State of the Controlled Environment Agriculture Market

A Qualitative Evaluation of Market Development and Operating Actors' Needs

Master's thesis in Quality and Operations Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023
www.chalmers.se

Report No. E2023:131

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Cover: A controlled environment agriculture system employed in a greenhouse. Image taken by: Erwan Hesry.

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Abstract

The purpose of this thesis was to assess the current state of the **Controlled Environment Agriculture** (CEA) market. It aimed to identify the factors that drive or hinder the market's development and explore how **Ericsson** can offer solutions that address the specific needs and challenges faced by industry participants. The study employed an inductive approach, utilizing qualitative data collection methods through interviews with CEA market actors, to identify underlying **needs**, **obstacles**, and **drivers**.

The analysis yielded three key results: the current state of the market, actors' needs and requirements, and implications for Ericsson. Environmental, financial, and political factors were identified as significant factors influencing the development of the market. Among the identified factors, environmental considerations, such as land use, water consumption, and climate change, were found to be key drivers for market development. However, challenges related to energy consumption and financial barriers emerged as obstacles hindering market growth. Furthermore, the study also identified 11 core needs among actors, grouped into 6 main categories: data collection, automation, parameter control, data transfer, financial, and energy. The implications for Ericsson indicate that the current market phase prioritizes product innovation over process efficiency, rendering Ericsson's existing solutions such as 5G less relevant for actors operating in the market. Rather actors are currently focused on developing their own products as opposed to adopting advanced automation or IoT systems.

CEA systems holds promise as potential solutions to global food production challenges, both in terms of yield efficiency and environmental impact. However, obstacles related to energy consumption, financial viability, consumer acceptance, and regulatory frameworks impede progress and must be addressed before the potential benefits can be obtained. A comprehensive approach involving policymakers, industry actors, technology providers, consumers, and research institutions is essential to fully unlock the potential of CEA in addressing the global food production crisis.

Keywords: Controlled Environment Agriculture, Ericsson, Needs, Obstacles, Drivers.

Acknowledgements

First and foremost, we would like to express our sincere gratitude to all the individuals affiliated with the Garage at Ericsson, Lindholmen, Gothenburg, who have supported us and made valuable contributions to our thesis project. In particular, we want to extend a thank you to Louise Hultén and Staffan Hellsvik for their unwavering guidance and support throughout the entire duration of the process. Their invaluable advice and assistance have not only facilitated connections to relevant companies, but also helped ensure the completion of the project.

Furthermore, we would like to acknowledge the individuals who graciously dedicated their time and efforts to participate in interviews, sharing invaluable insights that have greatly contributed to our understanding and evaluation of the CEA market.

Lastly, our gratitude goes to our dedicated supervisor, Susanne Kullberg, from Chalmers University of Technology. Susanne's support and guidance have played a pivotal role in our journey. Her consistent guidance has not only steered us in the right direction but also served as a constant source of motivation, spurring us on to overcome obstacles along the way and ultimately finish the project.

Martin Hjorth & Johan Hodges Dexner, Gothenburg, June 2023

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

CEA	Controlled Environment Agriculture
OEM	Original Equipment Manufacturer
HVAC	Heating Ventilation Air Conditioning
CAGR	Compound Annual Growth Rate
PV	Photovoltaic
RES	Renewable-based Energy Sources

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1
Introduction

All around the world, food shortage is affecting millions of people. Acute food insecurity grows more prevalent in today's society, with an estimated 258 million people suffering from severe food insecurity as of 2022, which is an increase from the 193 million in 2021 (FSIN & Crises, 2023). The number of people affected by moderate food insecurity in 2021 was even higher, World Health Organization (2022) reported that as many as 2.3 billion people suffered from moderate or severe food insecurity. These issues related to food security and unreliable supply of food are exacerbated by a number of effects, most notably in by the ongoing geopolitical conflicts in the world. World Food Program (2023) denotes war as the main driver of hunger globally and further elaborates that the ongoing (as of June 2023) conflict in Ukraine is proof of war's impact on food supply. This is further supported by Council of the European Union (2023) denoting that attacks on critical crop infrastructure increases the threat to the global food supply.

However, there are numerous challenges surrounding the global food supply and ensuring people have access to reliable food sources and eliminating food insecurity. A growing global population is an another factor that contributes to the strain on an already pressured food supply. Accommodating the growing global population will require more efficient and reliable food systems, the United States Agency International Development (2023) states that *"In order to feed a population expected to grow to 9 billion people by 2050, the world will have to double its current food production"*.

Moreover, another major issue with the current food system are the environmental impacts caused by food production and the conventional agriculture industry. The current agriculture systems significantly negatively impacts the environment in a number of ways, primarily through: water use, greenhouse gas (GHG) emissions, and land use. According to data from Ritchie et al. (2022), agriculture is responsible for 25% of the total global GHG emissions, consumes 70% of all the available freshwater, and occupies 50% of all the hospitable land area in the world. All of the aforementioned factors have a detrimental effect on the environment and further supports the notion that the current food system cannot sustainably accommodate the food supply for the world's population.

Hence, the demand for more robust and efficient food systems drives the demand for alternative cultivation methods, which can sustainably feed the growing population. Controlled Environment Agriculture (CEA) is a terminology commonly used to group several alternative farming methods. The term CEA refers to methods that cultivate crops within a controlled environment, meaning that variables such as sunlight, water, airflow, and nutrients are all controlled by the grower in order to establish optimal growing conditions for the crops.

1.1 Background

As previously mentioned, CEA clusters together several different ways of cultivating crops using alternative growing methods compared to conventional outdoor farming. In general CEA is practiced in indoor facilities or greenhouses, where a controlled environment commonly refers to the presence of a facility that shields the crops from external factors and the utilization of various systems to regulate the internal environment. More specifically, the growing environments can refer to a number of different growing structures and cultivation methods. These can range from simple shade structures and hoop houses to greenhouses and fully automated indoor farms with controlled lighting, water, and ventilation (College of Agricultural and Environmental Sciences, 2021). The variety of growing structures and cultivation methods included in CEA can be seen in figure 1.1.

Figure 1.1: *Examples of different growing systems and harvesting technologies commonly used in CEA systems. Source: Tbaumdesign (2023).*

Cultivation success rate depends greatly on the environment in which crops are grown. Erratic environmental elements such as droughts, floods, heat waves, and freezing temperatures can have a significant impact on crop growth (Xi et al., 2022). One of the advantages of controlled environment agricultural systems is the ability to mitigate these environmental factors effectively. Crops can be grown year-round using CEA, and the quantity of carbon and nutrients that plants receive can be adjusted to maximize productivity (Benke & Tomkins, 2017).

Another aspect of CEA systems is the control aspect of the system, which refers to the farmer's ability to control environmental parameters in order to optimize the growing conditions for the plants. In controlled environment systems such as greenhouses or indoor farms, plants have access to adequate water supplies, temperature control, an isolated and clean environment, and the potential for sophisticated monitoring or sensing systems (Xi et al., 2022). By using technology, i.e. data, sensors, and optimization algorithms, control over environmental aspects of growing conditions can be offered to the grower. Due to CEA's dependency on technology to control the growing environment, the concept of CEA is more closely related to technology than traditional agriculture, which is not as reliant on data and technological solutions.

Due to this reliance on technology and the potential sustainability benefits offered by CEA systems, an interesting synergy between the CEA market and Ericsson emerges. In line with its overarching mission, Ericsson has identified sustainability as a central pillar of its purpose, aiming to leverage technology to drive positive change in society (Ericsson, 2023). The Sustainable Development Goals, as defined by United Nations Department of Economic and Social Affairs (2023), refers to 17 broad goals that address large societal issues, such as poverty, climate change and world hunger and encourages countries and companies to support global efforts to solve these issues. Related to the sustainability efforts stated on Ericsson's website, a long-term commitment has been made to support the global effort of achieving UN's 17 Sustainable Development Goals (SDGs). Consequently, Ericsson has an interest in industries and markets that not only offer financial gain, but also align with the company's sustainability commitments.

Ericsson is a global leader in the field of information and communication technology (ICT), with expertise in telecommunication products and services. The company offers a wide range of products and services in various domains such as 5G, IoT, and wireless enterprise solutions, among others. Moreover, Ericsson seeks to extend its reach to other markets and industries that exhibit a need for connectivity and ICT solutions.

Despite deep technical understanding within Ericsson, there are uncertainties regarding the potential of the controlled environment agriculture market (CEA), its idiosyncratic challenges, and underlying needs of the operating actors. The operating actors as referred to within this thesis report, refers to actors that are a part of the value chain in the CEA market. This could be an Original Equipment Manufacturer (OEM) supplying components to a primary grower, a system integrator providing farming solutions to the market, and growers producing crops in a controlled environment. Given the unexplored potential of the market, Ericsson has an interest in understanding the market and exploring any possible synergies with its capabilities.

1.2 Problem Description

The main issues related to the CEA market and the potential implications for Ericsson are the inadequate understanding of: the overall state of the CEA market, the operating actors' needs, as well as the current drivers and obstacles for development of the market. There is currently a lacking understanding of what factors affect the overall state of the CEA market, how large the market is, and what actors are operating within the market. Furthermore, the needs and requirements of the operating actors have yet to be identified, consequently leading to an incomplete perception of what actors require to be successful and overcome their current challenges. Finally, the market drivers and obstacles are currently unknown. In order to address these issues and consequently expand the understanding of the CEA market and its implications for Ericsson, the issues will be evaluated from the operating actors' perspective.

1.3 Aim

This thesis project aims to understand the controlled environment agriculture market from the perspective of the operating actors. Therefore, following the completion of the study, the project aims to provide an in-depth analysis of the state of the market, by describing current operating actors, factors affecting the overall market, current level of market maturity and the overall development of the market. In addition, the project also aims to identify the actors' needs and requirements as well as the obstacles and drivers for the overall CEA market. Furthermore, based on the identified needs, obstacles, and drivers for the development of the market, the implications for Ericsson will be evaluated.

1.4 Research Questions

Based on the aforementioned background, problem description, and aim presented in sections 1.1, 1.2, and 1.3, the following research questions have been formulated:

1. *What is the current state of the controlled environment agriculture market?*

2. *What are the actors' needs and requirements in the controlled environment agriculture market?*

3. *What could these needs imply for Ericsson, in terms of opportunities, risks, and benefits?*

1.5 Scope

The scope of this thesis is to evaluate the CEA market based on: the state of the market, the actors' needs and requirements, and the implications for Ericsson. Hence, a number of considerations have to be taken into account to more precisely define the extent of the thesis. Firstly, the innate ambiguity of the term CEA has to be addressed. In the context of this thesis CEA will be defined as an agricultural practice within an enclosed structure that enables control over environmental parameters using technological systems. This means that when referring to the CEA market it includes various actors, such as both growers using artificial sunlight and nutrient solutions to grow crops as well as growers cultivating in a greenhouse where the temperature and airflow are controlled using sensors and automated ventilation.

Furthermore, primary growers act as the foundations for the CEA market, where other actors such as OEMs and system integrators provides the primary growers with products and services. Primary growers are actors who are actively growing crops using CEA systems, they also distribute and sell the crops to wholesales and retailers. In regards to the extent of the market evaluation, this thesis aims to evaluate the global CEA market. However, due to practical limitations of resources and time it is not possible to conduct observations and on site interviews with actors outside of Sweden. The intention is to conduct an analysis of the global CEA market, hence multiple actors globally were contacted with the intention of conducting interviews digitally.

2

Theory

2.1 Controlled Environment Agriculture

Various sources define the term Controlled Environment Agriculture differently, even though it is not a new terminology. According to Dalrymple (1973), CEA was already an extensive and ambiguous topic back in the 1970's. CEA has progressed from basic row covers used in open fields to intricate and technologically advanced facilities (Ting et al., 2016). Controlled environments have evolved from basic protected cultivation in greenhouses to encompassing extensive and complex environmentally controlled plant factories with the objective of optimizing the growing conditions for enhanced plant growth (Ting et al., 2016). Figure 2.1 provides a comprehensive illustration of the technological advancements and functional transformations that have taken place within CEA over the past five decades.

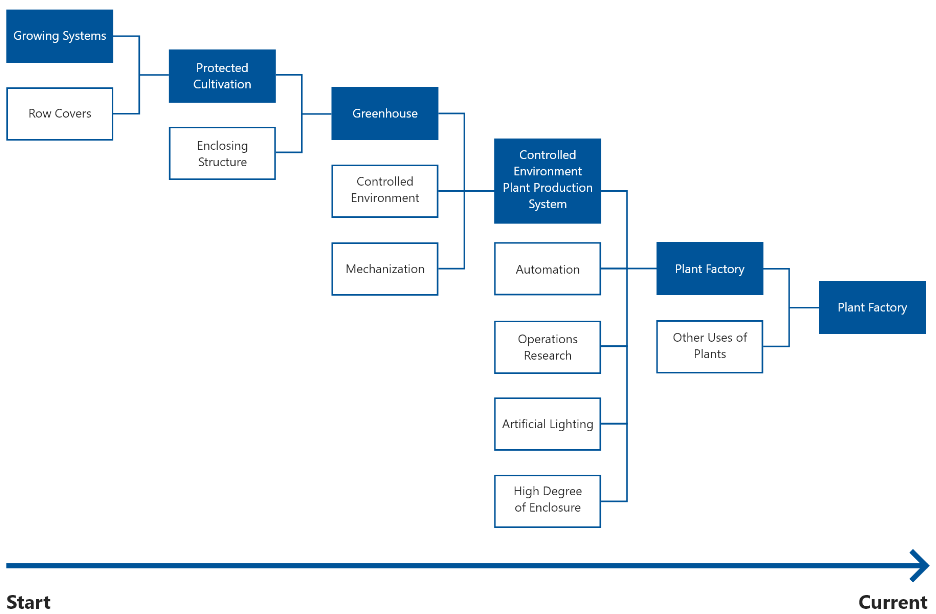

Figure 2.1: *Technological and functional evolution of CEA. Inspired by Figure 2.1 in Ting et al. (2016).*

Despite variations in how CEA is defined across various reports, contemporary studies have predominantly concentrated on the practice of cultivating crops indoors or within greenhouses, where the environment is regulated with the use of advanced technological systems. These technological systems control environmental parameters such as temperature, irrigation, light exposure, air and soil humidity, and nutrient levels (Abdullah et al., 2016).

2.1.1 Controlled Environmental Parameters

Optimizing plant growth requires precise control of both ambient temperature surrounding the plants and the temperature of the nutrients they receive (Benke & Tomkins, 2017). The root systems of plants are influenced by ambient temperature, impacting their capacity to absorb nutrients effectively (Srivani et al., 2019). Simultaneously, the temperature of the nutrients directly affects their ability to absorb oxygen (Srivani et al., 2019). As a result, it becomes crucial to exercise precise control over the temperature through heating, cooling, and ventilation methods in order to achieve ideal humidity and oxygen levels for the plants (Ting et al., 2016). An advantage of indoor farms, where artificial light is employed exclusively, is the ability to effectively insulate the inside environment from external factors, facilitating greater ease in regulating the internal temperature (Ting et al., 2016).

Sunlight, crucial for photosynthesis in plants, plays a significant role in determining their growth (Hall & Rao, 1999). In indoor farming systems, LED lights are widely preferred over conventional light sources due to their proven high efficiency (Srivani et al., 2019). The amount of light and which wavelengths can be controlled according to what the plants prefer (Benke & Tomkins, 2017; Van Delden et al., 2021). There exist three viable options for lighting sources in CEA: complete reliance on natural sunlight facilitated through translucent roofs and/or walls, exclusive utilization of artificial lighting from electricity-powered illumination devices, and a hybrid approach combining both natural and artificial light sources (Ting et al., 2016).

Soilless cultivation methods, commonly used in CEA, employ nutrient solutions, and involve growing plants in mediums like rock wool or perlite, while ensuring the necessary supply of essential nutrients (Benke & Tomkins, 2017). The balance and concentration of nutrients play pivotal roles in influencing optimal growth and maximizing yields (Srivani et al., 2019). Regular monitoring of the nutrient solution by measuring electrical conductivity and pH-value in the nutrient solution is vital to ensure the optimal growth of plants and can be adjusted if needed (Srivani et al., 2019).

2.1.2 Common Farming Practices

One common farming practice used in CEA is vertical farming. Vertical farming systems denote multi-tiered indoor cultivation systems incorporating artificial lighting, wherein growth parameters are precisely regulated (Van Delden et al., 2021). In vertical farming, the plants are organized in layers that are stacked on top of each other to create system with several stories of plants (Birkby, 2016). Organizing the plants vertically has benefits in terms of more effective arable area with the same footprint of land (Benke & Tomkins, 2017). Space can be more efficiently utilized since more plants can be compressed into a smaller volume, compared to horizontal farming where plants are spread out on larger areas. This indicates that vertical farming system has a greater crop yield per unit of cultivated area, compared to conventional horizontal farming (Touliatos et al., 2016).

The size and structure of vertical farms varies, e.g. the number of layers, if plants are mounted to a wall or placed in a vertical tower. However, every vertical farm employs one of three distinct soil-less systems to supply plants with essential nutrients, namely hydroponic, aeroponic, or aquaponic methods (Birkby, 2016).

Hydroponics is a cultivation method in which no soil is used (Khan et al., 2020). In hydroponic cultivation, the roots of crops are consistently immersed within a carefully monitored nutrient solution, which is regularly circulated to uphold the precise chemical composition necessary for optimal plant growth (Birkby, 2016; Van Delden et al., 2021). The nutrient solution provides the plants with all the nutrients and mineral required to stimulate growth. Various materials and methods are used to support the crop while simultaneously exposing the roots to the nutrient rich water (Encyclopaedia Britannica, 2023). All plants can be grown using hydroponic systems, however some crops are more often cultivated using this method, such as salad and tomatoes (RHS Gardening, nd). A hydroponic system is a closed loop system, meaning the water used for irrigation recirculates in the systems.

Another soilless agriculture method is aeroponics, which is a subset of hydroponics. In contrast to hydroponics, the roots of the plants are grown in air or mist in aeroponic systems (Van Delden et al., 2021). The plant's root system is suspended in air and, at regular intervals, sprayed with a water based nutrient solution to stimulate growth and provide the plant with the required nutrients (French & Roth, 2021). Aeroponic agriculture is highly efficient, both at maximizing yield as well as minimizing water usage. According to Dunbar (2007), aeroponic systems can reduce water usage by as much as 98% while simultaneously indicating more efficient uptake of minerals.

Aquaponics is a cultivation technique that combines hydroponics and aquaculture (Lennard & Goddek, 2019). Aquaponics is a combination of aquaculture, the cultivation of fish and other marine animals in a controlled environment, and hydroponics (Nation Agricultural Library, nd). The integration of the two cultivation systems is done by creating a closed-loop system that mimics an ecosystem. By recirculating the water and utilizing the excrement produced by e.g. fishes, the crops are fertilized while simultaneously filtering the water for the fish (Pattillo, 2017).

2.1.3 Global Factors Affecting the Market

There are many different macro forces affecting the CEA market, both driving and hindering market development. This is emphasised by Ting et al. (2016), which state that comprehensive attention should be given to social, economic, and environmental circumstances in order to scale up successful and commercial CEA systems.

2.1.3.1 Environmental Impact

When evaluating the environmental impact of agriculture at both global and regional scales, it is customary to consider various factors (Van Delden et al., 2021). These factors include, but are not limited to, the utilization of resources such as water, land, energy, and soil pollution (Van Delden et al., 2021).

Water Consumption

Many reports highlight low water consumption as a driving factor for the implementation of CEA practices. When comparing CEA to conventional outdoor farming, the ability to recycle water and reduce evaporation leads to lower water consumption in CEA systems (Benke & Tomkins, 2017). The enclosed structures and advanced systems controlling the environment, typically used in vertical farming, can facilitate a water usage of approximately 99% less compared to conventional open field agriculture (Van Delden et al., 2021). This is further supported by a report from Agritecture LLC and WayBeyond Ltd (2021), in which it is shown that 66% of the CEA respondents use 90-99% less water than conventional farming, see Figure 2.2. Low water usage is often contributed to how the irrigation is configured, for example in hydroponic or aeroponic systems, where water is recycled in closed irrigation systems (Van Delden et al., 2021; Despommier, 2011).

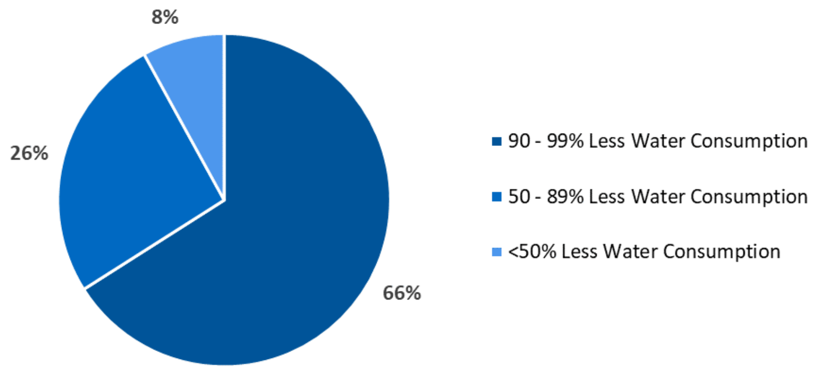

Figure 2.2: *Reported water consumption of CEA system compared to conventional farming. Inspired by graph 46 in Agritecture LLC and WayBeyond Ltd (2021).*

In the article (Lages Barbosa et al., 2015), the authors compare hydroponic and conventional farming methods, in regards to land, water, and energy usage when growing lettuce. The article shows that the water usage for hydroponic systems is around 20 liters per kilogram produces crop annually, whereas conventional farming requires around 250 liters per produced kilogram, see Figure 2.3.

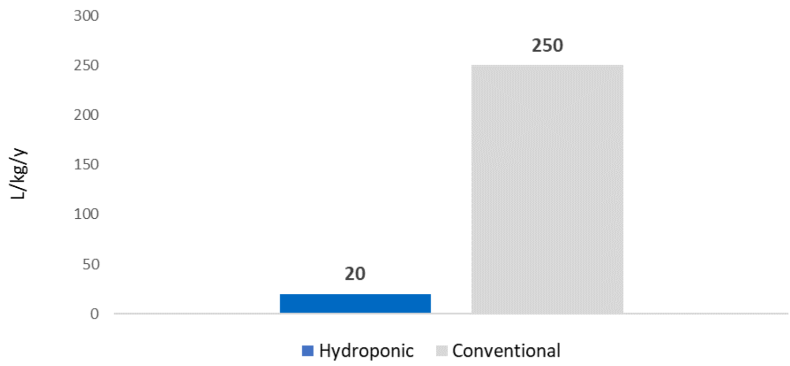

Figure 2.3: *Amount of water consumed (in liters) per kg of produced crops, a comparison between hydroponic systems and conventional farming. Inspired by Figure 2 in Lages Barbosa et al. (2015).*

Land Use

The efficient utilization of land is a factor emphasized by proponents of CEA and vertical farming. The growing global population, urbanization trends, and the impact of climate change are collectively diminishing the availability of arable land on our planet (Benke & Tomkins, 2017). Embracing the practice of cultivating crops vertically within controlled environments offers a promising solution to optimize land usage and enhance future food production (Van Delden et al., 2021; Benke & Tomkins, 2017). According to LeBlanc (2020), the cultivation of crops within indoor spaces has the potential to yield a production output ranging from four to six times greater than the capacity of equivalent outdoor areas.

Less land usage for hydroponic systems compared to outdoor farming, is also described by Lages Barbosa et al. (2015), stating that hydroponic systems can produce over 40 kilograms of crops per square meter annually, whereas conventional farming only reaches a production of barely 5 kilograms, see Figure 2.4.

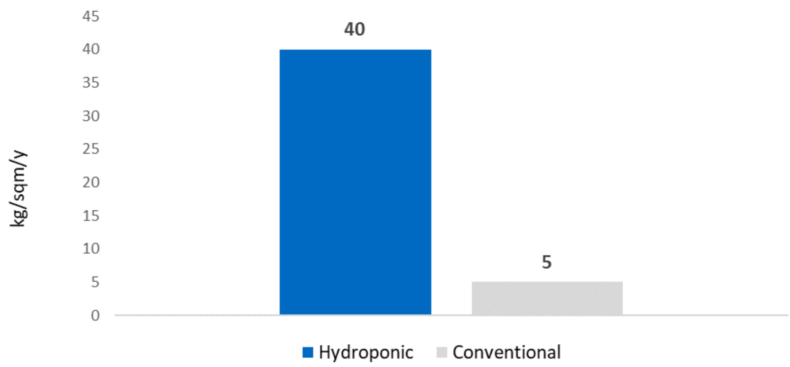

Figure 2.4: *Yield rate per square meter of land, a comparison between hydroponic systems and conventional farming. Inspired by Figure 1 in Lages Barbosa et al. (2015).*

Energy

Energy consumption is another environmental factor impacting how the CEA market is developing. CEA has been subject to criticism regarding how environmentally friendly this way of farming is, due to energy consumption. While the enclosed structure of vertical farming systems appears to mitigate their direct environmental impact, crop production within vertical farming necessitates a higher energy input compared to open-field agriculture (Van Delden et al., 2021). High energy consumption in vertical farming is also supported by Agritecture LLC and WayBeyond Ltd (2021), stating that vertical farms consume over seven times more energy per kilogram of produced crop compared to greenhouses, see Figure 2.5.

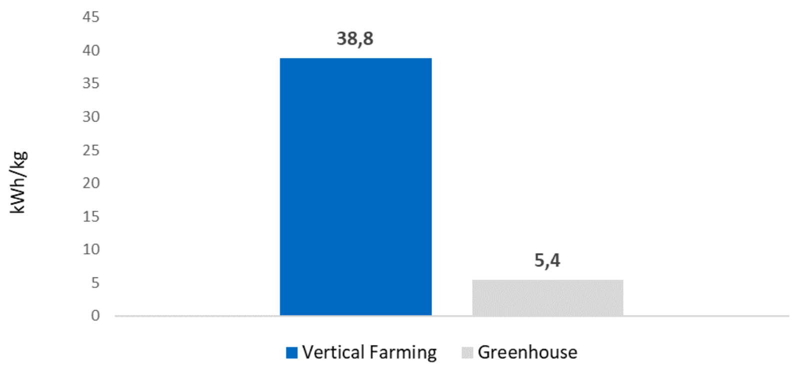

Figure 2.5: *Comparison of energy consumption per kg of produced crops between vertical farming and greenhouses according to responses from Agritecture LLC and WayBeyond Ltd (2021).*

A lower energy consumption in conventional farming compared to hydroponic systems is also implied by Lages Barbosa et al. (2015), see Figure 2.6. The graph depicts a notable disparity in energy consumption between hydroponic systems and conventional farming. Specifically, hydroponic systems were found to require an average of nearly 100,000 kilojoules per kilogram of produced crop annually, whereas conventional farming only utilized approximately 1,000 kilojoules. In hydroponics, the primary energy-consuming components encompassed circulation pumps, artificial lighting, heating, and cooling, whereas conventional farming primarily relied on fuel usage and groundwater pumping as the main energy-intensive activities (Lages Barbosa et al., 2015).

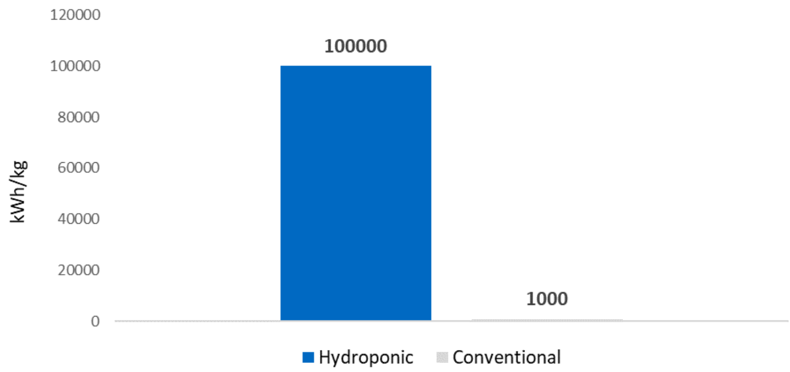

Figure 2.6: *Yearly energy consumption per kg of produced crops of hydroponic systems compared with conventional farming. Inspired by Figure 3 in Lages Barbosa et al. (2015).*

The energy consumption is mainly determined by the need to deliver artificial light to plants and later extract that energy using HVAC systems (Van Delden et al., 2021). Because vertical farming rely entirely on electricity to provide artificial light, it is essential to have a thorough understanding of the requirements and cost-effectiveness of lighting devices used for plant growth and development (Ting et al., 2016).

Although many reports suggests high energy usage in CEA, there are also reports showing that indoor vertical farms has the potential to use less energy compared to outdoor fields. For example in Benke & Tomkins (2017), where an example is presented showing that a indoor vertical farm in Japan has managed to use 40 % less energy compared to farming in outdoor fields.

Fertilizers and Pesticides

Vertical farming has the potential to yield food in a manner that is resilient to climate variations, potentially minimizing or eliminating the need for pesticides and fertilizers compared to open-field farming (Van Delden et al., 2021). Extensive control over the production process, including stringent hygiene measures, serves to minimize pathogen contamination while enhancing uniformity, nutritional value, taste, and shelf life (Van Delden et al., 2021).

Regions where human excrement is utilized as a fertilizer, which accounts for approximately 50% of global farming, frequently encounter diseases transmitted through fecal contamination, including cholera, typhoid fever, and various parasitic infections (Despommier, 2011). However, farming in controlled environments, free from vermin infestation, necessitates only the utilization of water mixed with nutrients, reducing the need for traditional fertilizers (Benke & Tomkins, 2017; Van Delden et al., 2021). While the availability of water is feasible for most nations, acquiring fertilizers poses challenges, particularly for less developed countries (Despommier, 2011).

2.1.3.2 Financial Benefits and Drawbacks

Vertical farming presents different economic benefits, for example the ability to label the produced crops as clean, green, and gourmet (CGG) and sell them as a premium products (Benke & Tomkins, 2017). Furthermore, crops can be locally produced, enabling domestic crop production and reducing long-distance transportation, but also the potential to export crops abroad (Benke & Tomkins, 2017). Additionally, CEA within or in close proximity to urban areas has the potential to offer a consistent and secure year-round food supply, while concurrently enhancing the economic progress of societies (Ting et al., 2016).

Across various regions, the energy consumption required for heating and/or cooling in CEA constitutes a significant proportion of both the initial investment and ongoing operational expenses (Ting et al., 2016). Extensive research and development efforts are persistently focused on addressing the considerable capital and operating expenses associated with LED lighting, which remain a prominent concern for the advancement of future plant factories (Ting et al., 2016).

Vertical farming poses notable financial challenges and obstacles in terms of high barriers to entry represented by steep start-up costs, unaffordable real estate in urban areas, and limited access to investment capital (Van Delden et al., 2021). In order to make meaningful contributions to the food supply chain, it is imperative to find ways to alleviate the substantial initial capital investment and ongoing operational costs inherent in vertical farming (Van Delden et al., 2021). The technology is still relatively new, and companies have yet to achieve large-scale crop production successfully, while also making it financially viable to meet the rising demands for food (LeBlanc, 2020).

2.1.3.3 Public Policies, Subsidies, and Certifications

Public policies concerning vertical farming have exhibited a relatively limited and fragmented nature, which is surprising considering the significant potential of vertical farming systems to address various social and environmental challenges (Van Delden et al., 2021). Many CEA practices are recognized in the American Improvement Act since 2018 (Nera, 2022). These practices include indoor farms, greenhouses, vertical farms, and different cultivation systems. When it comes to public funding, the United States Department of Agriculture (USDA) currently offers funding and research opportunities that could support various aspects of vertical agriculture (U.S. Department of Agriculture, 2018). Additionally, the National Institute for Food and Agriculture provides funding opportunities that could potentially be utilized to support research focused on vertical agriculture. In the European Union, initiatives related to vertical farming have been supported through research programs, the European Regional Development Fund (ERDF), and the European Agricultural Fund for Rural Development (EAFRD) (Nera, 2022). However, vertical farming is not explicitly addressed by EU agricultural and climate policies.

In a report from EIT Food North-West (2022), it is mentioned that funding and subsidies are identified as obstacles hindering the widespread adoption of CEA production in rural regions. Moreover, the report highlights that unlike many other industries, there is a lack of funding specifically allocated for energy usage by farmers and the horticulture sector as a whole. According to Nera (2022), integrating vertical farming into public policy frameworks is crucial for it to effectively contribute to the food supply. The author suggests that a strong integration can facilitate research and development efforts focused on reducing operational costs, addressing high energy demands, and overcoming challenges related to economic sustainability and consumer acceptance. According to Specht et al. (2016), the perception and acceptance of vertical farming systems have regional and cultural variations, with a relatively low societal acceptance globally.

EU producers can receive financial compensation for organic farming or animal husbandry (Swedish Board of Agriculture, 2023). The regulatory framework for organic certification established by the European Commission affects farming methods used in controlled environments. Crops grown without soil, such as those grown in hydroponic or aquaponic systems, cannot be certified as organic unless they naturally grow in water (European Commission, 2023). Farmers seeking to obtain organic certification while cultivating crops in soilless environments and control irrigation artificially can not receive the compensation related to organic certification mention in Swedish Board of Agriculture (2023).

3
Methodology

In this chapter, the chosen research methodology will be presented, which also includes elaborating on the analytical tools applied during the project. Furthermore, an explanation of the procedure used will be provided, which encompasses how the project was carried out, why it was done in that manner, and the order in which tasks were completed. Finally, the research subjects interviewed during this thesis will be presented and their respective companies briefly described.

3.1 Research Methodology

Research can be conducted using qualitative, quantitative, or mixed methods, which are the three most commonly used strategies (Williams et al., 2007). Qualitative research involves gathering and analyzing non-numerical data, such as words rather than numbers, to better understand a studied phenomenon (Bell et al., 2022; Punch, 2013). A qualitative approach is an effective method for uncovering nuanced details about a situation or generating new study areas (Bell et al., 2022). In contrast, quantitative research focuses on gathering and analyzing numerical data to identify trends, examine causality, and make generalizations for larger populations (Bell et al., 2022).

Bell et al. (2022) describes an inductive approach as drawing conclusions based on observations, where the theory or hypothesis is formulated based on the findings, as compared to a deductive approach that formulates a hypothesis before collecting data. According to Soiferman (2010), an inductive approach is more suitable for exploratory research where researchers formulate hypothesis based on the gathered data, whereas a deductive approach is better suited for research focusing on confirming or rejecting pre-formulated hypothesis . The aim of the thesis was to develop an understanding of the CEA market using the operating actors' perspective, without a predetermined hypothesis of the actors' views or the overall state of the market. Hence, an inductive approach was deemed most suitable for this thesis project.

Additionally, since the findings of thesis were intended to be based primarily on the operating actors' perspectives and needs, the information was predominantly verbal and of non-numerical nature. As described by Bell et al. (2022), an inductive approach is more commonly related with a qualitative research approach, which emphasizes words and understanding the interview participant's view on the world, seeking to explain phenomena by using rich descriptions provided by the interview subject. Given the aim of the thesis was to develop an understanding of the CEA market using the operating actors' perspective and needs, qualitative research methods, i.e. interviews and observations, were chosen to gather the necessary data.

3.1.1 Analytical Tools

There exists a plethora of tools suitable for actualizing verbal information and analyzing research subjects' needs and perspectives. A tool used to actualize verbal information about users' perspectives into needs is the concept of user needs. User needs is a term denoting a concept widely used within product development and other business areas. The concept of needs and requirements has many definitions, some related to technical specifications while others focus more on formulating challenges. However, for the context of this thesis, the definition from Gibbons (2019) described as *"A user need statement is an actionable problem statement used to summarize who a particular user is, the user's need, and why the need is important to that user"* is utilized.

Uncovering user needs and requirements is a process that involves multiple methods, each suitable for certain situations in order to discover different kinds of needs. American Association for Quality (2023) describes three different kinds of customer needs and states that some are unspoken while others are spoken needs. Furthermore, Dienes & Perner (1999) elaborates that knowledge can be both explicit and implicit and that the appropriate methodology to discover these types of knowledge within interviewees differs, e.g. verbal information is inherently explicit and can be discerned through interviews whereas implicit knowledge cannot be found using direct questions (Dienes & Perner, 1999).

One tool used to analyze verbal information is the KJ method, also known as affinity diagram analysis, or thematic analysis (American Association for Quality, 2019; Plain, 2007). The following description, of how to conduct a KJ analysis, will exclusively utilize information from the sources referred to in the previous sentence. The KJ method was first created by Japanese anthropologist Jiro Kawakita and is a method used to organize large amounts of information, particularly verbal information collected from interviews. Conducting the method requires a number of steps, and can be conducted either physically or digitally using tools such as Miro, Jira or other digital whiteboards.

The first step in the process of conducting a KJ-analysis is gathering data, which can be done by conducting interviews, analyzing transcripts or performing brainstorming sessions (American Association for Quality, 2019; Plain, 2007). The data is then transferred onto sticky notes or comparable digital options verbatim to preserve the original formulation, particularly regarding verbal information form interviews. Thirdly, the individual notes are placed on a common surface, such as a whiteboard where they can be sorted in groups. Fourth, the participants of the method start organizing the notes in groups by finding common themes or some affinity between the notes until all notes are organized into groups, this step is commonly done in silence to restrict participants from influencing each other. Fifth, discuss the groups amongst the participants and reorganize the groups if necessary. Once the groups have been finalized and all participants are content with the structure the sixth step is to assign headers to each group that captures the essence of the groups. The seventh step is optional and should be conducted as required. It entails clustering the groups from step six into larger so called "supergroups". This step can be done when groups have similar themes or when there are large amount of data that requires additional sorting.

Describing the relationship between a company's strategy for retaining competitive advantage and growth with the overall characteristics of the market the company is active is essential to understand how the market and the actors within it will develop. Utterback & Abernathy (1975) explains that the development of a company's production process technology and its growth plan corresponds with the specific innovation phase of the market. The rate of product and process innovation can provide a general indication of how mature a market is Shin et al. (2019). Product innovation refers to novel technologies or combinations of technologies which are introduced to meet an existing need on the target market, whereas process innovation relates to a focus on improving process efficiency through larger innovations such as automation (Utterback & Abernathy, 1975). In emerging markets, there tends to be a high level of product innovation, while in more established markets, the focus gradually shifts towards increasing rates of process innovation (Shin et al., 2019). When both process and product innovation rates begin to stabilize and no longer exhibit a decrease, it is a sign that the market has reached a state of maturity (Shin et al., 2019). An overview of the relationship between product and process innovation, and how it relates to market maturity can be seen in Figure 3.1.

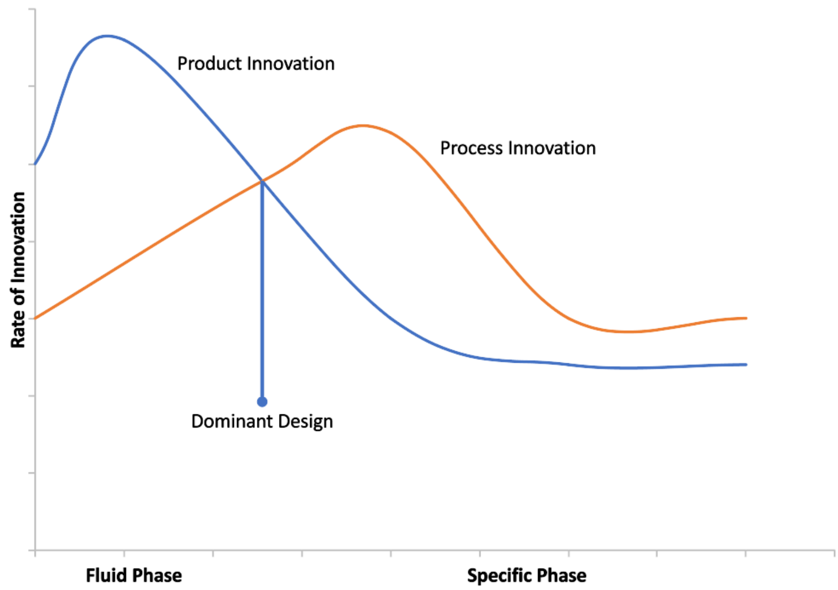

Figure 3.1: *Rate of innovation in regards to how mature a market is. Inspired by Figure 1 in Shin et al. (2019)*

3.2 Initial Exploration

During the initial phase of the study, the project's scope was determined, and specific details regarding the study's focus were defined. This involved collaboratively working with the project supervisor at Ericsson to identify the target market for the study. To narrow down the scope, a specific segment within the market was selected. The CEA market was recognized as a market of interest and became the primary focus of the study. Subsequently, companies that fit within the boundaries of the target market were identified, and an initial list of potentially relevant companies was compiled. This list also included companies that had previously collaborated with Ericsson on various projects related to CEA.

In the early exploratory phase of the project, several discussions and evaluations with employees at Ericsson were conducted. To get a better understanding of what initiatives had previously been conducted within CEA, why they were conducted, which ones were successful, which were unsuccessful. Additionally, an initial literature review was conducted, where reports, articles and relevant scientific papers about the CEA market and related concepts were studied. The results of the literature review would support the formulation of the state of the market. Furthermore, an overall plan was created to facilitate the workstream for the project. It was a plan that segmented the primary goal of the project into three main areas which were then broken down into smaller actionable tasks. This plan was then utilized as the foundation for the data collection phase and was based on theory presented by Bell et al. (2022) regarding planning and conducting research.

3.3 Research Subject Selection Criteria

Selection of research subjects for the thesis focused on gathering data from enough actors to construct a representative overview of the global CEA market. In order to formulate the overview a minimum number of interviews was decided upon, in collaboration between the authors of this thesis and the project supervisor. Which entailed gathering data, through interviews, from at least two actors on every continent, except Antarctica, resulting in a minimum of 12 actors spread evenly across every continent. The selection criteria used for screening potential research subjects was defined as: interviewed actors had to be operating within the overall CEA market value chain, meaning actors could be an OEM, system integrator or primary grower as long as they used, sold or operated using CEA systems.

However, due to time restrictions for the thesis project a limited amount of time was available for data collection, meaning that data collection had to be stopped at a set time, not once sufficient data had been gathered. In order to be able to gather information actors had to be able to disclose information that was not covered by their non-disclosure agreements that prevented employees from discussing certain topics such as company specific information. Difficulties obtaining information from actors in countries such as Singapore and the U.S., due to restrictive NDA's of actors in the respective countries, prevented interviews from being conducted with actors in said countries. Given the aforementioned circumstances, a total of 9 interviews were performed with actors. Regardless of the fact that the minimum number of required interviews was not achieved, the interviewed actors operated on markets on every continent in the world. Which ensures the gathered data takes into consideration nuances and potential differences between geographical markets such as Europe and Asia. An overview of the interviewed actors' roles in their respective companies is presented in Table 3.1.

Table 3.1: *Specification of the interviewees' roles.*

Company	Role
A	Chief Innovation Officer
B	Customer Support
C	Chief Executive Officer
D	Chief Executive Officer
E	Chief Executive Officer
F	Chief R&D Officer
G	Chief Executive Officer
H	Strategic Innovation Engineer
I	Chief Executive Officer

Additionally, several discussions and meetings were held with employees at Ericsson to gain a better understanding of previous engagements and projects done at Ericsson which related to CEA and similar subjects. These discussions and meetings were not counted as interviews since the main objective of the meetings were to gather information about Ericsson and understand what had been done, while the main results of the thesis emphasized the operating actors' views and perspectives. Similarly, internal documents analyzed to understand how Ericsson evaluates markets were excluded from the main results of the thesis.

3.4 Data Collection

The process of contacting companies, scheduling interviews, and conducting interviews was a continuous process. Interviews were conducted in succession as they were scheduled. Each interview was recorded with the participants' consent, and subsequently transcribed. Following each interview, a concise summary of the participants' responses was written to facilitate the extraction of information while it remained recent and easily accessible.

The effectiveness of the interviews hinged largely on the establishment of an appropriate interview process. This entailed employing the appropriate interview format. The chosen format for this thesis was a semi-structured interview approach, encompassing 14 broader areas of discussion rather than narrow, specific questions. These 14 discussion areas corresponded to the actionable tasks and key aspects outlined during the initial exploratory phase of the project. Adopting this format allowed interviewees to express their thoughts more freely within a particular topic and facilitated a comparison of responses across interviewees for the same discussion areas. For a comprehensive overview of the interview template utilized with the participating actors, see A.1.

3.5 Data Analysis

Upon completion of all interviews a KJ-analysis was conducted. The analysis was conducted according to the description of the steps involved in a KJ-analysis presented in section 3.1.1, which was based on information presented by (American Association for Quality, 2019; Plain, 2007). All interviews were transcribed and noteworthy quotes were extracted from each individual interview, in total over 300 different notes with individual quotes from different actors were gathered and used as the input data for the KJ-analysis. In order to be able to analyze all quotes an analysis was performed on each interview separately, were quotes were ordered into groups according to common themes identified within the individual notes. These groups of notes were then assigned a 1st level title that summarized the common theme among the notes in a short sentence, acting as a thematic representation of the common issue, these groups were referred to as 1st level clusters in Figure 3.2.

Following the completion of the individual interviews' analysis, a larger second level analysis was performed, which compared quotes across all interviews with different actors. The analysis was performed similarly to the analysis of the individual interviews, however instead of comparing single notes with each other 1st level clusters were compared and grouped according to underlying issues or common themes. These larger groups were referred to as 2nd level groups and composed of various numbers of 1st level clusters. After identifying the 2nd level groups, a unifying title called a 2nd level title was assigned to each 2nd level group, similar to the 1st level titles. These 2nd level titles described the common issue within the larger 2nd level group, an overview of the analysis process is described in Figure 3.2.

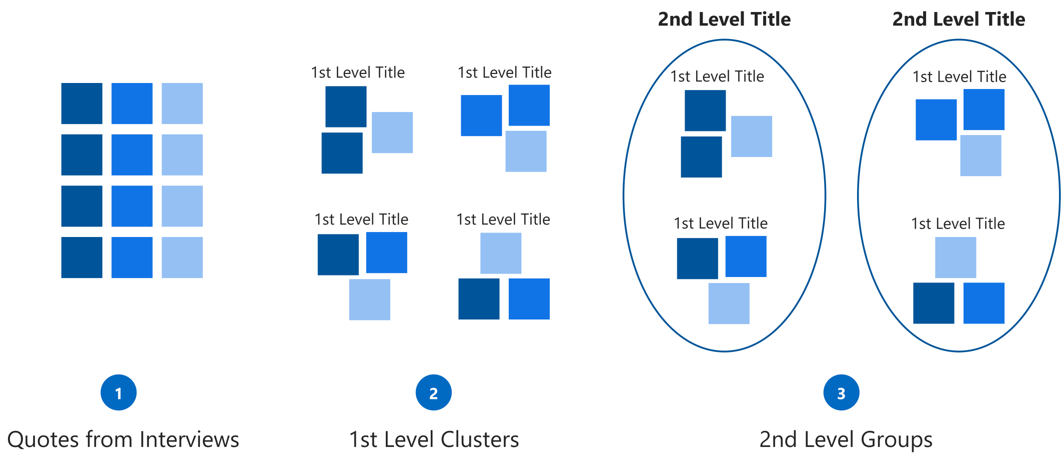

Figure 3.2: *Overview of how grouping and labeling was done during the KJ analysis.*

From these 2nd level groups, their respective titles, which represented the common issue for the entire group, and all the quotes within the group, needs were formulated. These needs reflected the underlying issue for all the quotes within the 2nd level group and were formulated according to the previously mentioned definition of user needs as described in section 3.1.1. With the gathered data, organized into large groups, needs identified, and comprehensive summaries written to each large group, the KJ analysis was concluded.

3.6 Concluding Analysis

Not only were the requirements of actors derived from the completed KJ analysis, but also valuable insights about the overall market were acquired. Such insights encompass aspects concerning the present state, trajectory, and dynamics of the market, encompassing its growth, development, as well as the factors driving or impeding its development. These insights served as the fundamental basis for conducting a comprehensive macro analysis of the market. Such insights enabled a comparison between the statements made by the interviewed actors and their perception of the market, with published reports and information gathered from the literature review. This allowed an evaluation of the alignment between the actors' experiences and findings of published studies.

Knowledge about the market's current state and the identified needs among actors were then combined to analyze its implications for Ericsson. Assessing how Ericsson could potentially integrate into this market has been an iterative process. This involved engaging in discussions with various individuals within Ericsson to explore the company's capabilities and past initiatives in the field of CEA. These discussions have been conducted on a regular basis throughout the project, serving as the groundwork for establishing connections between the insights derived from interviews with CEA actors and their implications for Ericsson.

Instead of adopting a perspective solely centered on Ericsson and evaluating what the company can offer to the market, the intention was to evaluate how the findings regarding the market could impact Ericsson, and assess whether the market's needs align with solutions Ericsson possesses. Based on the identified needs, drivers, and obstacles prevalent in the market, an understanding was developed which outlined the characteristics of potential solutions that correspond to these needs, drivers, and obstacles. Essentially, this process involved translating the needs, drivers, and obstacles into the specific problems that potential solutions should endeavor to address. Subsequently, a comparison was made between these potential solutions and the existing capabilities, solutions, and core business areas of Ericsson. By undertaking this assessment, an overview of whether Ericsson's offerings are capable of fulfilling the requirements of the potential solutions could be formulated.

3.7 Description of Interviewed Companies

Among the interviewed companies, there are various company types with various connections to CEA market. Some are serving as original equipment manufacturers or system integrators, whereas others are serving as primary growers. Information about the companies the interviewees represent can be seen in table 3.2 below.

Table 3.2: *Information about the interviewed companies. The information includes: company types, how many years companies have been active, market coverage in terms of on which continents companies have customers and operations, main customers, number of employees, and revenue (in million U.S dollars) generated in 2022.*

Company	Company Type	Years Active	Location	Market Coverage	Main Customer	Employees	Revenue [Million USD]
A	Service Provider	<5	Sweden	Europe	Grocery stores, restaurants	<10	<1
B	OEM	6-10	Kenya	Africa	Outdoor farms, greenhouses	10-25	<1
C	System Integrator	<5	Poland	North America, South America, Oceania	Indoor- and outdoor farms	<10	1-10
D	OEM	>10	Sweden	All continents	Indoor farms, greenhouses	10-25	1-10
E	Grower	<5	Sweden	Europe	Grocery stores, wholesale	<10	<1
F	Grower	6-10	Sweden	Europe	Grocery stores	26-100	<1
G	OEM	<5	Sweden	All continents	Farms, greenhouses	<10	<1
H	System Integrator	>10	Netherlands	All continents	Farms, greenhouses	>100	11-100
I	Grower	>10	Sweden	Europe	Grocery stores, wholesale	26-100	11-100

Company A - is a service provider that offers farming units to grocery stores, restaurants, and other companies interested in producing their own crops in-house. Rather than owning and operating farms to produce crops for sale to grocery stores, the company offers a service called “farming-as-a-service” (FaaS). This service encompasses the installation and maintenance of intelligent small-scale indoor farming units, and allows clients can tailor the service in terms of the size of the farming unit and the production volume of crops.

Company B - is an agritech company that provides both agricultural products and services. The company are selling greenhouses and drop irrigation kits to farmers. Additionally, the company offers a device that collects data from farms using sensors. The data can be used to automate part of the farms, e.g. irrigation. The company also maintains and offers an integrated application service. The application service enables the users to have contact with the company’s own agronomists that can assess data from the farms and provide farming advice to the user based on the collected information.

Company C - is an automation firm that creates a robotic solution for crop harvesting in the form of a robotic arm. The solution’s intention is to automate the harvesting process for farmers, reducing human inquiries and workplace accidents while also lowering labor costs associated with manual harvesting. The company's business approach is primarily direct sales where the machinery is sold to clients while continuing to manufacture for the next client. However, the company also provides harvest-as-a-service, in which they own the technology but deploy the robotic arm, gather the crops, and are paid depending on the amount of kilograms harvested.

Company D - is a well-established supplier of LED lighting to the horticultural market, with a major focus on smart lighting, managing the light spectrum for plants, and assisting customers in reducing lighting-related energy usage. The company offers a lightning solution with wireless controls, dim features, and algorithms that can optimize energy usage during the day based on weather forecasts. The usual customers for the company are actors that use greenhouses.

Company E - is a indoor grower that supplies wholesale with mostly lettuce, that is then resold to grocery stores. Lettuce is grown vertically, picked up by the customer, and then sold to the final consumer in grocery stores. The business approach is direct sales, with a focus on supplying clients a high quality crops to a competitive price. The price of the lettuce that the company sells to wholesale is a major focus area, with imported lettuce serving as their primary pricing benchmark. Future development plans include expanding their operations and move away from simply direct sales, and instead own more of the value chain and sell their vertical farms as compete solutions to farmers.

Company F - is an industrial indoor farming company that specializes in selling primary lettuce directly to grocery stores. It is widely recognized as one of the world's largest actors in indoor vertical farming in terms of production volume. The company's business strategy is centered on owning a substantial segment of the value chain. Rather than relying on external actors and merely concentrating on the farming process, the company is responsible for all aspects of production, including growing, washing, packing, and logistics. This comprehensive approach enables the company to realize the benefits of the margins that would otherwise be dispersed among other players involved in the value chain.

Company G - is a manufacturer of a proprietary solution that is utilized to construct vertical farming systems. While the company operates solely as a hardware supplier, it is a crucial component of a broader value network that collaborates to provide comprehensive vertical farming solutions to farmers. These systems can be tailored to meet the unique requirements of individual clients, with demand spanning from small-scale orders to large-scale projects. The business model of the company is primarily centered on direct sales and focused on two primary markets: the indoor farming and greenhouse sectors.

Company H - is both an original equipment manufacturer (OEM) and a system integrator in the realm of factory automation for the food and agriculture industry. The company strives to facilitate scalable food systems by delivering technology-based solutions to farms, greenhouses, and tissue culture laboratories. The company describe themselves as machine builders that create automation and logistic solutions. In the farming market, the company offers a wide range of equipment and services, including seeders, transplanters, fillers, watering and irrigation systems, and logistic and conveyor solutions. An entire track and trace system, including corresponding software, is developed in-house by the company.

Company I - is an agriculture enterprise that employs hydroponics cultivation techniques in a greenhouse environment. Its vision is to produce premium quality herbs and lettuces for the end-consumer. The company caters to a customer segment that primarily includes large grocery stores and wholesalers.

4

Result

In this chapter, the results of the conducted study will be presented. The result is comprised of three main parts: State of the Market, Actors' Needs and Requirements, and Implications for Ericsson.

4.1 State of the Market

Describing the state of the CEA market entails a comprehensive overview of several factors affecting the market. Based on the actors' perspective collected during interviews a number of key elements are described, to enable a thorough analysis of the overall CEA market. These factors elements include: factors affecting the market, predicted market development, size of the market, drivers behind market growth, as well as potential obstacles hindering market development.

4.1.1 Factors Affecting Actors on the Market

Actors described a plethora of factors which affected their businesses and subsequent growth. These factors varied widely from political aspects that hindered their causes, to environmental factors that benefits their growth and offered them competitive advantage towards conventional farming. In broad terms, the aforementioned factors were clustered in one of three groups: Environmental, Financial, or Political.

4.1.1.1 Water, Land, and Energy Usage

There are multiple environmental factors to consider regarding CEA systems, as described in section 2.1.3.1. Among these factors are: water consumption, land use, and energy consumption. Water consumption and land use are described by actors as aspects that positively affect their companies and grants them a competitive advantage against conventional outdoor farming. On the other hand, energy consumption was mentioned as a drawback and challenge straining the CEA market and the actors' respective businesses.

Several interviewed companies, particularly those directly engaged in crop cultivation, emphasize the notable increased water efficiency achieved through controlled environment farming and closed irrigation systems. The reduced water usage is considered as an environmental advantage in comparison to conventional farming practices, which is supported by theory presented in section 2.1.3.1. Interviewed actors engaged in the cultivation process of crops using CEA systems, assert that their farming solutions have the potential to conserve up to 95% of water, when compared to the water consumption of traditional outdoor farming irrigation.

Furthermore, some of the interviewed actors contend that their farming solutions can effectively minimize land utilization in contrast to conventional farming practices. Higher yield rate per square meter as well as less land use, are advantages of CEA systems compared with conventional outdoor agriculture methods, which is further described in 2.1.3.1. This environmental aspect is further elaborated upon by IMARC Group (2023), stating that scarcity of arable land is a catalyst for the growth of indoor farming practices.

CEA systems consumes more energy using HVAC than traditional agriculture, a topic elaborated upon in section 2.1.3.1. Several interviewed actors mentioned energy consumption as a challenge they have to overcome, both in order to decrease operational costs and to ensure sustainable operations. As energy consumption is closely associated with energy costs, this particular factor becomes especially relevant given the current, as of May 2023, energy crisis which has drastically increased energy prices. The CEO of Company D further emphasized this point when discussing the challenges faced by the indoor farming market *"I don't believe in indoor farming at the moment, until you have a solution for your energy."*.

4.1.1.2 Investments, Profit Margins, and Costs

A majority of actors emphasized that financial issues were some of the biggest challenges their companies currently faced in the market. These issues related to three main aspects of financial viability of CEA systems, namely: high upfront investment costs, low profit margins, and high operating costs. The combined effect of these issues resulted in long payback times on actors' investments into CEA systems, which subsequently hinders the process of attaining further investments and scaling their businesses.

In terms of the high investment costs associate with establishing CEA systems, the CEO of Company G described their challenges when building larger CEA projects as *"The big challenge is the funding of these projects"* (Original quote in Swedish translated to English). This further highlights how integral initial investments are to establishing CEA systems and for realizing larger customer projects. Even if demand for a CEA system is shown by customers, actors on the CEA market might not be able to capitalize on the opportunities due to insurmountable initial investment barriers. Company B's person responsible for customer support described their sales and expansion plans as being hindered by financial barriers, emphasized by a quote from said person *"We find that most of the farmers don't have the necessary financing, and that's why we are using financial institutions to partner with and give them loans."*

Actors described that the profit margins in the food industry were low in general, which affected the profitability in the CEA market and the entire upstream value chain from retailers to growers. This was highlighted due to the fact that retailers were pressed for prices by consumers buying patterns, an issue that was brought to light by the CEO of Company A *"It's about dollars and pennies all the time"* referring to retailers challenges when selling produce. This is a challenge emphasized by every interviewed actor regardless of their specific role within the CEA market, whether as a primary grower, system integrator or as an OEM. Company F's CRDO further supported this view by describing the bottleneck of the industry as:

"The bottleneck for the industry is price and volume, how can we make a difference if we can't produce enough volume to get a spot on the shelf and if what you can produce costs twice as much"

The operating costs associated with running CEA systems are highly interconnected with energy cost and achieving unit economy for each individual crop grown. Throughout interviews the evaluated actors expressed concerns regarding both aspects of the operating costs and the challenges they posed. CEO of Company E elaborated about how they viewed the financial barriers on the market, stating *"In the end it's the operational costs that eats away at it [profit margin]"*, referring to the fact that the operational costs diminishes the potential profit margins in their business.

Additionally, the cost of energy represents another financial challenge for indoor farming, particularly in environments where natural sunlight cannot be utilized, as artificial light is energy-intensive. Company E's CEO elaborated on this issue related to energy costs *"Of course, something all [actors] complain about is the energy price"* Because CEA systems consumes energy to a higher degree than conventional farming, as is described in section 2.1.3.1, this subsequently impacts the energy costs associated with operating a CEA system. The current energy crisis further exacerbates the operational costs associated with maintaining and running these CEA systems, rendering it more challenging to sustain a profitable indoor farming business. The CEO of Company D describes the relation between financial challenges and energy prices *"Capital expenditure too expensive and to run a vertical farm at the moment is too expensive especially with the energy price being four times higher than before the energy crisis"*

4.1.1.3 Public Funding

The majority of the interviewed participants emphasized the significant financial challenges they faced, in terms of achieving profitable operations and overcoming high investment barriers to scale up their businesses. Obtaining public funding through various subsidies or grants was therefore mentioned as a necessary support for operating actors. CEO of Company D described their reliance on funding in order to grow as *"in order to grow under that business model, we would need a lot of funding"*.

Conversely, many actors also asserted that they had received subsidies from governmental bodies, innovation facilitators, and other relevant institutions. Company A's CEO described subsidies for energy use as an important example of public funding *"When it comes to different types of subsidies you get, for example one of the biggest resources you need in this segment is electricity."* Nevertheless, some actors expressed that they believed the subsidies they received paled in comparison to the subsidies provided to conventional farming practices.

4.1.2 Market Development

Actors' perspective on the state of the market varies significantly. Many actors have high expectations for their own specific segment of the market and their contributions to the market, while remaining more skeptical towards other actors' business models and market segments. Which is understandable, given that actors' are likely to express more positive and optimistic opinions towards their own business and segment in the market.

There was no consensus among actors on what factors are inhibiting growth, what factors are enabling growth, and which segments of the market have the most potential growth. Certain interviewees expressed skepticism regarding the current growth of the indoor farming market, placing greater optimism in the greenhouse and outdoor market. In contrast, other operating actors advocate for the growth of the market, suggesting that the indoor farming market is experiencing significant annual growth and will progressively assume a larger role in the food supply chain in the coming years. These actors argue that the increasing need for food security will be a significant driver of demand for indoor farming solutions and greenhouses, particularly in countries that rely heavily on imported crops. Furthermore, actors, particularly those on the Swedish market, expressed that they expect the demand for food paired with the high import rate of crops will drive up demand and subsequently lead to additional growth. However, in countries with well-established reliable domestic production and supply chains, the growth of indoor farming and greenhouses may not be as pronounced. As is supported a statement from the CRDO of Company F, when discussing the maturity of different markets:

"...Sweden is very good because you have low volumes of domestic production and a high import rate meaning the market is ready. But to do the same thing [grow indoors] in for example Spain is not at all a good idea"

Public awareness and acceptance of CEA systems was mentioned as an important factor to consider by the interviewed actors, particularly among those involved in crop cultivation. Public understanding of CEA systems and the concept of CEA in general can vary, which can affect the growth and development of the CEA market in a number of ways. Low awareness among consumers about the benefits of CEA systems compared to conventional farming practices might limit the actors' customers' ability to sell the CEA cultivated crops to potential consumers. Additionally, governments may face challenges in formulating comprehensive and well-informed regulations and policies supporting CEA initiatives if they have inadequate understanding of the concept CEA.

Reluctance towards new technology in farming and in extension acceptance-rate among customers for CEA systems is an aspect operating actors brought up as a challenge. While interviewed actors reported having experienced low cultural barriers within their respective market segments, they did express concerns about customers reluctance towards technology-driven solutions within agricultural practices in general. This was particularly emphasized by a subset of actors such as Company B, who's team member responsible for customer support elaborated on acceptance rate as *"Introducing a new technology to farmers who are accustomed to their old ways of farming, it has been [the] greatest challenge."*

This reluctance towards CEA systems suggested that some individuals were hesitant to adopt new technology in their businesses and may be resistant to changing their traditional methods of operation. However, other actors noticed a shift in people's attitudes towards technology used in farming, indicating that while people were hesitant a few years ago, they now have a more accepting mindset towards tech solutions related to farming. As is explained by the CEO of Company C:

The mentality of the people has changed over the last nine years I've been in business ... I think from my experience people were more, like they were not so willing to accept this technology but that's changing and technology is getting every day closer and closer to people..

Regarding the differences between countries in terms of ease of market entry and sales, some respondents indicated that North America and Europe had lower barriers to entry in general. This is partly due to the geographical markets' adaptability to new concepts such as CEA, actors' understanding of the markets' needs, and the countries' financial strengths to invest in more effective farming systems. On the other hand, some actors suggested that in general, countries in Asia do not have the same needs and financial incentives to invest in new technological solutions, making them harder to sell to. Countries in Asia are often able to develop technology at a lower cost internally, paired with low cost labor and manufacturing made these countries though to enter. The challenges associated with market entry necessitate actors to adapt their business approaches for effectively selling CEA systems and solutions in these specific markets. This is described by the SIE of Company H:

In the case of countries like India, Bangladesh, Sri Lanka, Pakistan, Vietnam, I think those are the countries which are difficult to sell to. The whole focus from there is technology is not a problem, the business case is a problem.

Even in markets where there is sufficient financial support and a desire to develop and implement more effective farming methods, the context for alternative approaches to farming may not be adequate. For instance, regions where conventional farming is well established and deeply rooted in the country's trade and industry, and where daylight is not a limiting factor, may have the willingness and financial backing for alternative farming methods, but lack the fundamental need for them. Essentially, the context may not be conducive for the adoption of alternative farming methods. In contrast, regions with low domestic production and high dependence on imported agricultural products or regions with limited sunlight and short days, the need to achieve self-sufficiency food production through alternative farming methods could be higher.

Furthermore, the financial implications of the current geopolitical situation in Europe, and the world, impacts the growth and development of the market. Increased inflation and cost of resources has raised the cost of manufacturing CEA systems, which adds strain to the CEA market. This was brought up as a challenges by the CEO of Company D:

"At the moment there is hardly any new greenhouse build because of the energy prices, because of the uncertainty in the market, because of all the raw materials have become so expensive. So to build a greenhouse in 2023 you pay almost twice as much as 2018"

4.1.3 Market Size

The definition of controlled environment agriculture, as stated in section 1.1, encompasses both greenhouses as well as vertical indoor farms. The CEA market includes a large variety of companies, spanning from primary growers using greenhouses to OEMs delivering products to vertical indoor growers. In this study four different types of companies were identified: service providers, OEMs, growers, and system integrators, as can be seen in table 3.2. The diversity of the market is further supported when examining the different business models the operating companies employ, as seen in the company descriptions 3.7.

Due to the ambiguity of the term CEA, the boundaries for the CEA market also become vaguely defined. The ambiguity of the boundaries for the market results in issues specifying the current size of the CEA market. Multiple sources defined the market differently, subsequently citing vastly different total market sizes. One such source was a report published by IMARC Group (2023), stating that the global market for indoor farming, which includes both vertical farming as well as greenhouses, attained a valuation of $17.8 Billion in 2022. Furthermore, the report stated that the overall market will grow to reach $32.5 Billion by 2028, reflecting a compound annual growth rate (CAGR) of 10.6% during the period from 2022 to 2028. Conversely, a report by Grand View Research (2023) valued the CEA market at $34.2 Billion with a CAGR of 12.9% between 2023 and 2030. This entails that the authors estimate that the market would reach a valuation of $88.5 Billion by 2030, a significantly higher estimation than the previously mentioned article.

Ergo, an average estimate of the CEA market size was created using the previously mentioned estimates. This average estimate should be viewed as an indicative estimate of the likely size of the CEA market, not act as a precise measurement of its true size. Figure 4.1 showcases the aforementioned estimates and average market size, the figure indicates that as of 2023 the market is estimated to be close to $30 Billion.

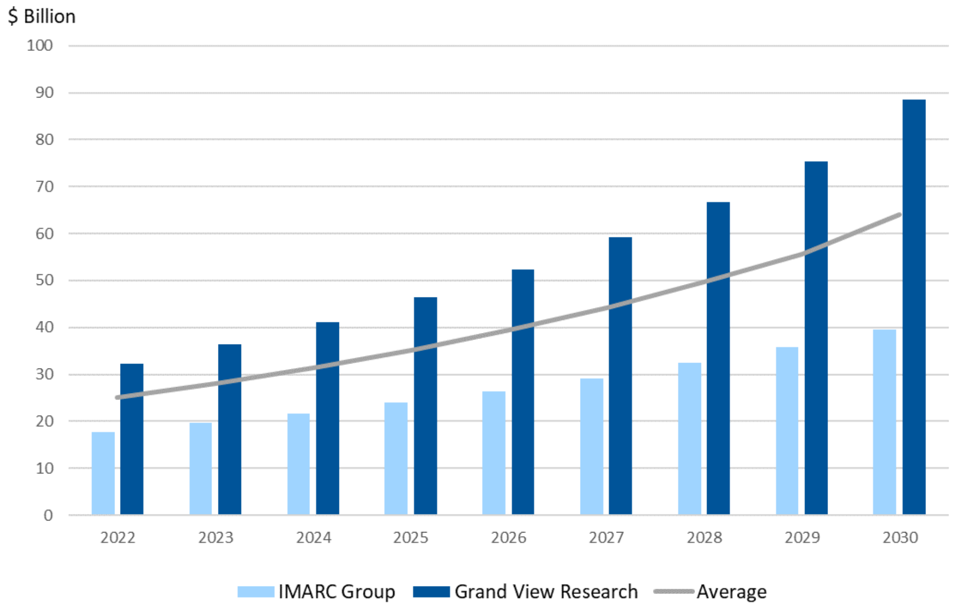

Figure 4.1: *Estimated Size of the CEA Market in terms of total revenue. Based on data provided by IMARC Group (2023); Grand View Research (2023).*

4.1.4 Market Maturity

Presently, the market is experiencing significant levels of innovation, with many new actors introducing novel concepts and business models. The rate of innovation and diversity in the market is further reflected in how many years the interviewed companies had been active, as can be seen in table 3.2. Which is consistent with Agritecture LLC and Autogrow Systems Limited (2019), which determined that approximately 70% of the survey's 316 respondents reported having launched their business within the past five years. This influx of new entrants combined with the variety of their employed business models contributes to a diversified market with a high degree of innovation (Klepper, 1996). While some actors are focusing on improving their offering others are attempting to standardize their processes and scale up their operations to enhance performance. Which is exemplified by a statement by the CRDO of Company F regarding their competitive advantage *"what sets us apart from other indoor growers is what we have learnt about scale, yield, and consistency."* As actors scale up and become more established in the market, the market itself matures and becomes less fragmented. When an industry matures, firms depart the market in greater numbers than new actors enter, causing firms to strive for process innovation while product diversity decreases (Klepper, 1996).

Consequently, the remaining operators in a mature market prioritize process improvements over product enhancements, which paves the way for the emergence of a dominant market-specific design. There are a plethora of definitions for a dominant design, as is stated in a report by Srinivasan et al. (2006). However the definition used in this study refers to an architecture that establishes dominance in the selected product category. Nonetheless, the fragmented and diversified nature of the actors in the market indicates that a dominant design has yet to be established. At present, numerous actors are prioritizing effectiveness over efficiency. This implies that actors are emphasizing product performance and effectiveness, referring to doing the right things. Rather than minimizing costs by maximizing operational efficiency, which refers to doing things the right. Once a dominant design has been established, actors will shift their focus to scaling up sales, improving efficiency, and optimizing operational processes, which results in higher revenue, cost savings, and greater productivity. Butturini & Marcelis (2020) stated that:

> *The sector is young, capital-intensive, and starting a business comes with a risk. Scaling up vertical farms is not straightforward: what works for some companies or on a small scale, might not be the right model for others.*

While some actors are attempting to increase efficiency, which highlights their focus on process innovation, the majority of the CEA market is still finding its bearings. In conclusion these results indicates that the CEA market is currently in a fluid phase where the market is establishing itself and actors on the market are prioritizing product innovation. The current phase, and subsequent level of market maturity, is illustrated in Figure 4.2

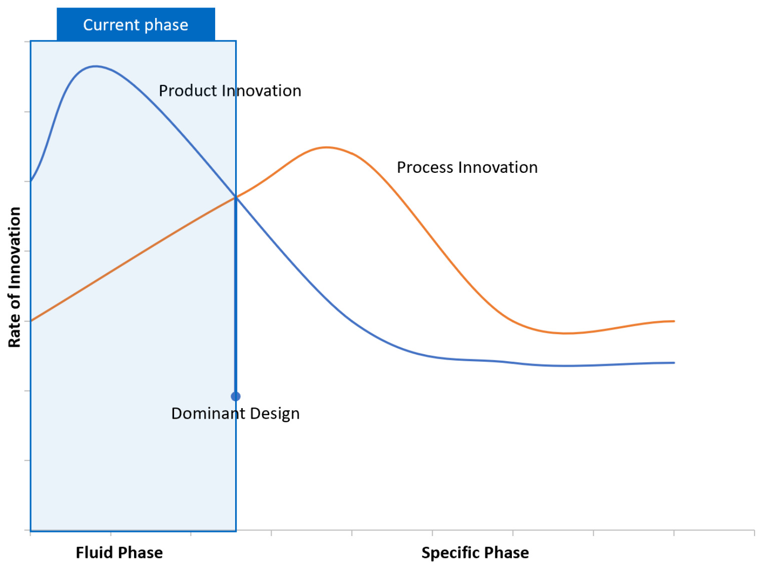

Figure 4.2: *Market Phases: Illustrating which phases the market is currently in regarding process and product innovation. Inspired by Figure 1 in Shin et al. (2019).*

4.1.5 Market Drivers

Some factors affecting the CEA market acts as drivers of demand for CEA systems and overall growth of the market. One of these drivers are the environmental factors of lower water and land usage, of CEA solutions compared to traditional agriculture. Traditional food production has significant negative impacts on the environment, Ritchie et al. (2022) describes traditional food production as occupying 50% of the world's habitable land and 70% of the available freshwater.

As described in section 2.1.3.1, CEA solutions use significantly lower amounts of fresh water compared to conventional farming. Since fresh water is a scarce resource in large parts of the world, e.g. the middle east, It acts a driver for implementing more CEA solutions due to the decreased use of freshwater in cultivation. Supporting countries efforts to increase the available amount of fresh drinking water by decreasing their use of fresh water for irrigation in traditional farming practices further drives the demand for CEA systems.

Furthermore, land use becomes particularly relevant for actors in countries experiencing a shortage of arable land or high population density, such as Singapore or Japan. In these locations, CEA systems could provide an alternative to conventional farming and imports of crops. By offering higher yield rates on significantly smaller land areas and reliable food supply regardless of how nutrient rich the soil is. These effects increase the attractiveness of CEA systems and drives the growth of the overall market.

Another driver for the CEA market's growth is the increasing climate and weather instability brought about by climate change. As the climate changes and becomes more unpredictable so does the supply of food. When heat waves becomes more common and with increased severity in large agricultural regions such as Spain, the demand for reliable, consistent and robust food supply increases. These phenomena are supported by numerous sources, such as United States Environmental Protection Agency (2022) describing that heat waves are becoming more frequent and severe. These factors contribute to the growing demand for reliable food supply that can withstand the growing changes to the global climate. Consequently driving the growth of the potential CEA market.

The high energy prices, raw material costs, and market uncertainties are mentioned as factors adversely affecting the greenhouse business. The constrained expansion of the greenhouse market, which can be attributed to global events occurring in recent years, is believed by some of the actors to be a transitory situation. These actors are of the opinion that the demand for greenhouses will resurge going forward, with Africa and Asia singled out as regions with significant potential for greenhouse deployment.

4.1.6 Market Obstacles

Energy consumption and increased cost of energy: The current global energy crisis affects all industries and countries, some more than others. The European continent has been particularly affected by the strained energy supply and associated increase in energy cost. As described by Statista Research Department (2023), the price for one megawatt of electricity in France had increased by 537% from august 2021 to august 2022. This dramatic price increase has an additional synergy effect with the high energy consumption of CEA farms resulting in a large burden on actors in the CEA market. Which is emphasized by the CEO of Company D *"...something everyone complains about are the energy prices."*. Therefore, the energy price and related energy consumption becomes an obstacle for the growth and development of the CEA market. This obstacle exacerbates the already strained financial situations of many actors and is especially relevant given the current energy crisis is the world in 2023.

Another obstacle for the development of the CEA market is the market's intrinsic financial barrier, as further described in section 4.1.1.2. As previously mentioned, there are numerous economic challenges to overcome to succeed in the CEA market. One of these challenges are the high upfront investments required to establish operations, which subsequently severely affects the companies' ability to generate a profit. Furthermore, smaller CEA farms struggle to attain economics of scale that would allow them to cultivate large volumes of crops while achieving profitability. CEA growers competing with traditionally cultivated crops from large traditional agriculture companies struggle to produce the necessary volumes at a comparable price point. The CRDO of Company F, one of the largest indoor farms by volume in the world, stated that *"...volume and price are what stands in the way for indoor farming and so far no one has been able to prove that indoor farming is a profitable way to grow crops"*. Ergo, financial and economic challenges acts as obstacles for the success of the entire CEA market.

4.1.7 Summary: State of the Market

Based on the identified results, as presented in the prior sections, the CEA market is currently in a fluid phase where innovation is prevalent, the market is fragmented and without a clear dominant design. However, the market is showing signs that it is starting to transition towards a point where a dominant design might emerge. This is evident by the fact that some companies are shifting their focus to increase efficiency in order to gain competitive advantage. As stated by the CRDO of Company F, when asked about their views on some of their biggest challenges, *"...volume and price are what stand in the way for indoor farming"*

While Company F exhibits signs of a stronger focus on process innovation, other companies still emphasize the importance of product innovation. As companies are shifting their focus towards more process innovation and less product innovation the entire market will approach a point where a dominant design will likely appear. A number of factors supports and enables the development of the CEA market while other factors blocks the markets growth and development. There are plenty of factors not considered in this study, however the key factors discovered during the project are described in the following section.

4.2 Actors' Needs and Requirements

The results found during the interviews were analyzed using the KJ-analysis, as described in section 3.5. During the analysis 11 second level groups were identified which consolidated data from several different interviews, which described challenges and issues actors faced in their operations and in large. These eleven second level groups were used as the foundation for the formulation of the actors' needs, each group was further analyzed to identify the underlying need indicated by the individual data points and first level groups within the larger second level group. In the following section all of the identified second level groups are described, in the end a table, compiling the information in the form of 11 needs, is presented.

Data Collection

Data collection serves as a fundamental pillar when building models used for optimization of growing conditions or to enable data-driven services. However, the extent of data collection can vary from a macro or micro level depending on the specific data requirements for the models or services. Companies: A, B, E, and F all described how data can be gathered at both a macro and micro level to effectively optimize growing conditions. Macro-level data collection involves obtaining information about broader growing climates, such as entire greenhouses or farms. For instance, this entails collecting data on humidity, temperature, and airflow within a greenhouse. Described by the CRDO of Company F, when discussing how data gathered on a macro level cannot be used for micro analysis *"today you have a large so called weather station that is traditionally mounted in the celing which does not give the same value for plants furthest down on the left side of the farm versus those on the right side"*. Conversely, micro-level data collection involves gathering data on individual plants or growth media, such as measuring the pH levels in the water for each individual plant or monitoring the plant's electrophysiological signals. This indicates a need to be able to gather data on both a macro and micro level in order to perform detailed evaluations and opimizations.

Dependency on Sensors

In order to collect the necessary data, different sensors are required. Several interviewees emphasized their dependency on sensors of varying nature to acquire the crucial data for their operations. The CRDO of Company F explained that they gathered data from three main categories of parameters: water, air and light. Within each category, a plethora of measurable parameters exist, each requiring different sensors. Further exemplified by the CRDO of Company F *"All of these 3 parameter areas are extremely dependent on sensors."*. To ensure proper function of their operations, Company B, Company F, Company G, and Company H all emphasized a need for reliable sensors.

Data Quality

To develop effective and accurate models for optimizing plant growth conditions, a significant amount of data is required. Specifically, large volumes of high-quality data are necessary to be able to train optimization models and, consequently, enhance yield rates. This is applicable to all companies employing algorithms and models that require data data for training and optimization. However, it was particularly prominent among large-scale industrial growers utilizing optimization models to create optimal growth conditions for crops, such as Company F, as well as industrial service integrators like Company H. While collecting vast amounts of data is valuable, building models with low resolution data will yield unreliable and inefficient models that are inadequate. High-quality data was perceived as a catalyst for model optimization, as stated by the CRDO of Company F *"Right now, the data resolution is too low to build efficient models."*. This indicates a need for transfer of high quality data in order to be able to build high quality models.

Degree of Automation

During interviews, it became apparent that the drivers of efficiency differed between actors, largely based on their particular situation and circumstances. Companies: C, A, D, and E indicated that their path towards increased efficiency in their operations lies in augmenting their level of automation. This is particularly prevalent in the aforementioned companies, as the yield they deliver to customers relies heavily on automated processes. Therefore, increasing the degree of automation would benefit their businesses. The CIO of Company A further highlights this dependency on automation, stating *"When looking at the technology itself automation is what is important to us. That way we can help save hours of work for our customers."* Hence, successfully automating more aspects of the operational processes is a vital element in growth and ensuring high-quality solutions for end customers for these companies. However, it should be noted that this need was not observed in all evaluated companies, indicating that it is not a universal requirement but rather more relevant to specific companies.

Controlled Variables

Maintaining control over multiple parameters simultaneously to create optimal growing conditions for various crops was a requirement a number of the interviewed actors emphasized. This was particularly relevant in Company: A, D, E, F, and H. All of the aforementioned companies must continually monitor and regulate numerous parameters in their operations to ensure the quality of their solutions. However, the quantity of parameters varied significantly between actors and was largely dependent on how advanced their operations were. For instance, the CIO of Company A stated in an interview that their solution involved monitoring a substantial number of parameters, where around 40 parameters were equipped with alarms and 120 parameters had specific target standards. It was imperative for this actor to have the capability to monitor and control all parameters simultaneously, to ensure the quality of their solution. On the other hand, this issue was less relevant for low-tech actors like Company G or for companies that exclusively monitor parameters without actively controlling them, such as Company B.

Latency

The results of the conducted interviews highlighted the interdependent relationship between real-time data and low latency requirements. Actors that worked with technology dependent on real-time data transfer, such as robots, cobots or live data, expressed stricter latency requirements. This was observed in Company C, Company D, and Company H which all share characteristics of utilizing robots or cobots in their operations. The CEO of Company D highlighted the importance of latency in ensuring safe working environments when robots and human workers collaborate in the same environment *"Yeah, especially when you work with these types of devices and when you mix people with robots in the greenhouse."* In extension this means that the companies using real-time data have to utilize connectivity solutions with low latency.

On the other hand, Company F highlighted that latency was not an important factor to consider to achieve 70% efficiency in terms of crop yield, but becomes more relevant the more efficiency the company strives to achieve. As exemplified by the CEO of Company F in an interview *"No it is not so important if you only want to reach 70% of the crops potential. "* However, in the same interview the CEO also stated that the company's profit margins lie within those last 30% efficiency. Consequently, achieving a profitable business model will require companies to achieve a higher degree of efficiency, real-time data has been mentioned by multiple actors on numerous occasions. This indicates that the need for low latency solutions could grow as the market transitions towards the specific phase where efficiency becomes the defining factor for success.

Data Throughput

Sending data reliably at intervals tailored to the specific situation and technology is crucial, and a need that was found in all the interviewed actors. All interviewed actors were in some way or another reliant on data, some to a higher degree than others. Data was used to ensure the actors' services were delivering high quality results, however data was also used by growers to optimize their crop yield. However, one of the difference between the actors' data use was the frequency of data transfer. The frequency depends on the actor's business model, core technology, current connectivity solution, and promised quality of service, among other factors. Therefore, actors reliant on real-time data require data to be sent reliably at continuous frequencies while other actors only sent data once or twice per day. Common for all actors was the need for reliable transfer of data at specific intervals tailored to their situation, although the specific interval will differ from actor to actor.

Connectivity Challenges

Ensure a stable and reliable connection regardless of the operating environment is a challenged faced by multiple actors. However, ensuring reliable connectivity to be able to provide a high quality service is both a business issues as well as a technical challenge. As stated by the CEO of Company C *"our business is depending on the connection and so is our service, so we want to make sure that we always have good service"*. Based on the conducted interviews and analysis, the companies that indicated this need are: Company B, Company C, Company D, and Company H. All of the previously mentioned companies offer solutions that operate at the customers' locations, meaning the connection has to work in varying climates and locations. Ergo, these companies need a reliable connectivity solution that allows them to operate their solutions without interruption.

Ensuring Competitive Price

Ensuring competitive prices reflects an overall pattern in the market, which in turn affects every actor in the value chain, regardless of their role. The pattern is that fresh vegetables are price sensitive goods and consumption behavior of said goods is highly affected by changes to consumers purchasing power, which is affected by increased prices or decreased available income. Furthermore, this is supported by interview respondents comments regarding competitive pricing of their solutions as well as statistics on the consumption of fresh fruit during periods with high inflation. In a study by Swedish Food Agency (2023), 40% of all respondents reported that they had decreased their consumption of fresh vegetables as a result of increased food prices due to inflation. Reflecting the fact that price is a critical driver in the consumption of fresh vegetables.

Therefore, to be able to produce goods that are competitive in the market, all actors in the value chain needs to provide their solutions at a low cost to ensure the end-product is comparable to cheaper imported crops. A quote by the CEO of Company E, when asked why they choose a certain supplier over another, further supports the view that pricing comparably to imported goods is a crucial element to be competitive in the market. *"What we are trying to do is change society, and eliminate the import [of crops], and we can't do that with your [referring to a supplier] prices."* - CEO, Company E, 2023

Issues with Funding

High initial investment costs was discovered as an issue all interviewed actors faced. Financial challenges were common for actors across businesses and country boarders. Company B faced financial challenges when offering their solutions to rural farmers in Africa, as their primary customer base lacks opportunities for loans to help cover initial expenditure. Whereas Company A faced financial barriers when attempting to scale their businesses to more locations, as funding has become more expensive and becomes harder to acquire. Common for all actors was that the required technology was expensive to invest in and the market overall has low margin, results in long payback times which makes it more difficult to attract external investors. As described by an employee at Company B *"another challenge is the financial bit. These things [their product] are expensive, they're pricey because the technology is new"*.

These financial barriers are also affected by the price sensitivity of the final crop sold to end-consumers. Because the consumption pattern of consumers is driven, in large part, by price of the produce, the final produce has to be sold with low margins. However, in multiple instances actors who sold their crops to retailers and wholesalers don't capture the profit themselves. The profit is instead captured by the retailers that can set an arbitrary price towards the customers. This limits the market penetration a grower can achieve and in extension how profitable the value chain up until retailers can be. This is further affected by the fact that growers have to maintain competitive prices on their final products to be able to compete with other cheaper alternatives, such as imported goods. Ergo, overcoming the initial financial barriers for actors further up in the value chain becomes difficult, and multiple actors have experienced slow growth due to these barriers. This is supported by comments from the CEO of Company C *"in order to grow under that business model, we would need a lot of funding in order to manufacture a lot of machines."*

Sustainable Energy Supply

From the conducted interviews it was concluded that sustainable energy supply to operations was an issue for growers, primarily expressed by actors operating on the Swedish market. The actors: Company E, Company F, and Company G brand share a common vision of having sustainable operations, which renewable energy supply enables. Ensuring a sustainable and reliable energy supply also allows actors to operate in various environments and locations that lacks the otherwise necessary infrastructure. As stated by the CEO of Company G when discussing the issues of establishing projects in remote locations in Africa *"Solar energy and cooling allows us to work off-grid in countries with issues of reliable energy supply."*.

4.2.1 Summary: Actors' Needs and Requirements

The findings derived from the KJ analysis regarding the needs and requirements of the actors have been consolidated in Table 4.1. The table presents an overview of the existing needs and requirements. Additionally, it is important to note that the order in which the needs and requirements are listed does not indicate their respective level of importance. Finally, the listed needs and requirements should serve as broad descriptions, indicating general needs and challenging areas faced by actors, rather than as specific technical requirements.

Table 4.1: *Actors' needs and requirements specification.*

Category	ID	Need	Description
1. Data Collection	1.1	Macro & Micro Perspective	Actors need to be able to collect data on both a macro and micro perspective to be able to fully optimize growing conditions.
	1.2	Sensors	Actors need reliable sensors to collect data to ensure their operations function as intended.
	1.3	Data Quality	Actors need high quality data to build effective models to increase operative efficiency.
2. Automation	2.1	Automate Operations	Actors need to automate their operations to increase efficiency of their solutions.
3. Parameter Control	3.1	Parameters	Actors need to be able to control a large number of parameters simultaneously to create optimal growing climates.
	3.2	Latency	Actors need low latency connectivity solutions when working with technology dependent on real-time data.
4. Data Transfer	4.1	Transference	Actors need to be able to send data at specific intervals to ensure the quality of their solutions.
	4.2	Reliable Connection	Actors need a connectivity solution that allows data to be transferred without interruption regardless of the operating environment.
5. Financial	5.1	Competitive Price	Actors need to be able to provide a solution at a price point that ensures the crop that reaches the consumer market is competitively priced with traditionally grown imported crops.
	5.2	Financial Barriers	Actors need financial solutions to overcome high initial financial barriers due to high investment costs.
6. Energy	6.1	Energy Supply	Actors need a cost-effective supply of green energy to maintain sustainable operations.

Overall, eleven different needs and requirements were identified during the conducted study. These needs were divided into six larger categories: 1. Data collection, 2.

Automation, 3. Parameter control, 4. Data transfer, 5. Financial, and 6. Energy. Each category contains a varying number of individual needs that share a common theme, such as relateing to financial challenges and requirements.

The needs described in table 4.1, are general needs that apply to the entire CEA market to varying degrees. However, some needs were more frequently directly indicated by the interviewed actors than others. A summary of the direct verbalization frequency for all the identified needs can be seen in figure 4.3.

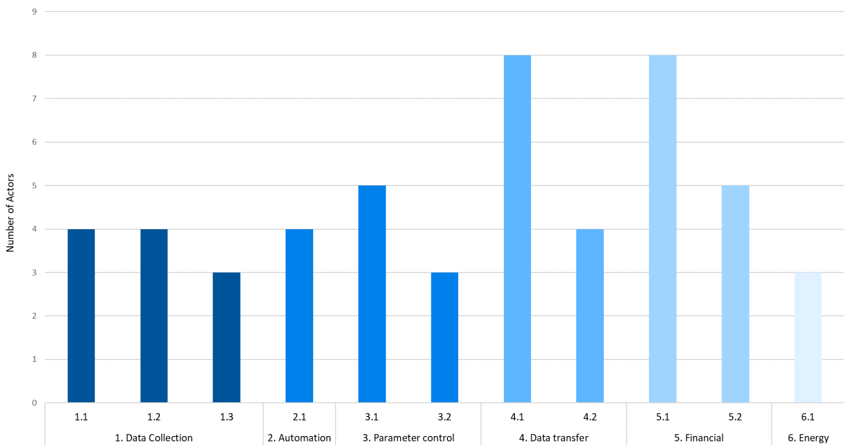

Figure 4.3: *Verbal indication frequency of each need, indicating the number of actors that verbally indicated each need explicitly*

As the graph indicates, the most commonly indicated needs were **4.1 Transference** and **5.1 Competitve Price**. These needs were consistently identified in all the interviewed companies and verbalized by all actors regardless of the companies individual traits and characteristics. From these two needs an overarching theme can be discerned, that companies have to be able to provide a competitively priced solution, regardless of the companies' role in the overall value chain, as well as a dependency on reliant data transfer to varying degrees. This underlying theme reflects challenges faced by actors throughout the CEA market, as it underscores the immense pressure on actors to provide their services or products at a low cost, ensuring the end-product is competitive in the market.

4.3 Implications for Ericsson

In this section the results implications for Ericsson will be presented, this includes presenting what needs and challenges a potential solution has to meet in order to be successful on the market. Furthermore, the business case for 5G will be evaluated based on the state of the market and the discovered needs.

4.3.1 Requirements for a Potential Solution

For a solution to be implemented successfully on the CEA market it has to address the obstacles facing the market and meet the actors' needs and requirements. This means that a potential solution has to overcome the challenges with energy consumption and the high energy costs as well as support actors to overcome the existing financial barriers on the market, such as the high initial investment barriers. Elaborating further on what this entails for a potential solution indicates that the growers on the CEA market are struggling to produce adequate volumes at a competitive price that allows them to be profitable. These issues cause ripple effects up the value stream and affects other actors supplying the growers with products or services. If the grower is under financial distress then that will affect the potential profits of the actors further up the value chain as well. Therefore, ensuring financial viability of a potential solution in this market is imperative.

Furthermore, the solution should meet the identified needs and requirements as specified in Table 4.1, which entails that at least eleven uncovered factors has to be considered. Some of these needs include: ensuring that actors are able to provide a product/service at a price point that ensures the end product is competitively priced compared with imported goods (Need 5.1). Which further supports the argument for the blockers of the market growth as detailed in section 4.1.6. This means that the potential solution cannot require high upfront investments or running costs that would add further stress to an already financially strained market.

Additionally, the solution has to enable actors to send data at specific intervals, unique to the actors' particular business models, to ensure the quality of their service. Actors' employ a variety of business models each requiring a different level of data transfer. Some actors send data daily, others transfer data once every other day while a few actors rely on real-time data. Ensuring the quality of their services relies on the actors being able to send data in a way that enables them to deliver their solution at an adequate quality. Meaning that the potential solution will have varying technical requirements, such as in terms of bandwidth, latency, coverage area, parameter control and similar. However, in order for a potential solution to be successful on the CEA market, it has to accommodate the needs of all actors. Otherwise the solution risks not fulfilling the needs of certain sub segments of the CEA market, and will risk not being able to reach the entire market. Overall, creating an attractive potential solution entails it has to be offered at a low cost to ensure actors meet their required financial needs as well as tailoring the solution to meet the individual actors' technical requirements.

However, some actors are apprehensive towards incorporating external solutions into their own business model, e.g. the CIO of Company A expressed why they were hesitant towards a collaboration with external partners *"an end-to-end solution that works just for us could be something that you could sell to others [actors on the CEA market]"*. This specific actor expressed a desire to not outsource just one specific aspect of their solution, but instead collaborate to outsource a larger part of their operations for it to be attractive. Successfully capturing the potential on the CEA market is not simply a matter of meeting technical needs and requirements but rather concerns understanding the actors situation and creating a solution that can help them attain competitive advantage and overcome their individual challenges.

4.3.2 The Business Case for 5G

One potential application area for Ericsson could be 5G, as it is one of their main capabilities. The following subsection evaluates the potential business case for 5G within the CEA market to examplify how a potential 5G solution would address the markets' needs and challenges. The interviewed actors expressed various opinions regarding the need of 5G technology. Discussions revolved around the current necessity for 5G and the changes required to make 5G solutions more appealing to these actors.

Many actors raised concerns about the cost associated with implementing 5G solutions, which is hindering them from adopting this technology. The SIE of Company H elaborated on the implementation areas of 5G and the associated financial barriers *"Just leave private 5G out of the scope right now because it is not commercially viable for these people [customers] to have private 5G in general"*. This indicates that the associated costs with 5G outweigh the potential operational benefits, which demonstrates that such a solution might not meet the actors' needs. Furthermore, some actors indicated that they were content with their current technical solutions. The actors emphasized that the current solutions were adequate for the current technical demand of their operations, in terms of technical communication. This is supported by the CEO of Company C, that stated when discussing their current communications solution:

I think we can survive very well with [our current solution]. So at the moment we are happy. But if we want to communicate more data then we need to go to another protocol and Wi-Fi is not the solution. Bluetooth, I don't think so. So then then it should be in 5G, kind of, that's the only thing I can relate to.".

Another actor discussed transitioning from their current wired connectivity solution to a wireless approach. The SIE of Company H described the benefits of their current a wired setup *"So quality of service, that's exactly why I said wired works better right now at this point of time, because the quality of service is really good with wired in general."* This highlights that a wireless solution like 5G would not supply the actor with any additional benefits to their service quality. Their current solutions therefore sufficiently meets their technical needs to such a degree that transitioning to a new connectivity solution becomes redundant.

Several actors praised the adequacy of the connectivity solutions used in the overall market, indicating that it sufficiently meets the needs of operating actors in the controlled environment agriculture market. Additionally, while some actors currently perceive no immediate need for 5G and expressed concerns about its cost, they believe that a future transition to 5G will be inevitable. As is described by the CEO of Company D when discussing the future connectivity needs in the CEA market:

It's too costly. Okay, that's the only reason ... when you use the outside antenna or 4G, yeah it doesn't go into the greenhouse far enough. So in conclusion, to have a dedicated 5G network in your greenhouse and then the question will be what we want to invest. The interviewee continues: *But I think in the end 5G will be standard, then we [have] a few choices to use 5G for greenhouse industry.*

In terms of the role of 5G in facilitating the future development of the CEA market, the interviewed actors highlighted data collection as a key aspect. Specifically, they discussed the potential for collecting larger volumes of data, as described by the CEO of Company C *"It [5G] would not have a use case in ... current farms, but this is good to keep it in mind for the near future, and [then] 5G will be able to help us also to send more data [and] to have more sensors"*. This suggests that while 5G may not currently hold significant value in the day-to-day operations of actors, there exists the possibility of its future utility as the demand for enhanced sensor capabilities and augmented data collection becomes increasingly evident. This notion is further supported by other actors who share the belief that 5G will enhance the frequency at which data can be gathered and transmitted in the forthcoming years. Moreover, actors have expressed optimism regarding the prospect of advanced connectivity solutions, as their operations steadily advance towards greater levels of autonomy and complexity. This is exemplified by the SIE of Company H who described the future of their wired connectivity solution in an autonomous greenhouse:

Plus you want the whole greenhouse to be autonomously controlled where you have algorithms of growth control. And based on your climate, on your monitoring, you want to open the vents, close the vents. You want to say [that] temperature is higher, the humidity is bad ... Those are real time actions. And once you get into that domain space, the current setup would never ever help you collect that data ... You can't have a wire which is as long as a greenhouse, it's not possible. So you have to go wireless. And that's where I think 5G can play a role when you go into that direction.

The interviewee (SIE, Company H) further elaborates that:

When ... people are going autonomous 100%, you want to rely more on your systems and you want your systems to have a more decision making power on a real time basis. That's when technologies like 5G can help. - SIE, Company H, 2023

To summarize, none of the interviewed actors explicitly indicated an immediate need for 5G technology in their current operations. Currently the actors on the CEA market as identified in this study do not rely on communication of data to such a degree that the financial costs of 5G are justified. Nevertheless, a number of actors anticipate that as the demand for data collection intensifies and 5G solutions become more cost-effective, more actors will be inclined to transition to enhanced connectivity solutions. This is when there could potentially be a business case for 5G in the CEA market. However, in the current state of the CEA market there is not be a fundamental need for improved digital communication motivating the associated cost of 5G. In conclusion, there is not currently a clear business case for

5G in this market, which is reflected in a statement by the SIE of Company H *"[5G] tends to be a bit expensive and you have to understand the fact that in these kind of industries, communication is the last thing they are concerned about."*

5

Discussion

In this chapter, the results of this thesis are evaluated and reflected upon, potential limitations and benefits of the applied research methodology are discussed, and future research areas proposed.

5.1 Obstacles, Drivers, and Global Factors

The current agriculture systems that constitute global food production exerts tremendous strain on the environment in a number of ways. As evident by statistics presented by Ritchie et al. (2022), which states that the current agricultural system consumes 70% of all available freshwater and 50% of all habitable land. Despite the environmental toll of the current agricultural system the amount of food produced is insufficient and cannot sustain the current global population, as supported by World Health Organization (2022) which states that as many as 2.3 billion people suffer from moderate or severe food insecurity. In conclusion, the current food system is detrimental to our environment, produces inadequate amounts of food, and cannot reliably sustain our society, meaning a change to the existing food system is inevitable.

The environmental advantages of CEA systems are clear, water consumption and land use of CEA systems are significantly lower than conventional agriculture, as described in section 2.1.3.1. The authors Lages Barbosa et al. (2015), state that hydroponic systems use around 92% less water than conventional systems and are 8 times more yield efficient than conventional farming methods. Furthermore, Benke & Tomkins (2017) describes that farming in controlled environment is free from vermin infestation which reduces the need for pesticides. In addition actors described that due to the fact that the growing environment is enclosed, sterile, and does not utilize soil it is therefore free from pests, eliminating the need for any pesticides.

Ng et al. (2005) indicated that certain pesticides commonly used during vegetable cultivation could inadvertently introduce microbial contamination to the crop, thereby impacting the shelf life of the vegetable. Because CEA systems are closed systems where the risk of unintentionally introducing pests to the cultivated crops is minimized, actors interviewed during this thesis reported using no pesticides during the cultivation of their crops. A longer shelf life becomes an advantage for primary growers, because retailers and wholesalers can keep their products on the shelf longer without worrying about potential waste and lost revenues. According to García-Gimeno & Zurera-Cosano (1997), the average shelf life of ready-to-eat salad is 7-14 days. However, actors interviewed during this thesis reported having longer shelf life on their CEA grown crops than conventionally grown crops. The CEO of Company E described how the shelf life of their products impacts waste: *We claim to not have any waste in our supply chain because if a wholesaler can't sell a salad in 2.5 weeks, then they shouldn't be a wholesaler.*

Given the current environmental situation where freshwater and land are consumed in enormous quantities by conventional agriculture systems in order to produce food as described by Ritchie et al. (2022), these environmental benefits of CEA systems emerges as unequivocal advantages. However, given the environmental advantages in land use, water consumption, and pesticide use, elaborated in section 2.1.3.1, the question about what obstacles hinder the development of CEA systems remains. The obstacles hindering the progression of the CEA market, and in extension the core problem with the market is not environmental in nature, but rather financial. Among the biggest obstacles currently faced by actors on the market were financial issues, namely high upfront investments, low profit margins and high operating costs. Van Delden et al. (2021) cite initial financial investments and operational costs as an inherent obstacle for vertical farming, which is further supported by actors' experiences. The CRDO of Company F explained their biggest challenges as "*...volume and price are what stands in the way for indoor farming and so far no one has been able to prove that indoor farming is a profitable way to grow crops*". These financial obstacles and the actors' experiences of them are further indicated by the identified needs in category **5. Financial**, as seen in Table 4.1. Need **5.1 Competitive Price** and **5.2 Financial Barriers** were two needs identified among actors relating to overcoming the financial obstacles seen in the market, as well as the ability of actors to competitively price the crops produced by primary growers.

Moreover, operating costs are driven in large by energy consumption and subsequent energy costs, as illustrated by actors experiences concerning issues coping with current surges to energy prices. This is emphasized by the identified need **6.1 Energy Supply** shown in Table 4.1, which relates to actors' need for a cost effective supply of energy. CEA systems' high energy consumption combined with the recent significant increases in energy prices has resulted in additional financial burdens. Energy prices has surged during the ongoing energy crisis, as indicated by Statista Research Department (2023) that stated that energy prices in France had increased by 537% from August 2021 to August 2022. CEO of company D further elaborated on the operating costs associated with energy consumption as "*...to run a vertical farm at the moment is too expensive especially with the energy price being four times higher than before the energy crisis*".

The cumulative result of these financial obstacles described by actors and previous research of the subject, is a long payback time for investments, as further elaborated in section 4.1.1.2. Long payback time for investments becomes an issue for operating actors as it makes it more difficult to scale operations and attract new investors.

Actors stress the need for financial aid and subsidies to overcome the significant financial challenges and investment barriers that hinder their profitability and scalability. Shown by the identified need **5.2 Financial Barriers** presented in Table 4.1, which highlighted actors' need for financial solutions to help overcome initial financial barriers. Meanwhile, the published reports, presented in 2.1, highlight insufficient funding and subsidies, and how a robust integration of CEA into public policies has the potential to increase research initiatives, encouraging comprehensive exploration and development within the field. EIT Food North-West (2022) highlight funding and subsidies, whereas Nera (2022) highlight inadequate integration of CEA into public policies, which negatively impacts research advancements, operational cost reduction, energy efficiency, and overall acceptance of CEA practices.

An example of how CEA practices are integrated into public policies, is regarding organic certification. Primary growers using CEA methods have difficulties with obtaining organic certification due to policies that fail to acknowledge its environmental benefits. Despite CEA's low water and land usage, as well as its pesticide and fertilizer-free nature, policies regarding organic certification focus on criteria such as artificial irrigation methods and soil usage (European Commission, 2023). This highlights the necessity for policymakers to recognize the specific requirements and advantages of CEA, ensuring comprehensive integration into public policies.

In conclusion, public support remains a critical factor affecting the current and future development of the CEA market, as noted by both industry actors and published sources. Enhanced integration of CEA practices into public policies would yield various benefits, including the allocation of increased research resources towards developing energy-efficient solutions, consequently reducing the operational costs linked to energy consumption. Furthermore, improved integration would result in greater funding opportunities for scaling up operations, mitigating the financial burden of initial investments, and ultimately enhancing profitability for CEA actors. This comprehensive integration would not only assist market actors in navigating the challenging financial landscape associated with initiating CEA practices but also facilitate smoother expansion and upscaling processes in the future.

The challenges faced by actors in scaling up and increasing crop production volumes primarily stem from financial issues. Public support is one aspect influencing these challenges, alongside the significant costs associated with constructing and investing in CEA systems. Furthermore, the combination of low profit margins from selling crops to retailers and wholesalers further complicates the quest for profitability and expanding production capacity. The low profit margin is directly linked to the need for CEA crops to compete with the prices of imported crops, which is emphasized in need **5.1 Competitive Price** as presented in Table 4.1.

In 2.1, the concept of labeling and marketing crops as premium products is identified as a potential economic advantage. Benke & Tomkins (2017) suggest that by labeling crops as clean, green, and gourmet (CGG), and positioning them as premium goods, vertical farming can reap economic benefits. However, the specific beneficiaries of this economic advantage are not elaborated on in Benke & Tomkins (2017).

According to the interviewed growers, they sell their crops to retailers and wholesalers at prices comparable to imported produce. For example, the CDRO of Company F described the pricing dynamics and premium labeling with their retailers as: *Some stores choose to price us as a premium product ... but for the retailer purchasing our product, there is only 1 SEK difference compared to an imported salad.* This approach allows them to offer a lucrative pricing structure to the retailers and wholesalers and, in turn, gain access to the market. This is emphasised by the CRDO of Company F, who stated that: *It is a very effective way for us to secure shelf space by allowing the retailer to make more money on our salad than on other salads.*

The premium label and higher prices associated with CGG crops are determined by the retailers and wholesalers, rather than the primary growers. As a result, retailers and wholesalers can purchase these crops at prices similar to imported ones, yet label them as premium products and sell them to end-consumers at higher prices. The situation leads to a portion of the profit margin being claimed by intermediaries, rather than the actual producers. Nonetheless, the economic benefit for the producers lies in their capacity to sell a greater quantity of crops and secure shelf space in grocery stores. The advantage for retailers is the possibility to capitalize on the potential to label crops as premium and charge a higher price from the end-consumer.

Based on the results presented in this thesis difficulties with scaling up operations, becoming profitable, and reaching a boarder market and more consumers is hindering actors on the market from growing. Despite all the environmental advantages of CEA grown crops compared to conventionally farmed crops, actors offering CEA cultivated crops are struggling to become competitive and profitable. In conclusion, based on the previously discussed obstacles and drivers actors require additional support to overcome obstacles facing the development of the market. If sufficient support can be acquired CEA systems can potentially contribute with a solution to the current problems facing global food production.

Promoting development of the CEA market and supporting operating actors can be done in several ways. In order to foster the growth and success of the CEA market, it is imperative that policymakers prioritize public support by providing financial assistance, subsidies, and revising existing policies. By doing so, they can alleviate the financial burdens faced by actors, facilitate research and innovation, and create an environment conducive to CEA's profitability, energy efficiency, and broader adoption. Such actions will lay the foundation for a sustainable and thriving CEA industry that addresses pressing global challenges in agriculture and food production.

Additionally, public support could help further the state of the art within CEA cultivation methods, specifically within controlling environmental parameters such as lighting, temperature, and nutrients as further described in section 2.1.1. This would entail conducting research on the topic of growth optimization using the previously described parameters and evaluating how to become more energy efficient, how to decrease technical costs and similar topics. Furthermore, the produced insights should be shared with actors in the market as all actors stand to gain from these eventual insights.

5.2 Future Market Development

Results presented in section 4.1.4 indicated that the CEA market is currently in a fluid phase, where the market is establishing itself and the majority of actors are prioritizing product innovation over process innovation. This indicates that the overall CEA market is still maturing with no clear dominant design having emerged, see Figure 4.2, combined with the identified needs as described in section 4.2.1, the majority of actors are currently focusing on achieving profitability and improving their products and services. The emphasis on product innovation and establishing a dominant design among actors indicates that the CEA market is in early stages of its development (Klepper, 1996).

The interviewed actors indicated different needs for technical solutions in CEA systems as shown by the need's categories: **1. Data Collection**, **2. Automation**, **3. Parameter Control**, and **4. Data Transfer** described in Table 4.1. However, the actors simultaneously indicated needs related to financial and energy issues as seen by category **5. Financial** and **6. Energy** presented in Table 4.1. This indicates that actors are both focusing on larger obstacles facing the market, such as financial barriers and energy issues, as well as on aspects of product innovation and process innovation in terms of use of sensors, data transference, and data quality etc.

Amongst the interviewed companies, the number of active years varied, some companies had been active for more than 10 years, whereas others had just been active for a few years, which was presented in Figure 3.2. Indicating that some actors could have secured crucial partnerships with supporting actors in the value chain such as distributors and retailers, which allows them to become more established in the market. This disparity in terms of how well developed operating actors are, means that some actors might be closer to the process innovation phase than the product innovation phase. Furthermore, when actors prioritize process innovation to a larger extent than product innovation as described by Shin et al. (2019), investments in systems and solutions that increase efficiency within their operations become more relevant and desirable. These systems and solutions could for example include real-time data connectivity, advanced automation, more advanced data collection and analytic systems.

As actors progress to focus on process innovation they will seek out solutions that can offer incremental increases to process efficiency. These actors that are in the process innovation phase focus on increasing efficiency through technology. Ericsson's expertise in areas such as smart manufacturing and industry 4.0, concepts and technology which could help increase actors' process efficiency, allows them to offer actors increases in process efficiency. Therefore, when the overall CEA market reaches the specific phase, as shown in Figure 5.1, where process innovation dictates companies' competitive advantage, the overall market, as well as the actors in the said phase, become more relevant for Ericsson.

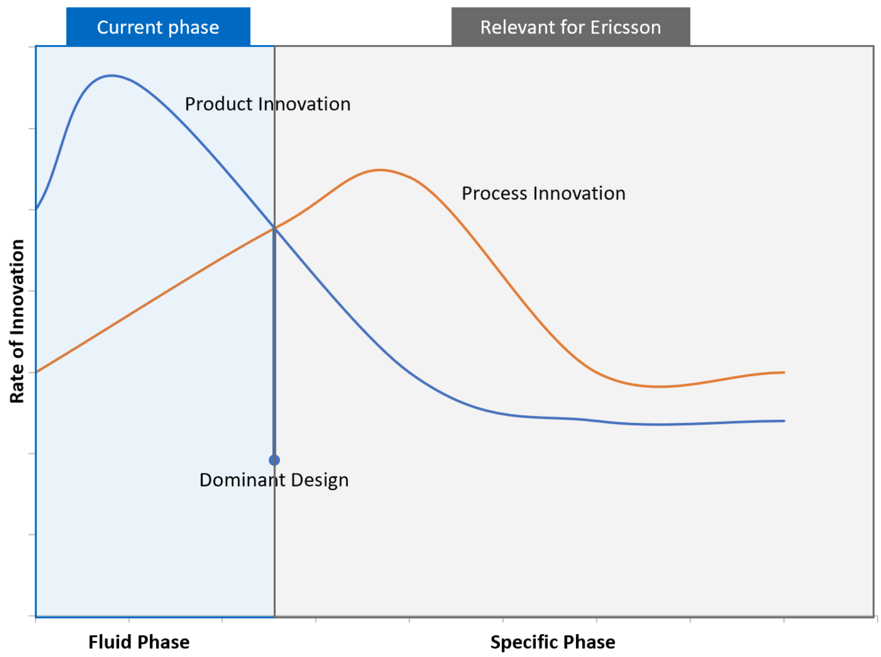

Figure 5.1: *Market Phase: Illustration of the current market phase and the phase when the market potentially could become relevant for Ericsson. Inspired by Figure 1 in Shin et al. (2019).*

Another interesting aspect to consider in terms of the market's maturity level, is the impact of awareness of CEA among customers and consumers. Some actors expressed that customers were apprehensive towards introducing new technology into existing food production systems, which could potentially hinder the development of the market. As described by Company B's customer support responsible representative *"introducing new technology to farmers who are accustomed to their old ways of farming, has been the greatest challenge."*. If customers are reluctant towards using technology, which is an integral part of CEA systems, to farm crops expanding actors' current customer base becomes more difficult, which might inhibit the growth of the overall CEA market.

The effects of low awareness of the benefits of CEA systems can also be seen in terms of organic certifications for CEA crops. According to European Commission (2023), CEA cultivated crops cannot be organically certified if the farmed plant does not naturally grow in a soilless environment. Therefore, even if hydroponically cultivated plants use less water, less land and no pesticides during cultivation compared to conventionally grown crops, they cannot receive organic certification if the crop naturally grows in soil. This impacts the market for CEA crops in several ways. First, actors using CEA cultivation methods cannot receive subsidies for organic farming practices, even if the farming method has numerous environmental advantages such as using less water and zero pesticides. Secondly, consumers' rely on well known certifications and labels to inform purchasing decisions, as described by European Commission (2023), the organic label aims to build trust among consumers. If CEA grown crops cannot be certified as organic then consumers relying on the organic label to inform their purchase might not purchase a CEA produced crop even if it in large fulfills the organic certification requirements.

In terms of supporting the future development of the market, Ericsson in particular could help by evaluating the possibility to offer a low cost connectivity solution that would help actors grow their operations at a low financial cost. Meaning, Ericsson could offer a connectivity solution to the market that meets the identified needs as described in Table 4.1. Furthermore, need **5.1: Competitive Price** as described in Table 4.1, addresses the cost aspect of a potential solution, which entails that the solution has to be offered at a price that ensures the end product sold to consumers is competitively priced. Ericsson has a wide range of offerings, solutions, and services, offering a solution that meets the actors' needs could therefore be one way for Ericsson to engage in the CEA market.

However, the question if Ericsson should engage in the CEA market and offer solutions to actors remains. In order to answer the question extensive further investigation is required. This includes taking a multitude of factors into consideration and investigating an extensive product-market-fit analysis. These considerations and further evaluations are outside the scope of this thesis and are therefore not evaluated in any further details.

5.3 Addressing Research Objectives

The research questions used to guide this thesis, presented in section 1.4, contained three main research questions. The first question focused on the current state of the CEA market, emphasizing an overview of the market in general. Chapter 4.1 compiles the identified results related to this research question and presents a number of aspects that constitutes an overall view of the market. The results presented in this thesis elaborates on the subject of the current market state and gives a comprehensive overview of its level of maturity, relevant factors affecting the market, drivers and obstacles for the development of the market. Therefore, we believe that the results address the first research question and presents a thorough description of the current market state.

Regarding the second research question related to the operating actors' current needs and requirements. Section 4.2 addresses the question of what needs are currently prevalent among actors in the CEA market. Presented in this thesis are 11 core needs, defined in six main categories, as specified in Table 4.1. These identified needs demonstrates some of the underlying and explicit needs among actors in the market, which addresses the purpose of the second research question to identify the actors' needs. On the other hand, there might be more unidentified or underlying needs that were overlooked in this study. Furthermore, actors not included within this thesis study might have different needs and view the market from a completely different perspective. Therefore, we argue that the second research question has been addressed but cannot definitively be answered due to the potential unidentified needs in actors excluded from this study.

In order to be able to evaluate the potential business opportunities for Ericsson within the CEA market, a through analysis of all of Ericsson's capabilities and offerings would have been required. Due to time limitations a comprehensive evaluation of Ericsson's capabilities and offerings was not feasible within the boundaries of this thesis. Meaning that research question three relating to the implication for Ericsson and the opportunities, risks, and potential benefits, was not completely answered. Specifically the potential benefits, opportunities, and risks were not definitively addressed and elaborated upon. However, an analysis of the implications for 5G was conducted to evaluate one potential business opportunity, indicating some insights into the potential benefits, opportunities and risks associate with the market. In conclusion, research question three was partially answered in chapter 4.3 but the entire scope of the third research question was not elaborated upon.

5.4 Evaluation of Research Methodology

Employing an inductive approach and utilizing qualitative research methods as done in this thesis, produced results that are based on the research subjects' perspective of the world and their subjective experiences of the challenges and issues in the CEA market. These results rely heavily on the actors' individual descriptions of the issues and provides nuanced insights that are more difficult to collect using quantitative methods, as described in section 3.1, which provides richer results that helps provide a deeper understanding of the issues faced by actors in the market. Therefore a strength of the employed research methods, is the ability to produce subjective and descriptive results that reflects the interviewed actors' reality.

However, in order to be able to produce some semblance of generalizable results that apply to actors not included within this thesis, a larger interview sample size would be beneficial. Because the gathered results are based on the subjective reality and unique experiences of each individual actor, the collective results changes slightly for every actor that is interviewed as they contribute with their own unique perspective. Meaning that results build on the data gathered from a larger sample of actors might not be the same as the collective results from a smaller sample size of actors, as the additional actors might contribute with previously unseen perspectives.

Moreover, apart from the question of sample size consideration about the reliability of the results should also be questioned, due to the results reliance on interviews and literature studies. As previously stated, using interviews to collect qualitative data has benefits due to its ability to describe the interviewee's subjective reality from their perspective. However, to ensure the stated information is representative, observations can be conducted to verify the information because discerning underlying issues during interviews is difficult and relies heavily on the interviewer's ability to lead an interview and correctly analyze its results. Using observations allows the observer to evaluate if the information stated during the interview correlates with behavior observed, which in the case of this thesis would entail conducting observations at actors' facilities to verify their described needs as well as potentially identifying underlying needs.

Additionally, Swedish based actors were over-represented in the interview sample potentially introducing bias into the data and subsequently the results of the thesis. Although, the Swedish actors were active on more markets than just the national Swedish market, over-representing one particular group in the sample could skew the results. Therefore, there is a higher risk that the results of this thesis are not applicable on a larger scale and or indicative for the general CEA market. Hence, definitive conclusions about the generalizability of actors needs cannot be drawn with certainty, due to the sample size and distribution of actors interviewed in this thesis as well as the absence of observations.

5.5 Contributions to Existing Research

This thesis's focuses on the qualitative aspects of the state of the CEA market, including the actors' underlying needs and their views on the market's development and obstacles. Expanding on existing research by providing more detailed descriptions of the actors' individual challenges and obstacles to help build a more nuanced understanding of the CEA market's potential and hinders. Additionally, the research methodology applied in this thesis furthers the understanding of how qualitative methods can be used to evaluate new markets, as well as highlights potential downsides and areas for improvements when using qualitative methods to conduct research. In conclusion, our thesis helps build a better understanding of the actors' situation, challenges, and needs as well as the drivers of the overall market by evaluating them from a subjective position.

5.6 Future Research

Future research areas could include evaluating various geographical markets, and investigating any potential differences in needs, drivers, and obstacles as well as any eventual similarities. This could include, focusing on understanding the CEA market on different continents, describe any similarities and differences between regions and what actors on each respective geographical market need to overcome their challenges and what larger factors are hindering development of the overall market. This could add a depth of understanding to each individual geographical market and highlight any potential differences, for example if there are other larger factors affecting the market in one specific region as opposed to another.

On the other hand, more research could also be focused on evaluating challenges and needs for actors in particular aspects of the value chain. Emphasizing obstacles faced by system integrators or primary growers and investigating how the needs for each specific part of the value chain as it may differ between OEMs and primary growers. These differences and particularities were not specifically addressed by the results in this thesis but could provide valuable depth of knowledge to the cumulative understanding of the CEA market and the actors' roles within it.

6 Conclusion

The purpose of this thesis was to understand the CEA market from the operating actors' perspective. It aimed to identify the factors that drive or hinder the market's development and explore how Ericsson can offer solutions that address the specific needs and challenges faced by industry participants. Additionally, the thesis aimed to examine how Ericsson's involvement can contribute to the growth and long-term viability of the CEA market. This thesis's results identified three major factors affecting the CEA market, including: Environmental, Financial, and Political, where each factor affects different aspects of the CEA market and respectively presents various obstacles for actors within the market. In addition, 11 core needs were identified among the interviewed actors, these needs were divided into six different categories which include: data collection, automation, parameter control, data transfer, financial, and energy.

The current agricultural system strains the environment, depleting freshwater resources and encroaching on habitable land, while food insecurity remains prevalent worldwide. CEA systems demonstrate environmental advantages that can help alleviate these challenges by reducing water consumption, lower land use, and minimize reliance on pesticides and fertilizers. Hydroponic systems, for example, exhibit significantly less water usage and higher yield efficiency compared to traditional farming methods. The absence of pesticides in CEA systems not only enhances crop shelf-life but also mitigates environmental contamination.

Furthermore, the success of CEA systems hinges on public awareness and support. The extent to which society understands and embraces CEA practices plays a pivotal role in the adoption rate of these systems. Several factors contribute to this relationship, including people's reservations towards the technology employed in CEA, the organic certification of crops produced using these methods, and the level of awareness regarding the environmental impact associated with CEA.

In addition, public support encompasses elements that directly impact the operation and expansion of CEA systems, including the presence of regulations and policies that govern the industry. The level of public support relates to the extent to which subsidies and funding are provided to individuals and organizations involved in CEA. Supportive policies and regulations that foster sustainable agricultural practices and actively encourage the adoption of CEA systems have the potential to contribute to the growth and development of the CEA market.

However, CEA systems face a number of obstacles, particularly in terms of energy consumption and financial viability. The financial viability of said systems hinges on three core aspects: initial investments, profitability, and operational costs. There are high initial investments required, which imposes financial barriers for actors to overcome. Moreover, the profitability of CEA actors is constrained by the low profit margins associated with crops, which can be attributed to the price sensitivity exhibited by consumers in their purchasing behavior. To secure shelf space in grocery stores, primary growers involved in CEA need to offer retailers competitive purchasing prices that are comparable to those of imported crops. The pressure of providing low and competitive prices, further impedes CEA actors' ability to become profitable. Additionally, controlling environmental parameters within CEA systems leads to high energy consumption, which coupled with recent surges in energy prices results in high operational costs.

Climate change affects the stability of growing climates by raising global temperatures, increase risk of droughts and other factors, which in extension decreases the reliability of food supply, subsequently acting as a driving force for the development of the CEA market. As food production becomes more unreliable, there is a growing demand for resilient and dependable food production which can help alleviate strains on the environment. Subsequently, leading to an increased demand for more sustainable food production systems. CEA systems have the potential to fulfill these requirements and be a complement to conventional farming, making CEA systems a promising potential solution for future food production.

Actors employ a wide variety of technical solutions, ranging from almost fully automated operations to more rudimentary systems relying on wired connectivity and manual labor. Regardless of the degree of technical advancement, the large majority of actors do not indicate a demand for more advanced technological solutions. As the market development progresses and a dominant design emerges, actors evolve to redefine their focus towards process innovation, where incremental increases to efficiency becomes crucial for gaining competitive advantage. As the focus on efficient processes increases, innovations such automation and IoT are likely becoming more relevant for the operating actors. Therefore, when actors invest in these kinds of technologies to improve productivity and enhance efficiency within their operations, the market in large becomes more relevant for Ericsson.

In conclusion, while CEA systems offer potential solutions to global food production issues, several challenges must be addressed. The environmental benefits of CEA make it a promising alternative to conventional farming. However, the high energy consumption, financial barriers, public acceptance, and regulatory landscape hinders its development and scalability. A comprehensive approach involving policymakers, industry actors, technology providers, consumers, and research institutions is necessary to unlock the full potential of CEA in addressing the global food production crisis. By addressing these aspects, the CEA market can advance and contribute to a more sustainable and secure food future.

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A

Appendix

A.1 Interview Template

Personal Introduction

1. Please give us an introduction of yourself.

   Follow up questions:

   (a) What is your name?

   (b) What is your current role at the company?

   (c) How long have you been at the company?

   (d) What is your interest in farming in general?

Company Introduction

2. If you were to shortly explain what the company does, how would you describe it?

   Follow up questions:

   (a) How large is your current operation?

   (b) Could you describe your farming operation, how does it work?

   (c) If your company opera:tes farms, how large is the farming area?

   (d) What are your current goals as a company?

   (e) Has your company previously worked/collaborated with Ericsson?

Business Requirements

3. We would like to better understand the business aspect of your company. Could you describe your business model?

Follow up questions:

(a) What aspects of your business model are critical for success?

Current Actors

4. We want to understand what actors operate in this market. Who are your competitors and customers?

   Follow up questions:

   (a) How would you describe your market segment?

   (b) What type of customers do you focus on?

   (c) How many customers do you have?

   (d) What kind of requirements do your customers have towards you?

   (e) How competitive is this market segment?

Value Chain

5. Could you briefly describe the value chain your company is a part of?

   Follow up questions:

   (a) What is your role in the value chain?

   (b) What kind of actors are you dependent on?

   (c) How does your company generate value for your customers/suppliers?

   (d) What partnerships are important in your value chain?

Current Capabilities

6. We want to understand what capabilities your company currently has to help us get a better understanding of your situation. Could you describe your company's current capabilities?

   Follow up questions:

   (a) What kind of competencies/capabilities do you have inhouse?

   (b) How much of the company's products/services is developed inhouse?

   (c) What is your current and target production capacity?

   (d) What are your current and target sales volumes?

(e) What blockers are hindering you from achieving your targets?

Competitive Advantage

7. What makes you stand out from your competitors, what are your competitive advantages?

   Follow up questions:

   (a) What are your biggest strengths?

Challenges

8. Considering where the company is now, what areas are the most challenging?

   Follow up questions:

   (a) What challenges do you expect to run into in the future?

   (b) Up until today, what has been some of the biggest challenges/hurdles the company had to overcome?

Critical Elements

9. Throughout your operations, which elements would you describe as essential for your daily operations?

   Follow up questions:

   (a) Are there any critical elements?

   (b) How do you ensure that these elements are carried out as intended?

Technical Requirements

10. We would like to understand your company's use of technology in your daily operations to get a better sense of your operation's technical requirements. Could you describe what technologies are essential in your daily operations?

    Follow up questions:

    (a) What activities in your daily operations are currently automated?

    (b) What activities in your daily operations are currently done manually?

    (c) How come these activities are not automated?

    (d) In your daily operations, how is the company dependent on connectivity?

    (e) How is the company dependent on wireless connectivity?

(f) To what degree are you dependent on technical communication to perform daily tasks?

(g) How connected are the systems that are used in your operations?

Drivers

11. How are you trying to grow as a company?

    Follow up questions:

    (a) What is driving the company's growth?

    (b) How is your company receiving public support/funding?

Obstacles

12. We would like to understand what obstacles are preventing success and growth in this market. Could you describe any obstacles affecting your company?

    Follow up questions:

    (a) Were there any barriers to enter the market?

    (b) Are there any other barriers hindering the growth of the company?

Development/Growth

13. In terms of development and growth, how much is your company currently growing and what changes do you foresee in the future?

    Follow up questions:

    (a) How much is your company currently growing per year (e.g. number of full time employees, number/size of farms, number of customers)?

    (b) What growth rate do you predict your company will experience in the upcoming years?

Maturity

14. When it comes to how mature the market is and how receptive people are to technical advancements in farming. How would you describe the maturity level of the market?

    Follow up questions:

    (a) How mature would you consider your market segment to be?

    (b) Would you say that this differs from the global market?

(c) How would you describe the demand for your products/services?

(d) How is the market viewed by potential customers?

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