	CFO & Founder	D	Zoom	English	50:58 Min
7	PHD & Teacher	SLU	Zoom	Swedish	48:23 Min
8	Advisor	Jordbruksverket	Zoom	Swedish	45:55 Min
9	Swedish Rural Network	Jordbruksverket	Zoom	Swedish	44:02 Min
10	Production & Founder	E	Zoom	English	41:26 Min
11	COO & Founder	F	Teams	Swedish	39:14 Min
12	CIO &Founder	Research Institute	Teams	Swedish	43:15 Min

3.5 Research quality

To ensure that the thesis maintained a high research quality both validity and reliability have been emphasized as important factors. According to Bryman & Bell (2013) these criterias are of great value in order to contribute with relevant research. Bryman & Bell (2013) are also emphasizing that the research strategy should be possible to replicate and apply to other situations within the context of the thesis but also to other similar studies outside this research. Even if the interview questions were constructed in a semi-structured way the validity was ensured since all the interviewed persons were given the same set of questions and were from that enabled to further elaborate with their own experience. The reliability does also cover the trustworthiness of the research and how it would react to accidental events such as deviations in respondents answers (Patel & Davidson, 2011). This problem was addressed by always having both the authors present at the interview session, enabling the possibility to have two observers at the session. All interviews were also recorded and reviewed afterward to confirm that everything was interpreted correctly . If any questions arose after the session the interviewees were contacted and asked for a clarification.

Triangulation is another analytic tool which has been used in the thesis in order to mitigate the risk of using data that turns out to be objective and only reflects the reality for one of the respondents. Triangulation means that multiple sources are compared independent from each other to ensure a unified view. This is done to ensure that relevant and trustworthy information was used in the thesis. Bryman & Bell (2013) describes triangulation as a method similar to that of navigation where you use different landmarks, and other geographically tools to find the same location. In a similar situation several sources have been used to ensure that the information gathered either can be confirmed as an individual experience from the specific respondent or an experience which is applicable on the industry as whole. A desired goal with using triangulations was to ensure that the thesis maintained a high validity and credibility.

There are a few different aspects of validity which have been taken into consideration in this paper, all of them being addressed by Bryman & Bell (2013) and are the following : measurement and external validity. The measurement criteria strive to ensure that the information gathered is truly answering what the data is supposed to do, this was done through triangulations as mentioned above. External validity emphasizes the question of whether a specific set of questions would be replicated to other groups of people besides those chosen from the specific session. In qualitative interviews it is therefore often of interest to invite participants that represent a sample of the general population. This was given great importance during the selection of whom to invite for an interview because of the importance of finding companies and representatives which had enough knowledge of the subject and would reflect and address upon the most common challenges. It was taken into consideration that the selection of interviewees could generate a somewhat objective point of view due to their business, however this was mitigated by inviting governmental organizations to represent a more objective part (Bryman & Bell (2013).

3.6 Analysis of the interviewed data

One of the biggest challenges with qualitative research is that the interview sessions generate large amounts of data in a short amount of time. The generated data is then often generated in the form of handwritten notes or transcription from the interview, in which the last option was the case for this thesis. As a strategy all interviews were quickly after the session transcribed by both authors and also discussed the most essential take away from each interview.

This information was thereafter put on a specific device to save it for later when the empirical chapters were constructed. Bryman & Bell, (2013) recall the large amount of data which quickly is generated through transcribing therefore it is important to find a pathway how to analyze the data in order to find the most essential for each session. In the thesis the open-ended questions were structured into different themes and asked subsequently to try to generate "sections" for the different topics, in which the analysis would later become easier to categorize.

Thematic analysis was partly used and is constructed through the analysis of several different aspects like: repetitions, analogies, transitions, similarities and difference between the respondents according to Ryan and Bernard (2003) which is referred to in Bryman & Bell (2013). The outcome from each interview was later compared with each other to find similarities and areas where opinions differed. From there the divisions and headlines of the empirical data was created. In accordance with Bryman & Bell (2013) all the coded data from the interviews was reevaluated several times during the process as new interviews was added and were the knowledge for the subject increased, to ensure that our initial interpretations stayed relevant as new insight emerged, a process called secondary analysis was used (Ibid). An Important working strategy was also trying to compare findings from the interviews, theoretical findings and with the problem discussion to compare their experience with other sources, a sort of triangulation.

Since the thesis is of qualitative character and it is the respondents perspective regarding the topics that is of interest for the purpose of the thesis the transcripted material from the interviews are very complex and broad as a whole. Because of this we chose to use the method of sentence concentration that is formed by Kvale & Brinkmann (2014). This is because we want to analyze the material in an effective way.

According to Kvale & Brinkmann (2014) this method of analyzing functions in the way that the interviewers thematize the respondents statements after how they perceived the statements of the responder. By identifying the main meaning of the interviews we could concentrate the words of the respondent to a few sentences and from that type a shorter summation that is more relevant for the report (Kvale & Brinkmann, 2014). This is exemplified in appendix C.

3.7 Critical aspects

One of the biggest disadvantages with qualitative interviews is that they tend to be very specific for the subject of the thesis or even uniquely adapted for the individual representative. Since we in this thesis interviewed several independent respondents from different CEA companies about their experience of the industry, the generated data was retold individually. Therefore, it could be hard to generalize and to replicate the generated data outside this research which sometimes could weaken the validity of the research (Bryman & Bell,. 2013).

However, the unique possibility to get several, independent from each other, insights of the industry from business leaders within a growing industry was considered to be of more importance. This since it generated a deeper understanding for the challenges and opportunities the enterprises have faced throughout the years, instead of a generalized findings which could be attained elsewhere.

The language which has been used to write this thesis is exclusively English, which has been used during the interviews with all international interviewees. There is always a risk of having interviews in a secondary language where the risk of losing important contributions is high due to different language skills and vocabulary. However, this risk was judged to be mitigated since all of the respondents as well as the authors handle English very well.

It was also of great importance to be objective towards the respondents and question why they are expressing themselves in a certain way and remember that they are representing a company. It is once again important to emphasize the use of triangulations to determine whether a standpoint or experience are representative for the industry or only an experience from one individual. It could also be of importance to acknowledge that all companies interviewed are in an expansion phase where their strategies are concealed from not employed people like ourselves. This could of course affect the representative's willingness to disclose the full truth regarding their experience on the questions asked. Another critique could be that the number of interviews from each company varied to some degree and that only Swedish governmental organizations were used in the thesis.

That only having a few representatives from each company was seen as acceptable since the people chosen for the interviews possessed a management role within the company and that they only had a handful of management positions in the company. It is also important to acknowledge that the amount of companies interviewed was considered acceptable due to the fact that they contributed a sufficient amount of data that enabled us to answer the question.

Since we did not manage to get in contact with any international counterpart to the governmental organizations we lacked the possibility to do a comparison between the governmental organizations. Instead the data collected from the Swedish organizations should be considered both as important input to the thesis and also constitute an example of how an possible interaction between companies and governmental organizations could look like in the other countries.

3.8 Ethical considerations

During the course of the study, ethical considerations have been made to ensure in the best way that no one is harmed or negatively affected by the execution of the essay. All respondents participate voluntarily in the interview and have all had the opportunity to find out in advance which questions that would be asked during the interview. This was also done to reduce possible stress during the actual interview situation for the respondents (Kvale & Brinkmann, 2014). In order to reduce the risk of possible incorrect reproduction of the respondents' statement, all interviews have been recorded and then carefully transcribed. All respondents have approved the recording of the interviews. Another measure taken to reduce possible ethical problems is that we let the respondents see the results of the essay before public publication. This is to ensure that they feel that they have been reproduced in an accurate way (Kvale & Brinkmann, 2014). In order to ensure that the research was constructed around a strong ethical framework the thesis have continuously been benchmarked and constructed with the available guidelines presented by vetenskapsrådet (2002) regarding how ethical research should be conducted. The guidelines especially emphasize how honesty, respect, reliability and responsibility are to be ensured by researchers in all various types of publicized information (ibid).
During the interviews it was made clear to all the respondents what the purpose of the thesis was, and in order to maintain their integrity every respondent was anonymous (ibid).

In further accordance with Vetenskapsrådet (2002) the collected data gathered from interviews and other sources was only being used to contribute with relevant insight to the project and was strictly limited to the only being used in the project. In addition, the collected data will be deleted as soon as possible after the necessary data has been extracted so that those who were interviewed maintain their anonymity in the project (Vetenskapsrådet, 2002).

3.9 Presentation of interview objects

For a general understanding about the companies and different persons that have been interviewed for this thesis a short introduction of each company and company representative are presented below. To protect anonymity as a company and individuals all companies except the governmental organizations have been replaced with Company A-D and the individuals as representatives for its company.

3.9.1 Company A

Company A is a Norwegian CEA company with roughly four full time employees and the rest of the workforce consist of students who have applied for internships at the company. The number of students and part time workers have varied in numbers over the years and even school profession varies significantly, where some are studying finance and economy and some are taking their studies within biology. The company was founded in 2020 by five students who had different academic backgrounds and saw the potential of entering the CEA industry with a business solution that can help to create a more sustainable and viable food production within CEA which has been their area of interest.

Company A are today in their early face of commercialization and do have high ambitions of providing their business solutions to several international markets where their technique could help to solve farming related problems, like water scarcity. The company is as of now only active in their home market. For the thesis the CEO and COO, both founders were interviewed for the project.

3.9.2 Company B

Company B is a Swedish company which was established during 2019 and has experienced a rapid growth since then and is today located in several outlets in its home market. The company's main focus and business model is to deliver a subscription model to its customers known in the industry as farming-as-a-service (Faas). The company calls themselves as an agrotech company whose business is to develop and systemize their hardware and software and later integrate them into the consumers facilities, as a result their crops are hyper locally produced with minimum to zero transportation and thus the transportation is further reduced. Company B´s primary idea is not to sell the harvested salad or herbs to the customer, instead the business idea is to offer the subscription for the hardware where uptime and production are optimized for their requirements This business model is according to company B a way to mitigate the risk for both parties since the customer doesn't need to invest in the infrastructure and Company B doesn't have to handle the logistics after harvest. The company representative was one of the original founders and currently holds an operative role as CIO and was also responsible for their innovation lab responsible for developing their products/platforms, new technologies and talent program but similar to many other companies the role includes much informal work as well.

3.9.3 Company C

Company C is a Swedish vertical farming company (CEA) founded back in 2017 where the main focus today is to produce and sell salad and other produce from their own facility. Currently the company has around 85 employees, where roughly 55 persons are directly involved in the farming and harvesting of the crops and the other 20 personnel are mainly involved in supporting roles such as management, sales and operations of the business.
For this thesis the head of R&D (CR/DO), who was also one of the original founders, participated in the interview regarding the development journey of the company. The company currently has a significant production in its home market where their current facility allows for around one ton of food to be shipped each day. Their management teams' long-term goal is to achieve a significantly higher production where they can offer an affordable sustainable alternative to the traditional salad which has a bigger climate impact and sometimes inferior qualities. The continuous growth is not necessarily restricted to their home market but they see a global need for this type of product.

3.9.4 Company D

Company D is a Danish company founded back in 2015 on a small-scale concept in order to verify the technique and business model, and 5 years later raised a significant amount of money and did also ramp up their production significantly to be one of the bigger producers in Europe within the CEA industry. The company representative who participated in the interview session is formally known as the CFO of the company but was one of the first to join the startup firm a couple of years back in time. As the company is currently going through a very expansive phase the CFO title is more of a title while the daily chores are enormously varied and goes far beyond the traditional CFO task. The current business idea is to grow organically within the home market but is constantly looking for opportunities regarding internationalization as soon as the market allows it. The company is currently focusing its production on herbs, kale and salad but are constantly researching new alternative products. The company today consists of around 35 employees with a range of educational backgrounds and nationalities, with some having a financial background and some having a biological background.

3.9.5 Company E

Company E is a Dutch company that was founded in 2019, the company was founded by two family members who acquired another vertical farming company that went bankrupt. The other company was also involved within the CEA industry but when company E acquired the company the whole business strategy was redone and rebranded and Company E essentially became a new entity. Since then the company has undergone a rapid expansion and currently has around 90 employees globally.

The company has a national presence in the Netherlands but also international presence in one Asian country as well as one country in the Middle east. Their ambition is to continue their internationalization as soon as opportunities arise in the market and industry. For the conducted interview with company E, one of the founding family members participated. She is currently having a leading role as a manager at one of their production facilities.

3.9.6 Company F

Company F is a Swedish company that was established back in 2015 by three friends who had a common interest in the CEA industry and saw the possibility to solve several inherent problems that traditional food production has and to offer a sustainable product. For this interview, one of the founders was chosen to participate. He is still active within the company and is a part of the management team, working as COO. The company started its journey by building their first proof of concept production facility after a successful capital round where they were able to prove their business idea to existing and new investors. The idea of building larger production facilities was later put on hold when Company F found a new business segment which seemed more suitable for the company. The Company is now a supplier of infrastructure and the technology that is necessary to produce the CEA products. Their products are mainly sold to restaurants, school kitchens as well as food stores who want to increase their sustainability profile by harvesting their own salad and herbs instead of relying on remote produced food. Company F are today also acting as the retail for the harvest products because the CEA market still lacks the maturity. Research and development are also an important business unit within company F since there is a constant need for developing new products and to optimizing the system and finding new markets to establish the company in.

3.9.7 Research institute

Research institute is, unlike the other companies, a company whose business idea consists of offering business services and research on performing tests and R&D on new technology within food production, in other words a research center. The company mainly conducts research on outdoor vegetables, greenhouse horticulture, arable farming and fruits but have during the last years also expanded their offering to companies that are interested in the CEA industry. The research institute is part of an independent international organization who ensures and conducts independent verification on crops and their characteristics and has around 25 employees as of today. The company has its own production facilities where they can conduct tests and simulations of the plant's characteristics, this is mainly done by the institute. However, they are also selling this as a service to other global food producers who want to investigate new ways of producing food, like CEA for example. The research institute was founded back in 1986 but has since then undergone significant growth and today consist of several research facilities for CEA test and traditional production as well.

The person interviewed for this thesis is currently working as project leader within hydroponics and horticulture and has worked with various projects throughout the years he has been active within the company.

3.9.8 Swedish Board of Agriculture (Jordbruksverket)

Swedish board of agriculture is a Swedish governmental administrative organization whose focus is within food production in Sweden. The organization's main responsibility is within food industries such as agriculture, fishery, rural areas and has an ongoing mission to ensure that Sweden as a country is producing enough food at the same time having a sustainable and viable business practice (Jordbruksverket, 2023a). The assignment the organization has in order to further ensure the food production in the country and protect the animals and plants in the process. The Swedish government is the direct supervisors and the principal and advises them about areas of interest and law implementations.
Furthermore, the Swedish board of agriculture is responsible for helping Sweden and its government to achieve the global climate goals which encompasses food production and is also responsible to give out soft funding from five different European union-based funds (ibid). The organization consists of seven different business departments each responsible for different tasks and together offer a national presence, as of today around 1700 persons are employed by the organization (jordbruksverket 2023a).

For this thesis two representatives from the organization participated where one of them worked half time within AKIS (agricultural knowledge and innovations systems) in rural areas in Sweden where the other engagement was to represent landsbygdsnätverket (landsbygdsnätverket, 2023) which is a subdivision on Jordbruksverket and also Sweden’s representation for the EU based organization: The agricultural European Innovation Partnership (EIP-AGRI) (European Union, 2023). Both this organizations main task is to develop and grow the national agriculture and its inherent regulations.
The other respondent worked as a special advisor for crop protection whose main focus is to interpret and convey EU and national regulation to farmers and producers in Sweden. It also works the other way around where farmers and producers can ask the advisor when they have questions regarding their operations or how they can conduct their business in the best way.

3.9.9 Swedish Environmental Protection Agency (Naturskyddsverket)

Swedish environmental protection agency is also a Swedish governmental organization responsible for environmental related questions and has acted on the Swedish government as their principal. As stated the organization helps the Swedish government on sustainability related questions on both national, international and within the European Union (Naturvårdsverket, 2023a). In Sweden it is Naturvårdsverket that is the leading and organizing organization regarding climate, air, ground, biological diversity, waste management and much more (Ibid). The organization is also responsible to distribute several governmental grants to other enterprises and organizations which have agendas in line with Swedish environmental protection agency long term ambitions. The organization today consists of five different departments and today employs 800 with two national offices in Sweden (ibid). Naturvårdsverket has a responsibility to guide and educate various groups in Sweden to effectively comply with the government's regulations and have therefore an extensive webpage where much of the guidelines can be found (Naturvårdsverket, 2023b). For this thesis one employee was interviewed. His job was to give innovation support and help to newly established companies in Sweden and to find the right knowledge-based support they might need to be able to navigate in the complex environment and to be able to comply with regulations etc. The department of where he is stationed is also sometimes a supportive group on EU level where they act as experts within their area of knowledge.

3.9.10 Swedish University of Agricultural Science (Svenska lantbruksuniversitetet)

The Swedish University of Agricultural Science is a Swedish based University which has both a geographical and knowledge-based breadth. The University was originally founded back in 1977 when it was the amalgamation of several other universities. Universities like Skogshögskolan, Veterinärhögskolan, Skogsmästarskolan in Skinnskatteberg and Veterinärinrättningen in Skara (SLU, 2023a). However, the university has been doing various research long before it was established in 1977, the universities have in some degree contributed with higher education since the end of 18th-century primarily within agriculture, forestry and veterinary medicine. This is something which still is the main profession of the university and where they contribute to world class research regarding these subjects (Ibid).

The University is subordinated to the Swedish department ministry of rural affairs and Infrastructure, mainly responsible for rural areas, food and land- and water-based industries and much more (Government office of Sweden, 2023). Subordinated to the ministry is the board of the universities and then several “business units”, for example different faculties library (SLU, 2023a). The university currently has around 3200 employees and has around 4400 active students on bachelor and master level. The university also employs 535 research students who are currently doing their PhD at the university (SLU, 2023b). For this thesis one PhD student was chosen to participate in the interview. She was currently doing her last year out of four at the university but had previously worked within various agriculture companies. During her PhD studies she had done much research into different CEA systems and together with her supervisors interviewed both companies within the sector as well as traditional farmers and their perception about the CEA adaptation, she was therefore considered highly relevant and could contribute with deep and relevant knowledge about the subject.

4. Empirical Findings

The chosen headlines in this chapter are those subjects that were identified as the most relevant after analyzing the interviews and are further motivated in chapter 3.6.

4.1 Investments

4.1.1 CEA Companies

When talking with the companies it was pretty clear that one challenge stood out from the others and that is to find investors, and in most of the cases private investors. The CEA business is a very capital intensive industry which often requires high initial cost in order to be able to set up the machinery that is required, because of the high costs the production often needs to reach a certain quantity in order to take advantage of the economies of scale. Several of the companies described investments as the single biggest barrier for growth, company E described the situation when asked what the biggest for growth was:

"Investments, money, Yeah. We are lucky that we can still go on and we have a good investor. And we didn't have a lot of money to start with. So we couldn't spend a lot. So our system is pretty cheap. That helps as well…. investment is really the only issue we're still dealing with."

Similar experiences were shared by Company C that meant that investments were the single largest anchor to accelerate growth.

"*It's money too. We are in a very capex-intensive industry. It costs a lot of money to build a factory. It is absolutely the biggest bottleneck. If we had a huge fund of money that never runs out, we could have grown much faster."*

As mentioned above the main reasons why a lot of investments are needed is that the equipment is very expensive but also that economies of scale are required to achieve financial success. Company B described how capital is needed both when it comes to building the organization but also developing the technology and that you have to find a balance.

Company A described the problematic situation with the expensive equipment within the industry which has generated a higher price level than similar fish products that are produced in a traditional way. This has resulted in consumers choosing other products instead.
One of the difficulties regarding investments has been that the general knowledge of CEA has been low since the industry still is very new and emerging. But even though the knowledge is improving according to the companies some of them have described that it is first after time when you have a finished product and something to show up, that is have been easier to attract investors This is described by a Company D when asked about if it is hard to find investors

"*Now it's a bit easier because we know that, okay, we're also asking for a really big amount. But now we have a product to show. We have a production to show. We can show that we have been doing this for a couple of years."*

Private investors have been described as the most important investors by a majority of the companies since they can deliver big investments, and are more flexible and can handle time limits better than soft fundings.

But despite its disadvantages soft fundings have played a decisive role for the companies especially in the start up phase where they have been extra important. Soft fundings mostly comes from public funds in the shape of grants or subsidies, but they can also come from universities. Company B described how they had applied for money from several different funds and mentioning Vinnova as an exemple who is described as an innovation authority who are working to strengthen the innovativeness in Sweden (Vinnova, 2022). They have announcements where you can apply for fundings and they assess whether it is something they want to finance or not.

Both Company A and Company C mentioned soft capital as an important part. Company A had received fundings both from governmental level but also from local partners like Universities and Municipalities. Company C in their turn added Almi as a key partner regarding soft capital, Almi is a state owned venture capital company that invests in growth companies (Almi, 2023). The company representative explained that they both had been supported through soft fundings and also had been giving a proper loan to the company.

Company D who are active in the Danish market has also received support from similar sources. They had received support from Vekstfonden, a Danish investor fund who works with banks but also domestic and international investors to support growth companies (Vekstfonden, 2023). They also described how having support from a governmental fund worked as a proof of the quality of the business and it was easier for them to attract other investors when they saw that Vekstfonden had chosen to support them.

> *"So just coming, it was much easier to get the funding when you had this governmental fund in your back. So when I was asking people, hey, do you want to go into this project? they were like: What are you talking about? I just had a piece of paper. And yeah, but Vekstfonden, they're helping. Okay, then we will look into it."*

As mentioned above the soft fundings played an extra important role in the beginning and it was described by company F who described soft fundings together with private investors have played a big role for the company and especially in the beginning. it was necessary for the survival of the company.

“Yes, but in the beginning it was directly decisive, it was the only thing we had. Then, of course, the idea is to land on your feet with the product you develop. Since then, we have continued to develop. So the soft financing is often linked to development, to make the country more self-sufficient in food production or green development. Projects are then built around these issues.”

Even though soft fundings have an important role, especially in the beginning, most of the companies share the same perception that private investors are necessary in the long run. Because the process to get soft fundings is very time consuming, uncertain and it is sometimes hard to get the big amounts that are sometimes necessary to scale up the business the way they want . Company B also describes how these projects often have a very narrow framework and are hard to adapt to the normal projects

“*It becomes more difficult to work with such types of actors. Because then the project's framework becomes a little wider. And they are not as fast as a startup usually is. So it became less and less during the four years when we started."*

Company C describes how the process for getting governmental finances is too long and too complicated so they had the experience that you put in so much work for the limited reward and that they need money faster to be able to grow at the pace that they want. It is only when you reach the EU level that they have found fundings that is big enough to make it worth it.

“No, it's too slow. Early on we did a simple one million check application. But when you work with private equity and investments, it's not worth the time and administration to go to these government parts. Now we are starting to look into it a bit, but then it is the first EU level and contributions of over 50 million. Then it starts to be worth it. Otherwise, it costs more than it tastes, is our experience.”

Company E has also received some support from funds where they did receive some money in the start up phase but for the rest they have relied on private investors even though they see a potential shift in the horizon where they have seen a greater interest from the state and municipality during the recent time. With the recent economic situation that we have experienced in Europe and the world, with high inflation and increased interest rates, a lot of CEA firms have gone bankrupt due to the increased costs.

This has, according to the companies, resulted in a more difficult situation when it comes to finding investors, since the situation has scared a lot of investors from investing in the CEA industry. Company E describes how it is very difficult at the moment to attract new investors but that they still can rely on their big investors but are aware that they are lucky to be in that situation.

> "*But I know almost all investors are very hesitant to actually put some money in farms right now, because a lot of farms went bankrupt. A lot of farms are losing money. There's farms in the US collecting 200 million and going bankrupt within two years. So it's just difficult to find other investors. We've been relying on our one investor that helps us a lot, but finding others to expand is just very difficult.*

Also Company C has experienced a big change when it comes to the investing climate, where they describe that it was very easy to attract investors until last autumn (the fall of 2022) but it has since then has become much harder, but they also see this as a way of clearing out the companies that aren't profitable,

> "*It was very easy until this autumn, now it is very difficult. It is volatile and fluctuating. There is no simple answer to that question. Is the will to buy strong? Is the will to invest strong? Is everything relatively good right now? Then it's very simple, a little too simple. This means that the whole CEA bubble and indoor cultivation are going through a proper self-examination. We filter out companies that have been good at talking, less good at doing."*

4.1.2 Research institute

Due to the fact that the research company has a slightly different role within the CEA market their view on investments differ from the CEA companies as well. The project leader emphasized that it is important to note that even if the research institute is active within the market and most probably will be affected by the growth of the CEA industry, their main business has always been within traditional agriculture. This is also where the companies have seen a majority of its revenue come from. The project leader did also emphasize that his institute should not be mixed up with the CEA companies as they are only doing consultancy for those within the agriculture industry.

So even if the research institute may look a bit different he still emphasized that they also need to invest heavily into the CEA industry in order to keep up with the new technology and stay as a relevant research institute for the CEA companies.

Further on since the project leader has a profession within agriculture and not economy, he did have some difficulties to fully understand to which extent the CEA companies need economic support or if they can survive on their own. He did however emphasize that new technology which is required to produce a sustainable and efficient crop in a CEA system requires significant investment into getting technology readiness and the infrastructure in climate chambers, which is very expensive. The representative did also emphasize that since the CEA industry is in an early phase the technology is still very expensive which has resulted in companies neglecting many different crops which are possible to produce in a CEA-system due to the low economic value and are instead focusing on high value crops like salad and herbs. The research institute does furthermore have some ongoing projects together with traditional producers trying to see if it is possible to make low-value crops, like corn, profitable in a CEA-system by shortening the production cycle or increasing the yield. The project leader also predicted that the cost for operating a CEA-facility in the future will come down as electricity problems are solved and the market reaches an economy of scale. That would take the industry from a high end (luxury) product to become a common product which can help solve the climate crisis.

4.1.3 Governmental organizations

When talking to the PhD and teacher from SLU university she highlighted the trouble that the CEA industry has regarding the huge investments which are required to make a viable business within the industry. She emphasized that the high energy costs and high initial cost are affecting the profitability of the industry and also burden the development of the whole industry and those costs need to come down in order for the industry to reach their full potential. She further said:

> ” *But the energy prices as well as initial investments have both been very high. But if you manage to achieve industrial symbiose then you can reduce those costs and reach profitability and manage a sustainable business. Then all the good characteristics can be achieved“.*

One of the respondents was responsible for the rural innovation network which emphasized the work which Vinnova and tillväxtverket has for these types of industries, in order for them to reach some degree of maturity. Even if she within her position never met the companies in question she had dialogues with member organizations which represent those companies as well as meeting with Vinnova where they emphasized the importance of funding in the beginning of their transition. The need for economic support was also emphasized by the advisor at Jordbruksverket which explained that many of the "climate friendly" investments often incur high cost and thus are seen as non profitable if looking at the traditional return on investments (ROI). She further said that the economic support which Jordbruksverket or other organizations provide in the form of grants could be the difference between an unprofitable investment or a profitable one. The grants are therefore of substantial value for the industry, but also from the political standpoint if they want to see a sustainable transition within the farming industry.

This importance for new investments and economically supports was also somewhat highlighted by the PhD from SLU which said that many of the traditional farmers (in a Swedish contact) have during a few years' time made incremental improvements and upgrades in their farming equipments making their ability to change to the new CEA technology and technique very limited without significant support. She emphasized that due to high investments they are as of now stuck with their chosen method:

> "*But in the interviews I've done, you can see that it's some kind of... Path dependence lock-in effect. You have invested in these systems for some time. So, you can't just start running vertical cultivation in your greenhouse*".

4.2 Important actors

4.2.1 CEA Companies

During the interviews some particularly important actors have been identified, the actors have varied in some ways between the companies but to a great extent similar actors have been named as important for the companies. A lot of the companies have mentioned the collaboration they have had with universities. The nature of the collaboration has varied between the companies, some have as mentioned in the previous chapter only got financial support while others have had projects with the universities or having students from the universities working or doing internships with the companies. Company E who is a Dutch company have had collaborations with a University and stated that it is helpful to operate in a country like the Netherlands where there is so much knowledge about both farming in general but also about CEA.

Company B also described how they have had collaborations with universities and how they could go about in practical terms where you can see which types of announcements that are available and from there you can apply from many to do the project

> *"You simply look at the different types of announcements that are available. And if you have an idea how to do a project, for example. Then you look for money within the framework of them."*

Company D who is a Danish company also described how they have collaborated with universities and having students over for internships both from Denmark but also from around Europe. Just as company B highlighted regarding how Vekstfonden functions, not only as an investor ,but also as a proof of quality, company A highlighted how the University not only give them competence but also functions as a way of approving the quality of the company:

"Yeah, I think that can be important. We have had some collaboration with the University of Bergen, and that has also been good in order to actually be, yeah, because as an entrepreneur, startup then in terms of the government to prove that you're doing something right in terms of animal welfare and new systems, then it's a much higher chance to not succeed or convince them, but once you partner up with, let's say, the University of Bergen or the municipality in Bergen, you now have an interest in what we're doing because it fits with their own goals. "

They also provide examples of how these collaborations could function in both a practical way, in both informal and formal ways. The indirect collaborations have functioned in the ways that they had master students that were doing their thesis on vertical systems and through that indirectly helped them. During the recent years they have had more direct collaborations where they are listed as one of the University of Bergens internship partners where students can apply for internships and at the time for the interview they had one student working full time during three weeks as a part of an internship.

4.2.2 Research organizations

The research institute is continuously conducting research. The collaboration with universities is also important since they can attract new employees through the university, engage in collaboration or participate in joint science-based projects. The project leader also believed that the actual CEA companies need several different actors in order to succeed both as a company and an industry. They need to collaborate with universities to gain access to intellectual capital, meaning both students and research. The technology required is very complex both for the autonomous moment and in terms of production or requires different types of skill sets which he emphasized are sources from different universities. As the industry currently is very capital intensive he believed that having a good relationship with investors and access to soft funding is important as well.

4.2.3 Important actors and Competence

All of the respondents from the governmental organizations and university emphasized the importance of their own role to enable this type of industry, but also the combination of several other actors, preferably other governmental organizations, food stores. According to the representative from Naturvårdsverket it was important for them to constantly collaborate with several different governmental organizations since every department has their own "core competence" and needs to cooperate with each other for best results. Since both Jordbruksverket and Naturvårdsverket are organizations, both commissioned by the government but with different "main purpose" all respondents from these organizations believed they played an important role in the industry and innovation network. The advisor from Jordbruksverket emphasized how they act as a mediator between the government and the farmers in many different aspects. One way could be how to interpret and implement new laws and regulations into the market where another could be to request new laws from the government to better suit the farmers' needs. So, she was emphasizing how the institution worked as a two-way communication street and said

> "*We will try to implement the policy that has been discussed into reality. And then it is about, that we work towards sustainable agriculture and sustainable horticulture. And then the regulations must be both economically, socially and environmentally sustainable. We also work on trying to bring back information from the cultivation to those who rule and write various laws. So that it works in practice. So that you don't write a law that cannot be applied"*.

According to the innovation supporter at Naturvårdsverket they played an important role on a more general level, as they were not directly involved in the CEA industry, since they often designed a more general process trying to support innovation and did collaborate with several other governmental organizations. He did mention the project "Smart city Sweden" as an example where several governmental organizations are working together in order to generate a common platform for Swedish companies with different environmentally friendly practices. These companies are then later used to promote Swedish innovative power in a global context where international delegations can visit their offices to learn about class leading technology and innovation. According to their website the purpose was:

> "*The story of Smart City Sweden began in 2016, with the aim to export solutions within environmental technology*. *Since its opening in May 2017 in Hammarby Sjöstad, a sustainable urban district in central Stockholm, Smart City Sweden has welcomed over 10 000 visitors from around 100 countries, all interested in implementing solutions within one or several of our focus areas" (*Smart city Sweden, 2023).

The Phd from SLU also mentioned the important connection between companies within the CEA industry, universities and various economic grants since these together can enable a very interesting collaboration and used some of her own colleagues as an example. The example was when a professor within a special profession worked on a special R&D project with a company to investigate a new product which had new characteristics. But since the company was fairly new within the industry they had not enough cash to fund the project which in addition was very time and cost consuming. The problem was solved when they had a grant accepted and could, due to the contribution, finish the project and further develop the business.

Both the Phd from SLU and the advisor from Jordbruksverket and the innovation supporter from Naturvårdsverket also mentioned that the food stores in Sweden and globally are an extremely important factor to collaborate with in the future to further grow the market even more. The Phd also mentioned the food stores as enablers of the industry and said:

> " *But they are enablers, since they will sell the products. It's a pretty smart party to do business with, I think. At the same time, they have to see that they have this with it being profitable in that context "*.

The Advisor from Jordbruksverket also highlighted that her organization might play an important role in the future regarding training different counselors so that they can give high quality advice to farmers on how they can use CEA products in an effective way.
She also emphasized that since the technique and technology is so new they and many other governmental organizations need to quickly learn and understand how this technology would be applied in society in an effective way.

4.3 Competences

4.3.1 CEA Companies

Apart from the fact that the CEA industry is very capital intensive it is also a very tech intensive sector where highly skilled labor is required and several firms have witnessed about the importance of being able to hire skilled labor. Company C mentioned a skilled workforce as a major bottleneck to growth, second behind energy. They further describe how they do things that have not been done before and they need the best talents. Therefore they needed to look both within Sweden but also abroad to find employees with the right competences.

Company D also described that they have a big urge for highly skilled people but that they have seen a strong interest for the industry and the company both from Denmark but also from around the world, and therefore have not experienced any trouble when it comes to finding the right competences.

> *"But we have hired really super skilled people and we have had the luck, as I told you, of getting a lot of applications all the time. So we have been able to find really, really clever people. We have three PhDs. They are coming from Brazil, Malaysia and Germany, all educated from Copenhagen University. So we are also working together with Copenhagen University."*

The company further described that more than 50% of their workforce has either a bachelor or higher education. This is something which the company believed was necessary since they do a lot of testing and development that requires education.
Company B who is selling vertical farming equipment and not the finished product described how their customers still are doing a lot of the farming work but that they still need a highly skilled workforce for further development of their products. They described that it can be difficult to find the right knowledge since they still cannot compete with the bigger tech companies when it comes to salaries.
Therefore they have found it challenging to find people that not only have the knowledge and skills that are required but also the understanding and interest in the CEA technology.

> "*..it is not so easy to find the people who are both talented and also like this area. Because you have to have a certain understanding of it and a little interest. To be able to be a part. Otherwise, it's just as fun to work for a larger tech company. Simply. Which pays more too. So that part is actually challenging as well".*

4.3.2 Research Institute

The project leader explained that since the CEA industry is very new and advanced compared to the traditional food production industry the competence is needed from many different sectors, which traditionally aren't so interlinked. For example the need of understanding both the horticulture (understanding of how to grow) aspects as well as the technology aspect where autonomy and production are optimized.

> "*How to grow a crop is very important, but the technique is also very important. It's much more important than in an unprotected crop situation it needs years, to build up the knowledge, to build up the experience with new growing systems and that's the same with this CEA*".

He further emphasized the complexity of innovating a new business which requires knowledge for how new companies should create their business model, attract capital and internationalize and more.

4.4 Market perception

4.4.1 CEA Companies

The CEA companies not only stand in front of the technological challenges they also need to reach the market with their products. This can sometimes be hard when smaller new firms shall compete against the older bigger firms with established relations. Several of the companies we have interviewed have experienced it to be hard to enter the big markets that often are dominated by old structures with large wholesalers that dominate the markets. Company E, which is a Dutch company, described that in the Netherlands it is impossible to find CEA products in the shelfs of the larger food markets. One reason is that vegetables are generally very cheap in the Netherlands which makes it hard for the CEA companies to compete with the traditional products. But also that the supermarkets still are hesitant and not sure how and what it would look like. They are pushing really hard towards the supermarkets and are at the moment working on a deal with a supermarket that they hope will be finished by the end of the year. *"But we'll have to see. Getting into a supermarket is almost more difficult than making the whole farm".* Company C shares a similar experience in the Swedish market where they have developed their capacity faster than their sales because of the trouble to reach into the big chains and explains that it is hard to break the old relations that exist in order for the store to bring in two new products. They explain how it often is opposites within bigger chains where some parts want the chains to bring in new environmental products but then on the other side you have the actual purchases on the other side that have the relationships with the big wholesalers. Since the wholesalers often sell many different products it is hard for purchases to stop buying some products when the wholesalers have so much bargaining power.
Further they explained how they have been forced to do agreements with individual stores because of the hard time to reach agreement with the centralorganisation.

> "*This transformation is taking longer than we had hoped. Then we can go store by store and so on. It works….But it is both expensive, it takes time and the distribution becomes too expensive. when we need to solve it ourselves and cannot get into the central part."*

Company B shared that experience and had also been working on signing agreements with individual stores which they mean work in some way since the word of mouth is spread between the stores. They thought that they could easily sell their product to the next store if they heard a good review from their colleague but they still mean that this way of working has limitations since it takes longer time to scale up and they are now working on a central agreement with a chain with multiple stores.

This experience was though not shared by all of the interviewed companies, company D who are active in Denmark was interviewed and asked if they shared a similar experience but they had an almost opposite experience where they from the start had felt a strong demand from the bigger chains for their products and was even able to do deal with one of the firms in the beginning.

> *"No, we have been talking with, it's called the selling group, which is the owner of Føtex, Bilka and Netto. And we have been talking with those guys, our founder has, for years before we actually got in production. And they really want to have our products in the supermarkets."*

4.4.2 Research Institute

The project leader from the research institute mentioned that the CEA industry is still in a very early phase of its journey which implies high cost and expensive products for the companies trying to enter the new industry. The emerging technology had met some skepticism in his domestic market and he said:

> "*I have almost daily discussions like this because we also have, and especially maybe in our country, there are people who are very skeptical about this technique. It's too expensive and costs lots of energy*".

The price picture and market acceptance were however something he believed would change as the market matures and reaches an economy of scale. Due to its favorable sustainability characteristics he thought it will grow internationally to countries that already have food scarcity or suffer from environmental effects.

However for that to happen he believed that the price needed to decrease and that new crops were introduced to the market and not only salad and herbs. One example which the market could need was protein products and corn.This is something that the research institute is investigating since a few CEA companies have approached them and used their services.

4.4.3 Governmental organization

All of the interviewed had a generally positive impression on the different CEA companies and the future market that they might possess, they believed that the environmental benefits which come with the technique will play an important role in the way we are producing food in the future. One problem which the PhD at SLU saw with the industry today was that it is very energy intensive as well as carrying high initial cost, which might affect the general perception. However, if this in the future is solved and the product could go from being a luxury premium product to actually being a climate friendly product she believed the perception would change in favor of the CEA industry.

4.5 Sustainability

4.5.1 CEA Companies

Several of the companies mentioned the ongoing climate crisis and people's increased understanding of the crisis has led to an increased interest in their products. All of the interviewed companies highlight the sustainability of the product as one of the biggest differences when it comes to the value proposition compared to traditionally farmed products. They described how they can produce in a more sustainable way since they can optimize the system to use as little resources as possible

"Yeah so vertical farming has a few qualities that make it so nice. So it's very sustainable, at least our system. So not all vertical farms are that sustainable because they use a lot of energy but we found a way to create our own energy from organic waste."

Another big advantage that the company's highlights is that they can farm wherever and whenever, which makes the CEA technique very sustainable in a time where the climate changes creates an uncertainty for how the yields will be from year to year. Company D described how they hypothetically could produce their products in all types of climates and it doesn't matter if it's 40 degrees or minus 30 degrees outside.

They also claim that their farming methods are way more water efficient compared to conventional farming, which means that they can produce in countries that are having a scarcity when it comes to water supply.

> *“If a farmer is using 100 liters of water, we are using 5 liters of water. So the water is going through our waterways and then it's going to be cleaned and then it comes back.".*

The CEO and COO from Company A did also emphasize the problem of having to adjust their industry to the already existing laws and regulations since this was something completely new way of farming and thus hindered the sustainable expansion. They further described it as the old regulation assessed how the production affected the near environment, this assessment took a very long time and restricted the possibility for establishment. This was considered problematic since they had close to no effect on the surrounding environment, but was judged by old regulations. The founder of company C and the CFO did both also emphasize the significant increase in yearly production that the CEA systems could contribute with. They said it was many times the amount per square meter compared to traditional production which in theory could limit resources used and also ensure food production for future population growth. Many of the Interviewed representatives like the CIO of company B highlighted that locally produced food like the one done in the CEA systems over time has the opportunity to drastically reduce the need of global value chains and the need for transportations of food globally. The possibility to decrease the need of transportation globally was also something which was emphasized by the COO of company A who said that the indirect emissions of the food production could as a result of reduced transports be reduced as well.

Even though CEA is, in many ways, more environmentally sustainable it operates in a gray area when it comes to legislation, this is because it is a new technology that doesn’t fit within classical farming. Several of the interviewed companies have described how this has led to problems sometimes where they have not been able to receive grants or markings like ecological since they do not fulfill the requirements.

Company D describes that they have not received any subsidies in Denmark because they are categorized as “waterflow farming”

> *“But we're not getting any subsidies at all from anywhere. It's not possible because we're not conventional farmers. We're not organic producers. We're just waterfowl farming, which is a new thing. And we don't see any pools, funds that are helping waterfowl farmers”.*

Company B also witnessed how the regulations didn't have any room for CEA firms and that they therefore have not been able to apply for subsidies since there's no place for this type of innovative solutions in the regulations. Company E described how CEA products, according to the EU, aren't classified as organic since they do not grow in soil which they describe to be frustrating since they think that they are better than organic and don't use any kind of pesticides.

> *“We don't spray anything. You don't have to wash your product. So at first we were kind of frustrated. But now we're like, well, yeah, it is what it is. We'll work around it.“*

4.5.2 Research Institute

Regarding the sustainability aspect, the project leader emphasized that it is one of the reasons why CEA companies have emerged during the last years as the environmental related problems have become more visible recently. He also emphasized that one problem today is that many people's perception regarding the industry is that it is an expensive “luxury product” which only the rich ones are buying, mainly due to low knowledge about the product in combination with the early phase the market is in. However, he strongly believed that once the industry matured it would play an important role in solving the global climate crises as it is not affected by the changing environment. As it often uses less fertilizer and minimizes the transports he guessed that it could also have a significant impact on the transport industry.

Sustainability was also present as an important aspect when the research institutes were doing their projects for new customers. It could either be to investigate how a crop could become more resilient, shorten the harvest cycle (do more with less) or try to incorporate it into CEA systems. Unfortunately, the project leader predicted that in order for the CEA industry to fully mature where it gets commonly accepted and the price point comes down the world needs to see several environmental disruptions. For example drought or heat waves where traditional crops are destroyed or similar events, and then could the acceptance for this new industry be more harmonized since they possibly could mitigate these effects.
The project leader stated that people's unwillingness to change is problematic since it takes time to adopt a new system.

> "*Yeah, that's a bit of a shame that we need some catastrophes, that we need disasters to convince people. That's a problem because I'm not only working on vertical farms but my main subject is working on new growing systems, so independent from soil for example, growing on hydroponics. And we experience every day that it's not easy, you cannot just say, we will start this year with a completely different system".*

4.5.3 Governmental organizations

Within the governmental organizations interviewed for this thesis, sustainability was something they all worked with continuously. It could be directly or indirectly linked to the CEA industry. The advisor from Jordbruksverket did for example emphasize the overall strategic goal of the department which was to ensure that Sweden has an active agriculture which is sustainable, socially and economically viable. This goal, requested by the Swedish government, stretches far beyond a yearly strategy, but this is a goal that aims to secure Sweden's food production for a foreseeable future. Although the advisor was not directly involved in the CEA industry she experienced a rapid growth in CEA related projects and directives in the recent year and believed the industry would affect them even more in the future due to the many sustainable characteristics.

The other respondents from Jordbruksverket, working within the rural network and AKIS described how sustainability-related questions within agriculture had intensified over the last years and were one of the main topics in one event last year.

Indicating that the members organization also had started to request sustainability directives and the possibility to produce food in a more viable way, in addition, she mentioned that this type of request has also started to be seen on EU level with projects like EU-Horizon for example. EU-Horizon encompasses several different EU-funded directives , all striving to achieve a better climate and fulfill the 17 SDG goals, therefore there are many different industries included in the project, but one concerns food, agriculture and environment (European commission, 2023a).

The innovation leader mentioned that Naturvårdsverket together with other governmental organizations may have to consider revising some legislation regarding agriculture and fish aquaculture since the laws concerning those industries were created when everything was done in an open environment with interaction with the "real world". When different industries within CEA now are emerging the laws need to be adjusted to better fit those industries, he said. This to the simple fact that they have little to no effect and interaction with the surrounding environment and therefore need to be treated accordingly, he said:

> "*They are looking into whether legislation can be changed. When the environmental code was created, it was based on the industries with the most environmental impact. Then aquaculture is one of them. Then you think of the big boxes off the coast of Norway. But here there are other types of aquaculture that can be positive* ".

4.6 Internationalization

4.6.1 CEA Companies

Like other industries, CEA companies vary when it comes to internationalization. Most of the companies we interviewed are currentöy only active within their home market, but some had already initiated their internationalization process. However, what is common to almost all of the companies is that they intend on taking their products and production to international markets. Company C was clear that they are planning on taking their company abroad *"Absolutely international. We are at this stage right now that we are traveling around the world a bit and looking for good conditions to establish ourselves."*

Company D are today operating in the Danish market but are planning on taking their production to the German market, where they have already seen a lot of interest due to the harder conditions for the conventional farmers which will aggravate the already stressed situation. But they explained that they wanted to do their own expansion first and solve the existing problems before doing an international expansion and when the first expansions are finished they will most likely solve the remaining issues and after that the expansion pace will most likely increase since they can duplicate the existing model and implicate in in other markets.

Among the companies that we interviewed only one today had a big presence in other markets, Company E who are having the Dutch market as their home market but are also operating in the Kuwait and Singaporean market, and are also planning an expansion into the US market. They are mainly looking for a market where there is a strong demand for locally produced food.

> *"We (the Netherlands) export so much. We don't really need vertical farming. But countries like Kuwait, Singapore, Dubai, and even the US, they really need fresh local food production. So we really go to the countries where there's a need for it.*

4.6.2 Research institute

The research institute described how several international actors reached out to the institute and asked for their services. According to the project leader he said that the business proposal the research institute gets is mostly from outside their home market, often from Asia or American countries

> "*But the motivation or the drive to develop that further is not coming from the domestic growers or from domestic companies. Of course, there are companies who are interested in that and are developing but the main drive is more internationally, Asia and the States and so on*".

For the CEA industry as whole, the project leader was very optimistic about the international growth in the forthcoming years and highlighted the many climate related problems we already today can experience,

> ”I *think that if you see it globally, this technique will increase in importance for feeding people. If you see what problems we have worldwide, think about water scarcity, quality of good soils and so on. All the transport you need to get food from one place to the other. Well, there are a lot of arguments in favor of this technique*”.

He also highlighted the high energy consumption and the high OpEx and Capex currently affecting it as the biggest disadvantages for CEA, possibly hindering internationalization.
As a result of the high cost involved in the industry the preferred crops are almost exclusively salad and herbs which are considered to be high value and high margin products.
Furthermore, the products are as of now often sold as premium products in store with a higher price point than comparable products.
However, the project leader believed that as the market matures, new “low value” crops will be introduced and the OpEx and Capex will decrease. This could facilitate the willingness to internationalize and the CEA industry could really make an impact on mitigating climate risk in food production.

4.6.3 Governmental organizations

The innovation supporter emphasized the project called “Smart city Sweden “as the way Naturvårdsverket worked within internationalization since they don’t engage in activity abroad, except when they sometimes are invited as an expert to different EU forums. “Smart City Sweden” brings together many of Sweden’s innovative companies in one common place acting as a “marketplace” for international companies to visit. This project gives innovative companies an amplifier to use their internationalization and their reputation by “piggybacking” on Sweden’s and other organizations' reputation. This project involves governmental organizations like Vinnova, Naturvårdsverket and Business Sweden and at least one of the interviewed companies was participating in the network.

The PhD emphasized that the international market is very promising for the companies since their main “selling point” is the environmental benefits they have, which if they are true, could play a critical role in reducing the risk of future droughts and heat waves globally. She also believed that the international market could work as an amplifier for the implementation of new crops and products since different countries are requesting different products. She did also believe that the effect of a “locally produced” product could have an interesting effect on the global supply chain of food, with everything being locally produced. This is combined with the fact that the CEA system is locally adjusted for maximal output, and could impact the international food system significantly in the future and was an interesting topic to investigate according to the PhD.

5. Analysis & Discussion

5.1 Investments

By using the empirical findings and the conceptual model several barriers regarding growth were identified, the need for investments stood out as the biggest barrier, all companies that participated in the thesis have had a need for external funding during their business journey, either through venture cap, institutional investors or governmental funds. This is common for new and radical innovations that often have a bad economic performance in the beginning due to the fact that they are inflexible and expensive (Geels, F. W. 2002). The need for external funding that these companies have can be understood through the conceptual model which describes the different barriers that influence the company differently depending on which growth phase they are in. It was understood from the interview that the need for capital is very significant and especially in the start up phase but they think this will change significantly throughout the businesses growth cycle. According to a majority of the companies the innovation systems to which they belonged were a crucial forum for them to participate in since they could get access to capital and the economic barriers could thus be significantly reduced if they were part of an innovation system. As described in the conceptual model the companies are in constant interaction with the factors described by the MLP model as well as the role that the innovation systems play in the wider context of the companies transition.

Several barriers were identified when it comes to attracting capital. Some of the biggest barriers were that the CEA is an unexplored business segment which the investors saw as a risk. The company representatives did also acknowledge that another barrier was the more established and traditional food productions that attracted a lot of capital from investors due to the fact that they are already known by the market and "took" capital which potentially could have been invested in the CEA industry according to the respondents. The barriers and difficulties to attract capital into an emerging industry and technology can be understood by applying the MLP (Geels, F. W. 2002). Where the barriers can be explained due to their niche product (CEA products) which is trying to compete and challenge already established products. The participating CEA companies are also experiencing difficulties with attracting enough capital since they have much higher capital expenditures and operational expenditures compared to already established technologies.

This is not something that is unique for the CEA industry and is typically the case for new innovative products that are brought to the market (Geels, F. W. 2002). It is therefore important to understand the different needs a niche industry and emerging technologies has in order to be successfully implemented in the market. By applying the conceptual model it was also possible to acknowledge the role that innovation systems have for the interviewed companies, as they emphasized that the more matured and involved in innovation networks that the companies were, the more capital they could get access to, as the barriers gradually were decreased. If these companies were able to get access into a more mature innovation system it could be assumed that a lot more capital would be accessible for the CEA companies. The importance for functioning innovation networks in the countries where the companies currently are operating should not be underestimated since they via established regional and national networks have managed to get access to external funding via governmental loans, grants or private investors. Both companies and the participating university did also emphasize the important role universities have within those new industries since they can contribute with skilled labor but also contribute with research and product innovation for the CEA companies, something which usually costs a lot of money and therefore could further help the industry to grow.

Several of the participating companies had also experienced direct investments from the universities due to their collaboration. Both the literature about RIS and NIS highlights universities as one of the key actors within the innovation systems and the events can be understood by the fact that a strong relationship and the participation in the same network generates direct investments or the possibility to apply for various grants directed for these types of projects (Lundvall et al., 2009. Asheim et al., 2019). The role of the University could therefore be said to help the companies and be an important actor in their early innovation networks and via the conceptual model be understood as a crucial factor which reduces some barriers that lie in front of niche industries and can gradually help to change the perception within the landscape of these industries.

In the case of the CEA industry it seems that there is an understanding from both investors and governmental institutions that the need for money is a pressing issue and hinders global expansion.
On the other hand, everyone interviewed in this thesis emphasizes that the available money for the industry has increased significantly over the years due to climate related discussions, increased knowledge and a viable business. This can, according to the MLP, be seen as a form of change in the socio-technical landscape in a favorable way for the CEA companies. A change in the socio-technical landscape puts pressure on the regimes to make a change and adapt to the current landscape and this can create opportunities for niche products like the CEA to break in and be a part of the regime.

5.2 Important actors and competence

As mentioned above the most important actor for most of the companies is the investor, but apart from investors several other important actors were identified. Almost all of the companies had in one way or another collaborated with the universities but the form of the collaboration differed between the companies. In some cases it was more of a financial collaboration where the companies had received financial support and in some cases it was more of a knowledge collaboration where there had been exchanges of knowledge or that they had students doing internships or similar collaborations. Another important role that the universities had was to educate skilled workers.

Several of the companies talked about the need for skilled workers since the CEA is both a new and advanced industry and therefore a highly educated workforce is necessary. Since it has been hard to get a skilled workforce within their home country, several companies did often solve this challenge by looking abroad for employees and thus recruiting international employees with the right knowledge. Some of the companies have also had collaborations with foreign companies to get access to the right technology. The need to attract the right workforce and thus overcome the perceived barriers is through participation in innovation networks. As emphasized in the MLP theory by Geels, F. W. (2002) the available workforce is adapted to the regime and thus lacks the availability within the niche. However, as some companies witnessed, the demands within the socio-technological landscape have started to change and the previous barriers within labor have quickly started to change in favor of the CEA companies. As the conceptual model stated, the barriers (in this case the availability of human capital) that is influenced by the regime and the landscape can be mitigated by participating in innovation networks as the companies currently are. By doing this the landscape will be influenced and in the long run make more qualified workers available.

In these cases the importance of having both local innovation systems like RIS and NIS as well as a global innovation system since the companies have been forced to search for knowledge outside the local innovation systems since the local innovation system can not provide the right knowledge. That the external knowledge is absorbed from different methods is aligned with the RIS theory (Martin et al., 2018). That External knowledge is needed is common for specialized RIS systems since they sometimes do not possess the knowledge themselves within the network (ibid). In order to be able to hire labor from abroad it is beneficial for the companies that the regulations and legislations in the country make it easy to employ foreign workers. Therefore in these cases also the government is an important actor. The governments, municipalities and other state authorities also play a role when it comes to innovation hubs and innovations supporting organizations, this has been especially important for a lot of the companies in the start up phase. Mostly because they have provided soft fundings and loans to the companies, for some companies this has been crucial for their survival and for others they have relied more on private investors but still used these fundings when available. Another trend within the CEA companies is the difficulty of getting access into the big chains in their home markets. Only one of the companies had experienced that it has been easy to penetrate the big chains.

But the majority of the companies have experienced it to be challenging to access the chains and break the old relations that the chains often have with the big suppliers. This could be explained by the NIS theory which emphasizes that some innovation systems have a hard time to absorb new technology due to the success of previous established systems (Chaminade et al 2018). Also the MLP can explain the barriers since the CEA companies are a part of the Niche segment they often find a hard time to enter the regime. It is first when the regime experiences pressure from outside (landscape) that it is possible for the nice product to enter the regime and change the structure (Geels, 2002). The CEA companies witnessed that they recently have started to see a change in the market demand as more and more of the established firms incorporated their products but have yet failed to make a general entrance within the big firms, but where previous barriers have changed in extent due to new partnerships and new influence in the market (Ibid).

Another important knowledge is the fact that the big chains and food producers (regime in this case) already belong to an innovation network. Since the niche and their newly created innovation system have to challenge the established innovation network this creates a difficult situation. This since established and successful innovation networks sometimes have a hard time to accept new partners into their network and tend to be stuck with their, once, successful partners (Chaminade et al,. 2018). This is important to understand for the CEA companies as they are trying to challenge the so-called regime, which indicates that they are challenging an established network with many different actors. The niche companies do also have to challenge the partners of the traditional food producers to reach a transition since they also constitute the established innovation network of the regime. Once again there is a need to analyze both the innovation network and the MLP perspective to successfully understand the ecosystem and was done individually and with the assistance of the conceptual framework that incorporates both theories at once and can assist the companies to address barriers to grow their business.

As mentioned above the CEA technology is very expensive and the initial costs are high and therefore companies often need to achieve the benefits of economies of scale before making profit therefore it makes it extra problematic to not have access to the big chains since they stand for a large part of the total food sales.

Several of the companies have highlighted the international collaborations both when it comes to technology where several of the companies have mentioned that they have been working with international suppliers. But also as mentioned above where they have been relying a lot on international labor to find the right knowledge. Several of the interviewed companies as well as the Swedish board of agriculture, emphasized The Netherlands as an important player within agriculture and also CEA production and research. The Netherlands seems to have taken a leading role within the agricultural industry can partly be understood through the innovation theories which explains how a functional innovation system and the participating actors can get a leading position within that industry (Asheim et al,. 2019).

The need for electricity is high for the CEA industry since the farming technique requires a lot of electricity compared to conventional farming and this sets high demands on the electricity supply. Both when it comes to the energy infrastructure at the location but also the general supply since this decides the price of electricity. This is a great challenge for the CEA companies since the electricity shortage within Europe has escalated the price level partly due to the Ukraine-Russia conflict but also due to the increased general demand for electricity. By further accelerating the expansion of the energy infrastructure the landscape will likely influence the CEA industry and the interviewed companies witnessed how they need to involve themselves in new networks that can provide these energy solutions.

In general we have identified that CEA companies are working with actors from differents kind of innovation systems and this is something that is in line with the GIS theories that means that the RIS and NIS are important parts of the GIS (Binz & Truffer, 2017)

5.3 Sustainability

Sustainability was something which every company representative stated to be one of the most important reasons why the CEA industry has emerged as a viable business opportunity. This can be seen as the climate change has changed the socio-technical landscape and generated a pressure on the current regimes to change the production to a more sustainable way which has created a crack in the existing regime that opened up for new possibilities (Geels, F. W. 2002). The companies described that their CEA system has the possibility to significantly reduce the environmental impact compared to traditional food production.

It is important to remember that the CEA industry is an innovation and a disruptor to traditional food production but where some of the environmental risks with conventional farming have been mitigated by the new CEA technology, like water consumption and use of pesticides. The company representatives all emphasized that their production is not dependent on the outdoor climate and could therefore farm wherever and whenever. In theory this indicates that those production facilities could be a global way of mitigating the climate disruption which the UN and IPCC have predicted, (further described in the introduction and problem discussion). One of the key concepts with CEA industry is that it is locally produced and was by some companies assumed to disturb already existing value chains within the food production.

Another sustainability related topic, which has been stressed by the UN, is the expected growth in population during the upcoming years. This will further put pressure on the innovation system to produce almost two times the amount of food compared to today and will further stress the existing food regime. The sustainability topic might put even more importance to the need for the global innovation networks since the fact that climate change does not have any borders and will affect everyone to some extent.
The global innovation network enables institutions and knowledge to be spread all over the world and can gradually be accepted in new markets since already established players in the home market confirms the new technology, something that could speed up a transition (Binz & Truffer (2017). Furthermore the fact that GIS should be seen as an extended arm of the regional innovation systems will enable the knowledge to be transformed more easily, something that was emphasized by the companies as important since their technology can be applied globally and they are in need of a global network to succeed with the expansion(ibid). Another interesting aspect with the CEA industry is that it offers solutions to the many of the climate related problems the existing food regime is affected by today. Problems that will need to be addressed in the near future anyhow. These sustainability waves we are witnessing globally are putting a significant pressure on the landscapes and the existing food regimes for a change, further influenced by regulations and the public opinion. In theory this could easen up the market dynamics where a structural change could take place and really affect how the industry and its regimes are governed. This creates an opportunity where the niche players are getting a chance to break out of the niches and be a part of a future regime (Geels, 2002).

Something which has been highlighted by the participating companies and the Swedish governmental organizations is the need for an integrated innovation system. Both on a regional, national and global level since there is so much with the emerging CEA industry that needs involvement from various organizations and stakeholders due to its advanced technology. Within the aspect of sustainability everyone agreed, including the governmental organizations that the regulations needed to be adjusted since the current regulations handle the CEA companies the same as traditional companies when it comes to environmental risk and that crops produced in CEA systems could not be ecological labeled due to regulations. In these cases a change in regulations would mean a change in the socio-technical landscape which in the longer run could open up for changes in the regime as well.

Having a functioning innovation system is very important when there is a desire to develop a new technology, like the CEA technology, since the collaboration between university, governments, companies and society contributes with their part in transforming the old market and implementing the new technology. This could be witnessed through the CEA companies and the need to be included in an innovation network to successfully meet the new trends regarding sustainability and increased food production.
The sustainability related innovation networks have started to emerge more and more according to Altenburg & Pegels (2012) since there is an increased need for sustainable technology to solve various climate risks. The need for governmental involvement in the SoIS is important since the current market and its regulations often adhere to the old market and a structural change can be hard on itself (Ibid). This was something which the interviewed companies and some governmental organizations agreed to and there was a need to further support the CEA industry due to its climate related benefits which indicates that new innovation networks are to be formed and thus new influences from the landscape will probably be witnessed in form of regulations and market demand further challenging the regime.

As a concluding sense, the need for involving several different actors in this new sustainability innovation system is crucial when it comes to sustainability since this production technology being promoted has several positive environmental characteristics.

The companies themselves also emphasized the need for an innovation network that focuses more on sustainability since their main advantages are the sustainability aspects of water consumption and production per sqm and that a more focus on this could speed up the transition of the industry. This can be done through close collaboration with companies, governmental actors, and universities. The knowledge for the technology needs to be increased and it is therefore important for close collaboration via innovation systems to facilitate the transition of the industry and to involve the market actors and public opinion for an industry transition.

5.4 Internationalization

The CEA industry is significantly different from the traditional food production when it comes to internationalization since the main scope of the CEA industry is to have a local presence and produce food where it is consumed. This is done to maximize the environmental benefits and to limit the global transportations, however all of the interviewed companies had the ambitions of being a global actor in the future. Their internationalization would then characterize as an exporting company where their systems or technology would be exported and established overseas, the crops themselves will not be shipped any longer distance. However, in order to successfully internationalize the companies emphasized the need of first having an established presence in their home markets where they are successfully embedded in the necessary networks and build up their organization before internationalization. The companies did also emphasize the need to participate in the global innovation system since the strategic partnerships can simplify an internationalization from several aspects. One reason for the companies to participate in an international network was to find strategic partners that could vouch for their business idea and thus give them international recognition and simplify the internationalization. An aspect that was acknowledged as a benefit within the GIS theory and that international partners could give access to distant markets (Binz & Truffer (2017).

One finding from the interviews was how the willingness to be included in the different innovation networks were dependent on the maturity of the company and how well established the company was at the moment. In the early phases of expansion there was an increased need to participate in the regional innovation network and national innovation systems where collaboration with the right actors was really important.

But even though only one of the companies was active outside their home market, almost all of the companies have the ambition for participating in the global innovation system in the near future. This to get access to the knowledge and technology that were missing in their local networks. This is as mentioned above something that is not uncommon within local innovation systems where the knowledge and technology that are missing needs to be obtained from outside the local innovation system (Martin et al., 2018). The belonging to more local innovation systems was however something which some participants thought would decrease in importance within a couple of years since they were already trying to find national and international actors which could help them to an internationalization.
This could for example be governmental organizations like business Sweden or smart city Sweden and also different EU fundings that can offer bigger amounts of money that are needed to scale up the production.

The need for different innovation network was more visible when it came to find the relevant competence within labor and also research because all companies where already looking both national, regionally and international to find the right competence and to source the right components for their systems, e.g. almost all of the companies had some international workforce since they needed to look abroad to find the right competences. Also, to find the right components companies needed to look internationally. As there is an emerging business which doesn't have any real counterpart they have been forced to look to other industries which can deliver a comparable production but within another industry, for example a japanese company who previously had been active in automation within warehouses but manage to deliver a functioning CEA system. The limited international presence for CEA companies can also partly be understood via the MLP theory since the traditional food industry has not previously been ready to adopt this emerging technology and have therefore rejected the expansion since they maintain the already established industry (Geels, F. W. 2002). The companies did also emphasize that there is a need for them to develop their business model so they are ready to handle the growth and internationalization and can facilitate the increased business opportunities. The companies also emphasize that in the long run they need to participate in the global market and innovation systems since their products can address issues on a global scale. But also since many industries are becoming more globally interconnected, which also applies to the CEA industry, and was something that has been emphasized by Carlsson (2006).

According to the participating companies their innovative solutions have theoretically been ready for an internationalization but have been hindered both by the fact that they need to develop their business organization and their productions technique before being able to internationalize but they also been hindered by the established regime who wants to maintain their traditional way of doing business which have prolonged the acceptance for the disruptive CEA industry. Some did also emphasize that the public acceptance has not reached the needed breakthrough and thus hindered the desired expansion.
This is also a dilemma which could be understood via the MLP theory regarding the need for an emerging industry (disruptor) to be socially accepted before it can challenge the already established industry (regime) practice (Geels, F. W. 2002).

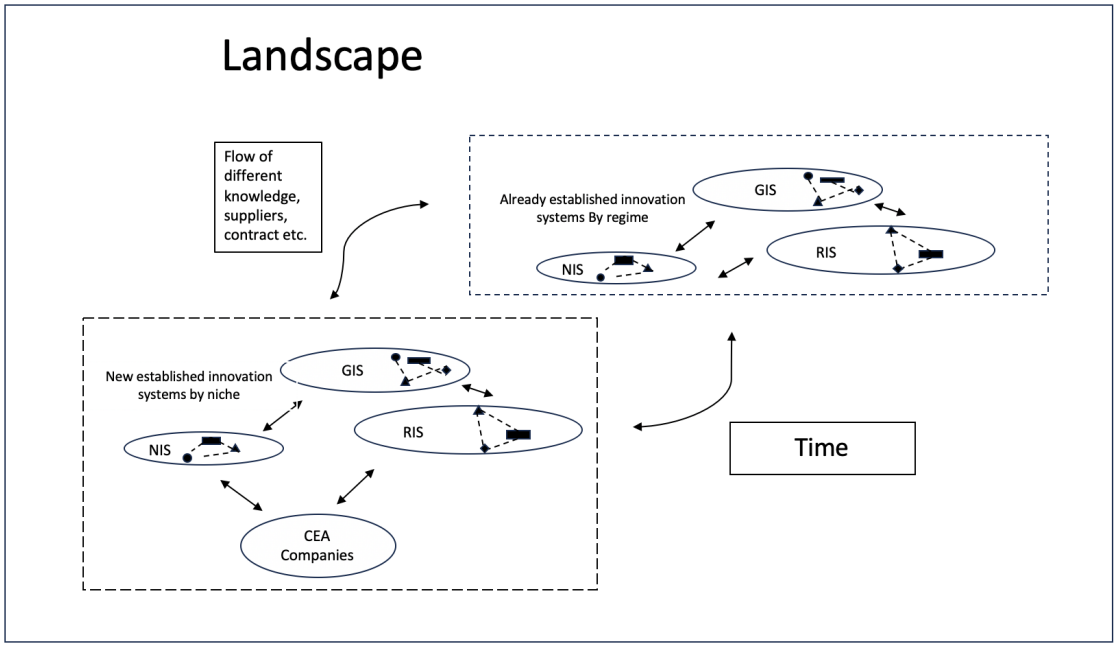
5.5 Market perception

Since the CEA is a new industry, some barriers regarding the market perception have been identified during the interviews. There were mainly two bigger barriers that have been identified. The first is the price level, since the CEA industry has high initial costs the products have generally been put at a higher price compared to conventional farmed products. This is though something that is normal with radical innovations that have a bad economical performance in the beginning since they are inflexible and expensive (Geels 2002).
The price level is something that has started to change since the companies are approaching economies of scale and are therefore able to lower the price of their products. Almost all of the interviewed companies agreed that in order for the industry to get a major breakthrough and to be able to compete with the other food producers they need to be able to produce products that the average consumer can afford to buy and have a similar price level as comparable products. This is a progress that historically has happened to several industries as they transform from being a niche to becoming a part of the standard regime (Ibid).
A majority of the companies that were interviewed are today producing vegetables and today they are seen as a luxury product and have higher prices compared to the conventional vegetables, a challenge that all companies emphasized as a significant barrier to growth. A possible breakthrough for the CEA products would be if the companies managed to achieve economies of scale in their productions and could offer a sustainable “mainstream” product with a similar price point, instead of a luxury product. As mentioned in the MLP theory the Socio-technological landscape needs to be addressed and involved in the change in order to overcome the skepticism of a new innovation (Geels,. 2002).

It is also a challenge to make CEA products a standardized product since the new way of producing differs significantly from the conventional farmed products which have resulted in the CEA companies being met with skepticism from the customers that are used to traditional farming. This can be seen as that the norms and culture within the innovation systems still favor conventional farmed products and the change in the institutions has not been made yet (Asheim et al., 2019).

Once again there is a possibility to successfully apply the conceptual model since challenges from the different frameworks are exclusively emphasized and can successfully be analyzed simultaneously with the conceptual framework to understand the barriers where the interviewed companies in general witnessed that they have started to see a change, since the general knowledge about CEA have increased. This can be seen as the socio-technical configurations are about to change in a more favorable way for the CEA companies which could eliminate some of the barriers that the companies are facing regarding the market perception. This goes in line with the multi level perspective theories that claim that new radical innovations sometimes face a miss match with the rest of the society and therefore they have a hard time to break through immediately. But when a change in the socio-technical landscape configurations occur, possibilities for new niches to enter the regime take place (Geels, F. W. 2002).

5.6 Revised conceptual model



After having completed the interviews and done the analysis where the empirical findings and the chosen theory have been combined we found it necessary to revise our conceptual model presented in chapter 2.3 as this aligns with our abductive approach and new important insight were gained throughout the interviews.

The main theoretical contribution from the original model is still maintained: how the MLP and the innovation systems theories interact with each other in a dynamic process and generates an possibility to analyze the barriers a CEA companies faces due to the MLP and how the participation in innovation systems gradually can effect the importance of the barriers and the socio-technological landscape influence of the CEA companies progress.

However, after the interview sessions there was a need to further expand the scope of the model since the interviewed companies contributed with important insight. One very important factor which was added were time and another were the ruling regime and its innovation systems that together with the innovation systems of the CEA companies coexist in the “landscape”.

The reason that time was added to the model was to be able to describe how innovation networks could change over time since the companies emphasized how they had the need for different constellations depending on their maturity phase. By adding the “snapshot” perspective given by the revised model, our vision is that the new conceptual framework could be used as a theoretical timeline where the relation between the regime and niche could be compared and understood by analyzing their different innovation networks over time. Moreover, as the belonging and the need for different innovation systems, according to Binz & Truffer (2017), can be changing as the companies grow, it adds a new dimension when analyzing the dynamic between the CEA industry and the traditional way of producing food (Binz & Truffer (2017). The need to also include the regime and the regime's established innovation networks became very clear after the interviews as many of the companies saw themselves as part of the future regime network. As many of the actors (packages or transport etc) within the current regime could become strategic partners with the CEA companies in the future. It is therefore important to convey an extensive model of the theoretical landscape from the beginning. The fact that this also enables a “snapshot” of the dynamic constellations that are constantly in change within several aspects enables the analyzing part to compare change over time. The original MLP theory focusing and thus our original conceptual model focusing on how niche companies could go from being a niche to become the regime and to some extent replace the previous regime. However this was needed to be revised since many of the interview companies saw themselves as future important actors in the regime rather than a replacing factor. Therefore the model tries to capture how knowledge, constellations between the niche and regime might change over time to a constant interaction between the actors.

This revised model is supposed to better help companies and other people of interest to navigate a complex constellation this situation might possess and could with advantage be used as a supplement to the MLP and the innovation systems theories since it offers a combination of the two and complement where we believe the theories lack the the ability to singlehanded explain a phenomenon.

6. Conclusion

6.1 Summary of the thesis

In this thesis, we had the opportunity to conduct several interviews with both CEA companies and governmental organizations, where our primary objective was to delve into how innovation systems can facilitate growth of the CEA companies from a MLP perspective. By exploring the innovation systems and the MLP, both playing an important role in facilitating the growth of CEA companies, we aimed to gain a deeper understanding of the underlying mechanisms that drive their growth through analysis of a multilevel perspective. A growth that possibly could take the CEA industry from being a niche in the market to being an established market actor and a part of the regime.
To find the significance and analyze the different factors, we based our research in theories considering both Innovation Networks and the Multi-Level Perspective. These theories provided us with a robust framework to examine the complex interplay between various elements that exists within the CEA industry. To further understand the interplay, a conceptual model was created in which the two theories were combined into one model.

By comparing the empirical findings from our interviews with the theoretical underpinnings of Innovation Networks and the Multi-Level Perspective, our goal was to identify critical factors that facilitate and influence the growth of the CEA companies and the industry.
This approach allowed us to examine the relationships, knowledge-sharing mechanisms, and technological advancements that enable the future growth for companies within the CEA industry. Overall, this thesis represents a comprehensive exploration of the different innovation networks that can facilitate growth for CEA companies from a multilevel perspective.
By bridging the gap between theory and practice, we hope to contribute to the existing literature within the research area, contributing with valuable insights to policymakers, industry practitioners, and researchers alike.

6.2 Answer to the research question

How can innovation systems facilitate growth for CEA companies through a multilevel perspective?

Throughout the thesis we have experienced that CEA companies in their current phase requires support from multiple innovation systems and supporting infrastructure. It can further be concluded that participating in many different innovation systems are of importance for the CEA companies, but each of them vary in importance depending on the maturity phase of the company. Nonetheless, since the CEA industry is relatively young we have experienced that the global innovation system's primary role today is to provide the companies with the knowledge, technology availability and support when local and regional innovation systems fail to provide the right competences needed.

It can also be concluded that the industry currently is positioned as a niche actor in the food industry and participating in various innovation systems are extremely important to be able to make the shift from being a niche to being part of the regime. The conclusion is also that participation in innovation networks are positively influencing the socio-technological landscape and favor the transition for the CEA companies. Participation in these networks is an effective w
ay to influence the public opinion, regulations and push the market for a change.By analyzing the empirical data through the MLP we found that several of the barriers that occurred for the CEA companies in the innovation networks could be explained by the fact that the companies are experiencing a mismatch in the current regime and landscape. Where the regime and landscape is adjusted to conventional farming methods. With the urgent need for increased availability of sustainable food production several indicators in the market that the socio-technical landscape is experiencing pressure to change. Indicating that more pressure on the regime will be experienced as well. This pressure can possibly create opportunities for the CEA companies to grow in the market.

By utilizing the conceptual framework, we have been able to identify and explain several of the barriers that hinders the CEA firms to grow and how they can be addressed. The biggest barrier proved to be investments, where almost all companies rely on their investors to survive the start-up phase, since they currently are running an operation on deficit.

However, our findings suggest that through participation in a functioning innovation system the companies can get access to the needed investments.

We have also found that regulations and collaboration with governmental institutions is of great importance, this is because the companies need a functioning and updated regulatory framework that is adjusted to the CEA industry and not to the traditional one. The governmental organizations globally are also playing an important role since they are regulating emissions and promoting a sustainable transition globally, putting pressure on existing business (regimes) to transform their business into a more sustainable one. This could in turn promote CEA rollout as traditional farming is being subjected to penalties. Both the national and international organization also plays an important role when it comes to finding soft fundings for the start-up phase for the companies.
We have found a pattern, indicating that younger companies are in greater need of participating in local and regional innovations systems whereas more mature companies are looking internationally. When the companies eventually reach a more mature phase they will have a stronger need for participating in global innovation systems since they often require more funds, more knowledge and new business partners as they expand outside their domestic market.

Our findings also indicated that innovation systems and MLP have a lot in common and are constantly affecting each other in a dynamic process. It was therefore extremely useful to through the conceptual model, be able to incorporate both perspectives into one model to further expand the knowledge of how different innovation systems can facilitate growth for the companies via an MLP perspective.
A concluding sentence to answer the research question: the investors are of great importance for the success of the company, but governmental institutions also play a crucial role due to regulations as well as availability of capital. Additionally, it is important to acknowledge that the company growth includes a highly dynamic process where the importance of different actors will vary overtime and thus acknowledge that different companies require different constellations in the innovation system.
It can be presumed that during the business cycle the requirements will change over time and that one size does not fit all when it comes to providing the optimal innovation system for a CEA company.

6.3 Theoretical contribution

As a consequence of doing research within the CEA industry which is considered to be relatively new, existing theory is underdeveloped and very limited in relation to other established theories and industries. However, existing theories which are often used in other research areas can successfully be applied to the CEA industry, of which this thesis is a proof. By doing this it will hopefully result in growing interest in investigating this emerging food industry that hopefully will provide the CEA industry with important insight.

As the goal of the thesis was to investigate how innovation networks facilitate growth for the industrie from a multilevel perspective we hope to have increased the awareness and answered some of the uncertainties that previously existed around the CEA industry.
Our ambition was also that future students and business developers can use these findings in order to understand the risk and opportunities for companies in the industry as well as using this report as a basis for further research within the industry. The ambition was also to contribute to an increased understanding among people who had decision-making posts like politicians or governmental organizations since they could use this research to better understand the needs these kinds of companies have in order to grow successfully and understand the barriers they are facing.

6.4 Limitations of the study

It is important to consider and acknowledge the aspects where the thesis finds its weaknesses and analyze how this possibly could affect the result of the thesis. One of the most important limitations of this study is the geographically concentration of the countries chosen. This factor is important to acknowledge since all countries have similar economical standards and similar socioeconomic standards. This is a perspective that could affect the perceived difficulties since the business environment can be very different in other geographical areas.

That all countries belong to EU/ESS could also influence the perspective of the companies since EU/ESS have common laws and regulations which determine working conditions, access to capital and international collaboration etc. These are factors that could differ if a company is located outside the region.

Another limitation of the area of study is that the CEA industry is relatively young and therefore lacks well established companies and processes, something that traditionally food producers have. This has made the scoop of the research smaller and make it harder to achieve generalizability since the processes differ more inbetween and the available data is limited.

6.5 Future research and recommendations

Since the CEA industry is a relatively new industry which is projected to experience significant growth over the upcoming years, both nationally and internationally there are several interesting areas which are identified as areas for future research within international business. The further expansion for the CEA industry would be of great interest to investigate as the industry matures even further. It could be of interest to investigate in the upcoming phases which global partnerships are needed as well as barriers and possibilities that would enable the CEA industry to internationalize.

Since only countries with a close geographically proximity were investigated it would also be of interest to expand the survey to other countries to see which actors that CEA companies located in other countries are including in their innovation systems and what they need in order to succeed.

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Appendix A

Interview guide:

- Can you briefly explain about your company and your role within it ?
- What are the main differences with your value proposition compared to traditional food producers?
- What supporting infrastructure do you need?
- Are there any partners/actors who have been especially important for the company? (other companies, universities, government, municipality etc)
- Have soft fundings played a decisive role for your industry ? Is it still so?
- Is it hard to find investors willing to invest in your products? How has it changed during the years, any forecast?
- Do you believe that the food industry is going through a transition or is CEA more of a supplement?
- What barriers, regarding growth, have your company faced over the years? How has it affected you? (Country, legislation, price or human perception etc.)
- What are the drivers for the company?
- Are governmental incentives something which affects your expansion significantly?
- Are there any specific products which are difficult to produce in a CEA system?
- Are there any other aspects which you believe are important to mention?

Appendix B

To Governmental institutions**:**

- Tell us briefly about you and your organization?
- Do we need more governmental support within the industry?
- Which actors play an important role for the CEA of food production?
- Are there any new partnerships you believe to be of extra importance?
- Are there any international partnerships you believe are going to be changed?
- How could CEA change the global value chain of food as we see today?
- Do you believe that CEA is a trend shifting technique or something else?

Appendix C

Extract from interview	Central theme
"No, it's too slow. Early on we did a simple one million check application. But when you work with private equity and investments, it's not worth the time and administration to go to these government parts.	The respondent highlights how public investments are too slow for rapidly growing companies.
"But we're not getting any subsidies at all from anywhere. It's not possible because we're not conventional farmers. We're not organic producers. We're just waterfowl farming, which is a new thing. And we don't see any pools, funds that are helping waterfowl farmers."	The respondent highlights how CEA companies often end up in Grey area since they don't fit in with the classical farming categorizations.
"We have our own laboratory. So we have PhDs and master's students going and testing all the time for this, having a really clean environment. You will never see a farmer running around like we're doing. We have, I think we have 35, 36 people employed right now. And I think 20 of them have a background from bachelor's and up. So it's very well educated people(...)"	The respondent highlighted the need CEA companies have for highly skilled and educated people.