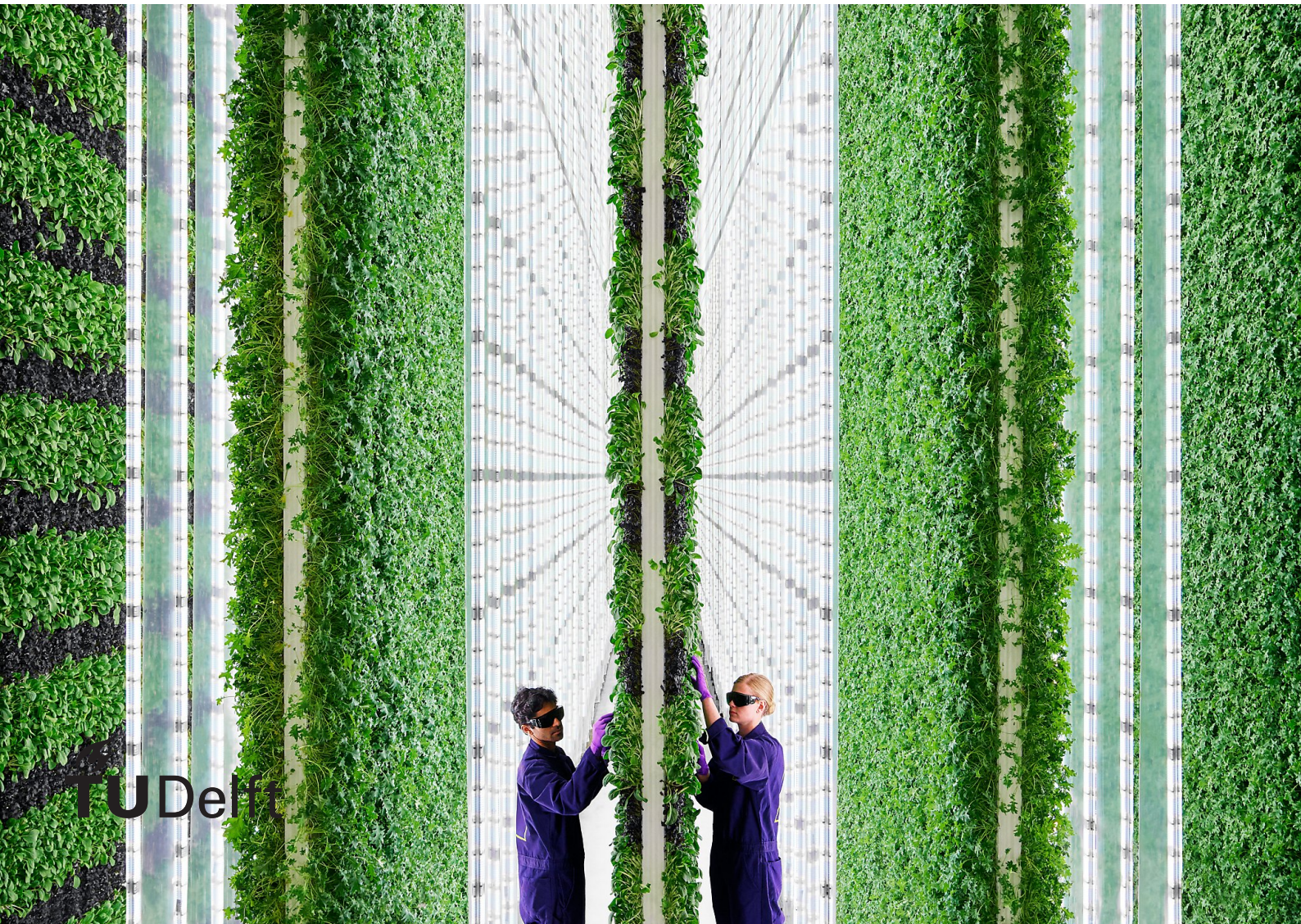
Vertical Farming in the Netherlands

Tim Koning



A special note on the cover image (Plenty, 2021); This is a North-American vertical farm.

Vertical Farming in the Netherlands

Towards a Circular Food System: A Business Ecosystem Perspective

by

Tim Koning

In partial fulfillment of the requirements for the degree of:

Master of Science

in **Management of Technology**

to be defended publicly on Thursday the 23th of September 2021 at 11:00 AM.

Graduation Committee

Chairperson:	Dr.ing. V.E. (Victor) Scholten,	Delft Center for Entrepreneurship
First Supervisor:	Dr.ing. V.E. (Victor) Scholten,	Delft Center for Entrepreneurship
Second Supervisor:	Dr.ir. J.N. (Jaco) Quist	Energy and Industry

Student number: 4289366

Date of submission: 9th of September, 2021

TU Delft

Vertical Farming in the Netherlands

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **Management of Technology**

Faculty of Technology, Policy and Management

by

Tim Koning

Student number: 4289366

To be defended in public on September 23th 2021

Graduation committee

Chairperson	: Dr.ing. V.E. (Victor) Scholten, Delft Center for Entrepreneurship
First Supervisor	: Dr.ing. V.E. (Victor) Scholten, Delft Center for Entrepreneurship
Second Supervisor	: Dr.ir. J.N. (Jaco) Quist, Energy and Industry

Preface

Finishing my TU Delft studies has been quite a journey. It started in 2013 with a Bachelor in Aerospace Engineering and ends at this moment with a Master's thesis focusing on the commercial success of a start-up in vertical farming. During this journey I followed courses in almost all directions that TU Delft offers and have met fantastic people on the way. These are too many to mention, but all have helped me to successfully finish my studies.

I was only able to realize this last individual research assessment with the help of people around me and my supervisors Victor Scholten and Jaco Quist. I would like to thank them, in particular, for allowing me to pursue a topic of personal interest and for guiding me through the research process. I was lucky to have two experienced supervisors that taught me the finesse of theoretical frameworks and the details in establishing one coherent research process. Moreover, my colleagues at Glowfarms deserve a special thanks; without their support and willingness to participate in this study it would have been impossible to complete my research.

I would like to thank my friends and family for supporting me at the times I needed relief and assistance. I would like to especially mention those who have had a formative impact during the research process for this dissertation. Thanks to Menno Koning, Max Breeman, Jelle Blom, Paddy Carew and Mitchell Borst for assisting me with insightful new perspectives. A special thanks goes to Tessa who was always by my side in difficult times and who must have been driven crazy by all of the facts and studies on vertical farming I shared with her.

Tim Koning
Delft, September 2021

Executive Summary

The world's current food system is unsustainable and considering the increasing human population, there is a demand for innovations in the circular food production. Simultaneously, food security becomes a topic of interest as greenhouse gasses cause more extreme weather conditions. Vertical farming potentially plays a vital role in the food system of the future. With its year-round production, clean facilities and urban farming principles, vertical farms proliferate themselves as circular and sustainable providers of food security.

However, proponents of vertical farming may overlook certain practical implications, such as its context dependence and financial business models. These implications are evident from the absence of any successful large-scale vertical farms in the Netherlands, who is a pioneer in the horticulture and supports circular practices in the food system. In addition, current academic literature lacks a holistic study on the Dutch vertical farming sector. For those reasons, this study aims to find the enabling and constraining factors that influence commercial success of a Dutch vertical farming start-up. It does so in an exploratory setting and from a business ecosystem perspective, which is a constellation of actors that work towards a single goal by means of a focal firm that orchestrates those loosely coupled actors.

A six dimensional empirical framework (6C-Framework) analyses the business ecosystem perspective by scrutinizing the context, construct, configuration, cooperation, capabilities and change dimension. A thorough actor search, technological analysis and in-depth case-study provide data for the analysis. The case-study investigates a start-up business ecosystem and delivers most in-depth knowledge on a Dutch vertical farming business ecosystem. With the help of internal observations at Glowfarms by the researcher and interviews with vertical farming business managers, this study portrays the inner workings of the case. Afterwards, interviews with experts in the sector verify the drawn conclusions to increase the external validity of this research.

The obtained results form into conclusions by means of an explanation building technique, which results in non-conclusive propositions for further research. A first finding is the overall good relationship and trust in combination with a shared vision towards a global sustainable food system. This creates commitment and enthusiasm in the business ecosystem. In this way the business ecosystem keeps on maturing and growing in knowledge that fosters success. A second finding is the lack of co-creation due to limited resources and the birth stage of the sector. This birth stage in the business ecosystems lead to an absence of a dominant design and constraints the volume of the inter-ecosystem projects. Without this dependence on vertical farming or volume constraints, suppliers are less likely to start co-creating products. Such flow results in sub-optimal environment for the vertical farm.

A third finding is the secrecy that vertical farms have about knowledge and design hamper a forefront of vertical farming niches. Such a group may provide knowledge exchange, but also assist in infiltrating the set food system as sector. In this food system, which grants knowledge and advocates for infrastructural requirements, vertical farming must position itself. This exclusion from the food system hampers commercial success. A last finding focuses on the new value creation from vertical farms. The investments for vertical farms as well as the energy consumption are high, yet it offers food security, improved circularity and year-round production. These aspects lead to a different business model, where the farms accentuate the improvements to the products by branding and sell at a premium price.

This study recommends the focal firms to collectively create a forefront of the sector for an acceleration in commercial success. A unified group of vertical farms has more bargaining power for entering the food system and is able to educate the retailers and consumers in a better way. Also, the attraction of more resources or the partnerships with smaller third party suppliers increases co-creation. With a dominant design in place, it is more straightforward to identify the advantages of vertical farming for the food system actors. Thus, vertical farming is becoming increasingly popular among food system actors, due to its sustainable and innovative character in both the technology as in the value creation. Yet, to disrupt the food system, the focal firms require more volume and dependency. Moreover, vertical farming must never renounce its circular principles to continue to make a difference in the world!

Contents

I

First Part

1

Introduction

The human population on the Earth continues to increase. By 2050 an estimated 10 billion people live on the Earth of which 75% is estimated to live in cities (FAO, 2009) (United Nations, 2014). These cities require an enormous amount of nutrients and fresh water. However, when extrapolating the current food system to future needs, there is a lack of fertile land. In addition, food needs to be produced according to circular principles according to Ministerie van Infrastructuur en Waterstaat (2018). That are the ultimate reasons why the food system needs to revolutionize the upcoming 30 years.

On top of that, the ever increasing emission of greenhouse gasses start to show their effect on the Earth. More reports of extreme weather conditions are present. These weather conditions affect the food security (X. Zhang & Cai, 2011). So, the evolution of the food system requires more than solely an improvement in sustainability and circularity. The food system requires a comprehensive transition of which the underlying problem can be interpreted from various perspectives. This latter aspect makes the transition in the food system a wicked problem (de Zwarte & Candel, 2020).

Scoping to the food system of the Netherlands, there are other primary concerns. The efficiency of agriculture and horticulture in the Netherlands is already of a high level. The greenhouses of the Westland are truly high-tech and precision farming introduces a level of efficiency that is new to mankind. Unfortunately, the energy input is higher than the energy output in these greenhouses (Smit, 2020). Moreover, when looking at agriculture, the depletion of the fertile soil in the Netherlands contributes to less nutrients in the food (Raad voor de Leefomgeving en Infrastructuur, 2020).

So, there are improvements to envision. The Netherlands wants to live according to circular principles by 2050 (Ministerie van Infrastructuur en Waterstaat, 2018), which is a vast challenge on its own for the food sector (valued over €90 billion in 2019 (Baarsma, 2020)). This transition of the Dutch food system, therefore, is of a scale not seen before. In particular, since the Netherlands wants to stay in the frontier of agricultural and horticultural knowledge and considering that different geographical cities require more context dependent solutions (Li et al., 2020)

There are multiple new technologies that may radically change the food system in the Netherlands. One of these new processes is to farm in urban areas, which may shorten food supply chains and increase the area available to farm (Kozai, 2013) (Thomaier et al., 2015). Vertical farming is such an urban farming method that proliferates itself as both an efficient and circular concept. Yet, this method is far from widespread in the Netherlands, even though the circular and innovative vision set by the government completely aligns with exploring the vertical farming method (Farhangi et al., 2020).

Figure 1.1 depicts a vertical farm as a schematic figure as option d. The other options in the figure represent small-scale urban farming methods which are less driven by technical innovation. Vertical farming is the cultivation of plants in a closed multi-layer environment that optimizes its indoor growing climate by an artificially controlled environment. It is a high-tech method that minimizes its water usage by soil-less cultivation and precision farming techniques. Multiple authors emphasize the potential vertical farming has to disrupt the food system (Klerkx & Rose, 2020) (Orsini et al., 2020).

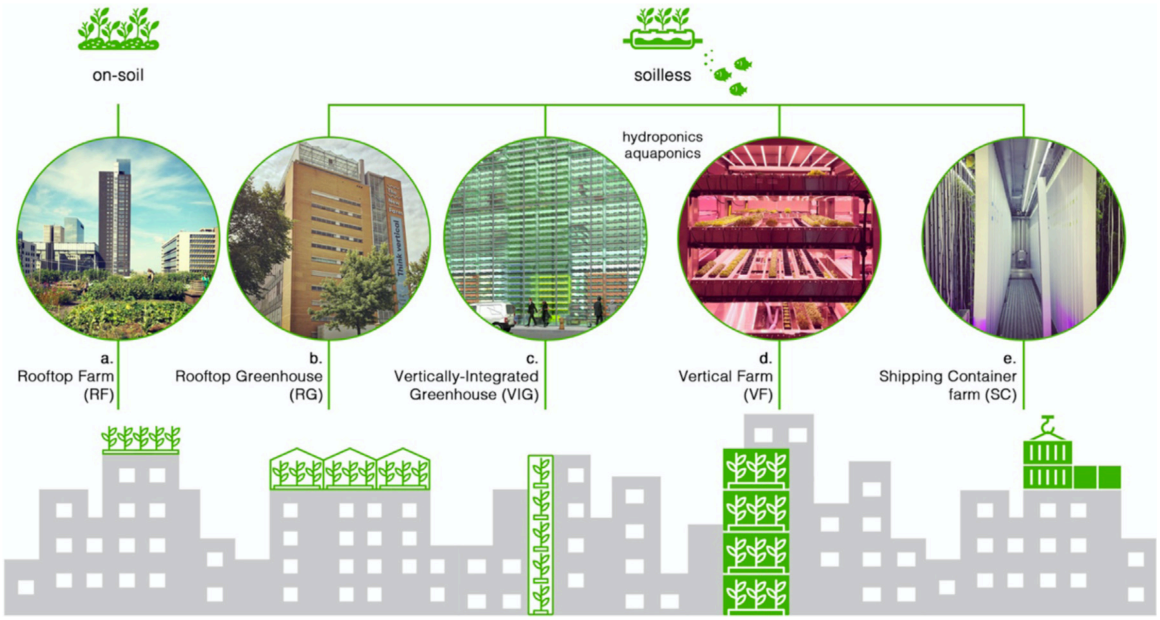


Figure 1.1: Some Examples of Urban Farming Techniques (Benis & Ferrão, 2018)

1.1. Problem Statement

The circularity movement gains momentum and focus in the Dutch agriculture and horticulture, which results in a new terminology to make its entry on the Dutch political agenda: ”Kringlooplandbouw”. Vertical farming may potentially contribute towards this circular goal, while simultaneously decreasing the lengthy food chains that are present in the world. The Netherlands is a ’food paradise’, however, the Dutch still import fresh produce due to inconsistent cultivation options throughout the year (Baarsma, 2020). This leads to longer food chain, where fresh produce gets imported during seasonal dips.

There is, however, a chasm between describing a goal with the required technology and the practical implementation of such. Preceding attempts of Dutch starts-ups utilizing the vertical farming method for cultivation were fruitless. In the early days, the underlying technologies proved to be deficient (den Besten, 2018). Yet, with all technological advancements of the present times and historical prominent position of the Netherlands in this sector, commercial success of vertical farming in the Netherlands is still scarce. Despite the funding and support of the Dutch government that shows their enthusiasm and eagerness (Rijksoverheid, 2021).

Furthermore, the maturity of Dutch firms in vertical farming is limited when comparing globally and taking the historical inventiveness of Dutch agricultural and horticultural firms in consideration. Vertical farming is quickly gaining ground in Asia and the USA (Kozai, 2013) (Thomaier et al., 2015). For example, Japan has a rich history with urban and vertical farming due to its aging farmer population and high density (Pieterse, 2019). There are already over 200 vertical farms in operation (Kozai et al., 2019). It seems the Dutch are one step behind in the commercial exploitation of urban farming.

Since the Dutch government wants to be circular and leading in innovation in agriculture and horticulture, it is difficult to justify the early niche state of vertical farming in the Netherlands. In particular since society more often opts for sustainable and circular services and products. It is therefore interesting to research the the causes of this under represented high-tech cultivation method in the Netherlands.

1.2. Research Objective

This study aims to find the factors that result in the current discrete position of vertical farming in the Netherlands. The more detailed objective, however, originates from a literature research on the aforementioned broader problem statement. A main research question describes the exact focus as this section elaborates. There are three sub research question that help to steer the research process and the expected results help to find a balance between scope and in-depth analysis.

1.2.1. Research Gaps

A literature study on the topic of factors that explain the current state of the Dutch vertical farming sector identified gaps in the current academic articles. Vertical farming is not a new technology, but the effective large-scale and commercial utilization of this technique only started recently (Farhangi et al., 2020). This is evident by analyzing the chaotic and scattered terminology in literature (Benis & Ferrão, 2018). Many authors inconsistently use vertical farming and urban farming throughout their work. On top of that, the definition of the terminology is inconsistent across different works. There is a need to set proper definitions to what each phrase entails.

Most scientific work focuses on the potential of these vertical farms and study the sustainable factors. The authors mainly compare lettuce production in vertical farming versus other methods and describe. Since most literature identifies positive aspects regarding vertical farming, it is evident that there is a role for the method in the upcoming circular economy. However, literature is indecisive on what role vertical farming plays as there is a lack of research on the exact details and optimal purpose. For a specific country, such as the Netherlands, more research must be conducted to find its optimal use. In particular, since the effective implementation and exploitation of vertical farming is context dependent (Klerkx & Rose, 2020)

Since the Netherlands has a large economical dependence on agriculture and plays a central role in the frontier of agricultural knowledge worldwide (den Besten, 2018), there is a desire to research the optimal fit for vertical farming within the Dutch circular food system. Farhangi et al. (2020) define the current state of Dutch high-tech urban farms, but do not distinguish between vertical farming and single small scale facilities. As further studies on the topic are absent, there is a research gap on the role vertical farming plays in the circular food system of the Netherlands and its agricultural export position.

Weidner et al. (2019) focuses on urban farming in a more general sense, but still mentions two research gaps linking to indoor vertical farming. There is a need to study the effect and impact of financial incentive schemes for urban farming techniques and more research can be conducted on the understanding of scaling-up mechanism for urban farming. Both these research gaps are defined by Weidner et al. (2019) on a global scale and not in particular for the Netherlands. However, this makes it more plausible that no study is conducted on these topics for the Netherlands and so no real understanding of how to accelerate the exploitation of urban farming is present.

Thus, current literature lacks a clear definition of vertical farming. In addition, there are no studies on the optimal use-cases for vertical farming and its role in the new circular food system of the Netherlands. It is reasonable to assume both these latter gaps are connected to the understanding of the commercialization of Vertical farming. The academic literature fails to understand this commercialization and scaling-up mechanisms of vertical farming that clarify the problem statement.

Weidner et al. (2019) identifies in a similar fashion these financial and business model issues surrounding vertical farming. Benis and Ferrão (2018) agree with the further need to investigate the financial models and accentuates the need for a holistic overview that current literature lacks. The performance of vertical farming, however, is often measured and impacted by context dependent factors (Benis & Ferrão, 2018). This is the reason for focusing on the Netherlands.

1.2.2. Main Research Question

The research objective for this dissertation stems directly from the problem statement and identified research gaps as section 1.1 describes. This thesis explores the factors that influence commercialization and scaling of vertical farms in the Netherlands. In order to grasp the development and maturing of vertical farming in the Netherlands, the focus is on a Dutch vertical farming business ecosystem as a case-study to achieve in-depth insights in the networking and birth stage full of opacity. A business ecosystem is a business analyzing perspective, which Moore (1993) developed by borrowing the ecosystem workings from the field of biology. By exploring a business ecosystem within its context, this research answers the research question:

*What are the main **enabling and constraining factors** that influence the **commercial success** of a **Dutch vertical farming start-up?***

Some phrases from this question require further explanation. First, this research focuses on the enabling and constraining factors to provide a holistic perspective. knowing the factors may catalyze

commercialization by adjustments in the 'right' direction. Second, commercial success is required for a firm to position themselves firmly on the market, so a focus is set on the business aspect. Last, a start-up in the Dutch vertical farming sector provides interesting information on the construction of its business ecosystem and since few Dutch vertical farming firms got through the start-up stage, it is logical to research this stage.

Using the business ecosystem framework has advantages. Despite a scattered literature on business ecosystems and variations among definitions, there is existing academic work on such a perspective in different sectors (Anggraeni et al., 2007) (R. Gupta et al., 2019) (Möller et al., 2020). This earlier work assists in the application of the business ecosystem framework for this research. Furthermore, the framework provides a different perspective to other methods and may provide therefore different interesting results. Due to the distinct combination and use of technologies and intended logistics, vertical farms are expected to have a vastly different business ecosystem compared to the current actors. This may be reason for its minor status in the Netherlands.

This research on the vertical business ecosystems has an exploratory character. Current literature lacks a holistic review of the factors that enable or constrain the commercialization of vertical farming products and services. In addition, there is no earlier academic work on the vertical farming industry with a business ecosystem perspective. Hence, this research is exploratory and may contain interesting results on how the Dutch vertical farming business ecosystems operate. One of the main goals therefore is to provide directions for further research and depict a holistic perspective on the factors influencing commercial success.

1.2.3. Sub Research Questions

The main research question of this dissertation is, **what are the main enabling and constraining factors that influence the commercialization of a Dutch vertical farming startup?** There are authors that touch upon the subject of enabling and constraining factors, but no scientific literature includes a complex business environment perspective to study the success of the commercialization of vertical farming. That's why this study aims to conceptualize the vertical farming sector in a business ecosystem framework to research. In order to get clear and concise results the following sub-questions are included:

Sub Question 1:
How is vertical farming envisioned and embraced by experts in the business field?

Sub Question 2:
What is a preferable framework and its corresponding dimensions for analysis?

Sub Question 3:
In what degree are similar factors present across the Dutch vertical farming sector?

These sub-questions do not only serve as a foundation and broad timeline of this report, these questions also help to place the main question into context. The first sub-question helps to define the momentum that vertical farming currently has in The Netherlands. It is necessary to derive some expected results in order to improve the direction for the scope of this research. Experts from the business field provide this research with such information. Obviously, the problem statement keeps a central position in this dissertation.

The second sub-question is about the theoretical framework to analyze the Dutch vertical farming industry. This research requires a deeper understanding of the business ecosystem framework as this research needs to grasp both its boundaries and its principles as a perspective. Furthermore, the business ecosystem needs to be analyzed which requires an analysis method. The inner workings of this method of analysis must also be described for an improved understanding.

The last sub-question assists in verifying the results of a single case-study with the broader sector. As there are various different start-ups in vertical farming each with their own method, this research requires such a check to improve its generalizability and overall scientific impact (Sekaran & Bougie, 2016). By verifying the conclusions with an expert in the business field and a different yet similar type of start-up, this research establishes an appropriate level of generalizability.

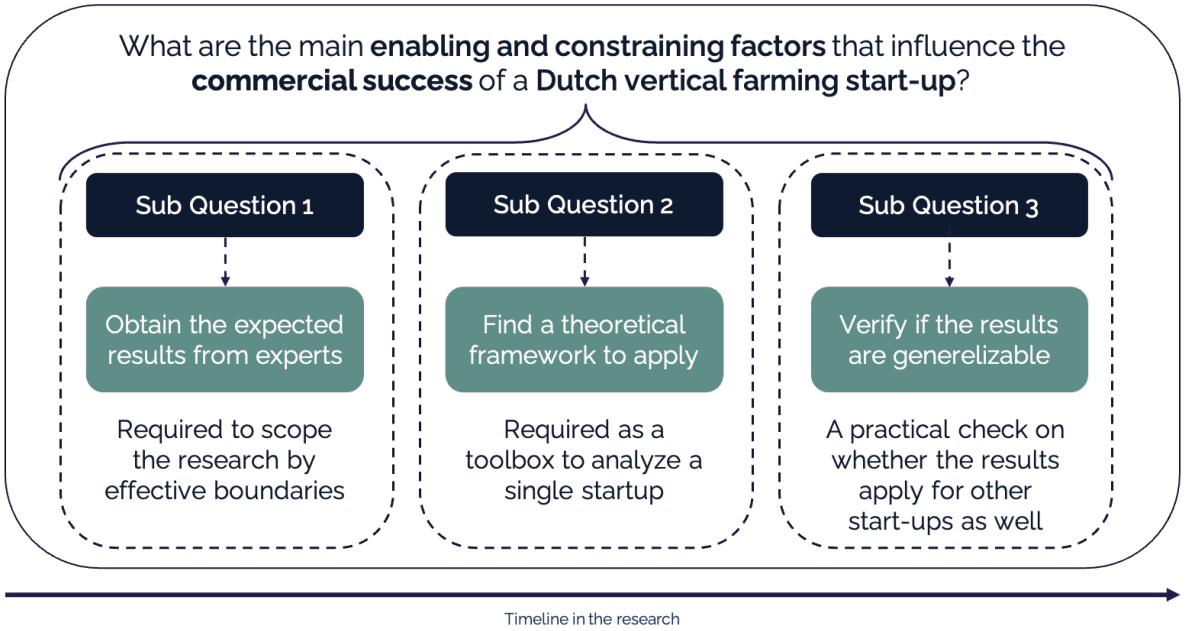


Figure 1.2: Connecting the research questions to the objective and main question

Figure 1.2 depicts the connection between the sub questions and the scoping of the research. The numbering of the sub questions express a chronological order of the research and all contribute towards a improved answer to the main question and problem statement. Thus, it are those three questions that steer this dissertation into the correct direction. First, this exploratory study required more scoping and narrowing down of the topic by means of expected results. Second, a theoretical and empirical framework to analyze the vertical farming industry is chosen. Third, since a single case-study lack a sector wide perspective, verifying the results improves this studies generalizability which is required for academic research.

1.2.4. Expected Results

This introduction needs further assistance in setting the correct scope. This is the exact reason for drafting the expected results that are an initial mechanism to steer and define the topics to include. Due to the exploratory character of this study and the time-span boundaries, the expected results make sure that the study finds a balance in scoping by assuming some initial results. While a broad scope may assist the exploration of unexpected aspects and prevent any important aspects from slipping the results, it hinders depth in a research. A narrow scope makes sure that a single researcher is able to perform the complete study.

This study drafts these expected results, and thus balance in scope, by interviewing three experts in the business field and taking note of the literature study. These interviews are in a unstructured format. Figure 1.3 depicts from what layer of the nested business environment these expected results originate and what the expected results are. The figure, which is an adapted version from Möller et al. (2020), represents four layers that exist in any complex business network. The actor, the focal ecosystem, the business field, and the set system are the different layers and each represent a larger part of the complex business environment. Chapter 2 and 3 elaborate on this figure.

The interviewed experts belong in to the business field layer and the information on the set system is more widely available in literature. It is this format that prevents inductive research. As the focal ecosystem is the object of analysis and the employees in the micro layer the object of observation, interviewing experts in another layer splits the expected results data collection from the obtained data collection during the research. Other experts in the business field, also, verify the conclusions at a later stage to close the research circle. Chapter 3 describes this research approach in more detail.

This study made careful choices in the process of forming expected results. Certain statements made by expert contradicted with each other, which accentuates the exploratory character, yet this

complicated the process of forming expected results. This study prudently included a mix of most mentioned topics with the aim to increase the diversity of the propositions, but simultaneously limiting the number of expected results to keep the research simple and narrow.

The number of five expected results is reasonable as this number finds a balance in the broadness of the scope as aforementioned. The five boxes on the right side of Figure 1.3 already summarize these expected results, however any detail is missing. Chapter 7 discusses and compares, among other aspects, the expected results and the obtained results form this study and the next paragraphs elaborate on what the expected results entail.

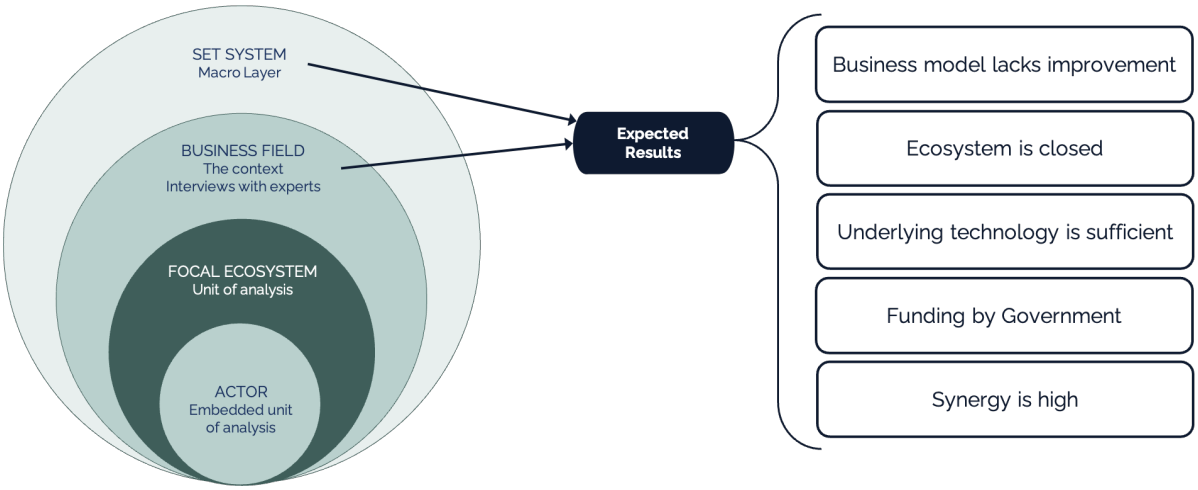


Figure 1.3: The propositions in the wider context

From the unstructured interviews with experts and the literature, this study noticed proponents and opponents of vertical farming. Whereas the proponents envision a new sector on the rise with a bright future, opponents notice a strong greenhouse sector that is unbeatable with its 'free' direct photosynthetic energy from sunlight. Also, a lack of succeeding vertical farms in the Netherlands cause suspicion on the underlying business model. This lack of improvement to the business model is depleted by the proponents as vertical farming is still in an early stage. Therefore, this study expects the lack of improvement in the business model to be a hampering factor for the current commercial success of vertical farming in the Netherlands at the moment.

Another impression from the literature and interviews is the secrecy that is present. It feels like the horticulture sector is closed to new firms and researchers in the business. At least that is the feeling for this researcher after a couple of weeks reading and talking about the vertical farming sector. Of course, a reason could be that this research is not as interesting to the firms. However, an expected result is a closed ecosystem that hampers new actors to be involved and hampers the knowledge sharing aspect that results in almost no successful commercialization.

A third expected results emerges from the literature. Since vertical farms are operational elsewhere in the world (Aerofarms, 2021), this study expects that the underlying technology is of a sufficient level nowadays. In addition the technology keeps on evolving, which would stimulate the vertical farming sector at the moment (Klerkx & Rose, 2020). The underlying technology caused failure in the earlier times when the Netherlands pioneered with vertical farming research.

Since the Dutch government has ambitions for circular food production and food security (Ministry of Agriculture, Nature and Food Quality, 2021), there is focus on the food production and its innovations. This study, therefore, expects that this momentum from government and societies help to thrive the research and commerce of vertical farms as people familiarize with this new cultivation method.

The interviewees do all agree that this momentum causes some form of synergy among actors in the business ecosystems. This study expects it makes co-evolution possible and enables growth and success of the business ecosystems. This synergy is therefore expected to help grow commercialization of the Dutch vertical farms.

1.3. Research Impact and Layout

A last section of this chapter elaborates the scientific and societal relevance, the aim and desired impact of the research, the connection to the Management of Technology study and the outline of this document. These subsections provide the reader with essential information about the reasoning of starting this research and what the researcher expects to achieve with this academic work. Also, the outline of this document may assist in finding the right information in this document at a glance.

1.3.1. Scientific and Societal Relevance

This research utilizes a modified fit of the 6C framework from Rong et al. (2015) in order to gather all necessary information and input to answer the main research question. Literature lacks enough studies on the practical use of business ecosystems and this research adds to that field. It scopes the business ecosystem in a holistic manner before applying the framework to the vertical farming business ecosystems. Thus, this study improves the scientific knowledge of complex business operation in the perspective of business ecosystems.

Simultaneously, this framework allows to create a comprehensive view of vertical farming in The Netherlands from a business perspective. Such a comprehensive scientific view of vertical farming in The Netherlands is not yet established and therefor, this exploratory study adds to the understanding of vertical farming practices in The Netherlands. Also, this thesis covers scientific work on the prospects, best applications, and enabling and hampering factors for business breakthrough for the vertical farming method in the Netherlands. Since this study is exploratory, it may serve as a starting point of more academic business research in the agricultural sector.

From a practical and societal perspective, this study helps firms operating in the Dutch vertical farming industry by connecting it to the literature and by identifying the enabling and constraining factors. As the results from this research are drawn from interviews, it is inevitable that participating firms may already have identified some of these factors. Nevertheless, it is interesting to verify these factors among other actors in the field and moreover, other actors may not be in possession of the results. By regrouping the enabling and constraining factors, a better plan may be introduced to help increase the speed of transition. Furthermore, by analyzing the synergy within business ecosystems and reflecting the results with literature, new information that improves the operations of the business ecosystems may be generated by this research.

While the firms that operate in the vertical farming business field may flourish from this research, the original problem statement gets dealt with simultaneously. This has a direct impact on the society in the end. If the vertical farming business field as a whole finds solutions for the constraining factors, it is not only the businesses that flourish but the global population as well. A side-note to this statement is the presence of the assumption that vertical farming is a sustainable and circular approach to agricultural practices. Most academic literature acknowledges this improvement, however, not all research as sustainability is a broadly defined definition.

1.3.2. Aim and Desired Impact of the Research

The aim of the research is to find means and aspects that may improve the growth of the commercialization of vertical farming in its optimal circular usage. In that way, this research aims to support the implementation of an economic viable and sustainable agricultural sector. As the aforementioned problem statement clarifies, the next generation on this world desires such a circular food sector. Connecting the business ecosystem perspective with the vertical farming sector is therefor of great importance as new conditions under which this sector thrives and fails may be revealed.

The desired impact of this dissertation is to give insights in the inner workings of the vertical farming business ecosystems and compare these with the known literature on business ecosystems to get practical results. The participating actors in this research may benefit and improve their business ecosystem to gain commercial success. Also, the distribution of this study among students via the TU Delft repository may spark interest in this high-tech sector. There is agreement on the huge food problem that awaits humanity that this research creates awareness about. This aspect may generate more dissertation and student work on a circular food system, which indirectly educates the next generation high-tech food producers and distributors that this world desperately needs. Next to this awareness creation among students, there is awareness creation among the agriculture and horticultural actors.

Furthermore, this preliminary study hopes to spark enthusiasm among scientists and researcher to continue to explore and explain the vertical farming sector. As the research gaps and literature accentuate, there is a giant chasm in the current knowledge on how such new agricultural innovations gain ground in the food system and what fosters their growth. Thus, there are many research topics to consider in this sector, far more as solely with a business focus. It would be wonderful if more academic work could provide understanding and a sharpened vision on this topic.

1.3.3. Relevance to the Management of Technology (MoT) Master Program

During the MoT program from the faculty of Technology, Policy, and Management, students learn the underlying innovation processes and a broader context perspective about fostering commercial success with technological innovation. The students require an engineering bachelor, which grants a firm basis on technological know-how. Instead of going more in depth and details, this master program aims to provide a systematic approach in managing a firms strategic direction around its technology and innovation. In addition, it positions the technology in the broader socio-technical environment. So, when describing MoT from an engineering degree perspective, it is a knowledge broadening program that provides tools that connect engineering to the commercial markets.

The research objective and aim fit this master program perfectly as the commercialization of new technology is central in the dissertation. Vertical farming is a vibrant and new technology that has momentum at the moment due to its circular and sustainable proliferation. By considering these circular and sustainable movements and connecting those to the technology, the socio-technical environment gets a firm position in this study. This is also relevenat in courses in the MoT program.

Furthermore, the technical innovation, which enables these 'factories' to grow plants in urban areas, disrupts the food system potentially. Yet, this innovation is far from settled in the food system and commercial markets. There are multiple firms aiming for the optimal design with each another interpretation of the vertical farming technology. This technology battle fosters the innovation process and provides a natural focus on the fit of the innovation in the market. Thus, a topic on the commercialization and the exploratory character that the niche state of vertical farming brings, makes it perfect for a MoT thesis.

1.3.4. Outline of the Thesis

Figure 1.4 illustrates the outline of this work by depicting the main steps in a chronological order. The first, second, and third part are the chapter dividers and split this dissertation in three main categories. The first part contains the research introduction and setup. This starts with the problem statement and research objective at the start of this chapter. Next, with the help of a thorough literature search, this study scrutinizes the current academic literature on the potential research gaps on the topic of commercialization of vertical farming. Chapter 2 describes this literature search. In order to study the identified research gaps, chapter 3 elaborates on the proposed research approach.

The second part consists of an elaboration on the collected results. Both a desk research and a case study, as chapters 4 and 5 define, obtain the qualitative data that this research requires. Chapter 6 describes the obtained data objectively and describes data from the verifying interview.

The third part is all about the discussion of the results and research perspectives, which continues with the conclusions and recommendations of this research on the research questions. Chapters 7 and 8 describe these aspects, respectively.

Figure 1.4 depicts this division. Each chapter encloses a version of this figure to illustrate the position of the chapter within the research process. The bright colored step, is the current position of the chapter and the less accentuated steps are described by different chapters. Thus, Figure 1.4 represents that the current chapter introduces the problem statement.

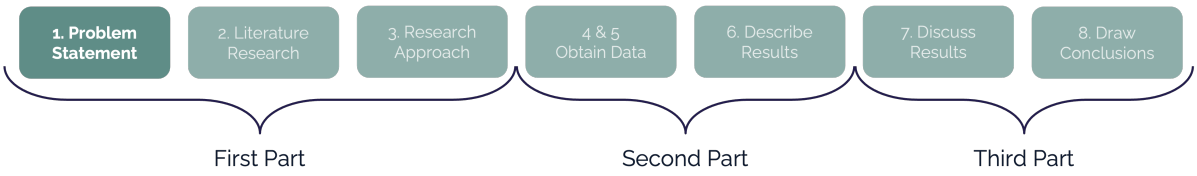


Figure 1.4: The research process steps for this dissertation

2

Literature Review

This dissertation conducts a thorough literature study to find the research gaps and to define the scope of the research. Figure 2.1 depicts where in the research process this literature study fits. This chapter contains the documentation of the literature study. It starts with the main literature study on the Dutch vertical farming industry. The chapter continues with an elaboration on the theoretical framework, which functions as the main perspective of this study. The last section describes the chosen empirical framework that fits within the scope and boundaries of this research. Furthermore, for a detailed justification on the included academic works, appendix A contains a description of the search method.

Figure 2.1: The research process steps for this dissertation

2.1. Literature Research on Vertical Farming

This section presents the results from this literature study on the progress in vertical farming in a comprehensive way. It starts with a basic discussion on the correct definition and terminologies used by academic research and widespread literature. A more holistic review of a circular food system in the Netherlands and the potential role vertical farming has in this system is described in the subsequent paragraphs. The chapter continues with the positive and negative aspects of vertical farming. A last section is devoted to elaborate on the current known enabling and constraining factors for the vertical farming industry.

2.1.1. What is Urban Farming?

Before going into detail about vertical farming, another terminology must be explained. Vertical farming, together with other related principles that are depicted in figure 1.1, fall under the category of urban farming (Benis & Ferrão, 2018). Urban farming is interchangeable with urban agriculture, which is another term that is often used in scientific literature. Both these terminologies refer to cultivating crops in the built environment. Examples are rooftop gardens, community gardens, but also green walls and vertical farms. For vertical farms, the location must be within the built environment to be called urban farming as well (Benis & Ferrão, 2018).

In addition to urban farming, the terminology urban horticulture is often seen as a misinterpreted synonym in academic literature. According to Weidner et al. (2019), the terminology of urban horticulture fits vertical farming better, however, from the search method described in appendix A it seems urban agriculture and farming are the most often used terms. Benis and Ferrão (2018) do use the terminology urban agriculture and urban horticulture interchangeably in their review, but none of the other included literature do such. Weidner et al. (2019) draws a similar conclusion to the main author of this review and therefor, this review is not using urban horticulture as a specific terminology.

The last higher-level terminology found in the literature study was Agriculture 4.0. Klerkx and Rose (2020) describes Agriculture 4.0 as a terminology that fits in the definition of Industry 4.0. Technology plays a more central role in this method of subdividing. Processes and techniques that contain state of the art data driven decision making are often connected to this term. However, as the authors mention themselves, the terminology is poorly defined. That's why this terminology is not used within this study, in spite of that vertical farming fits within this category as defined by (Despommier, 2020).

2.1.2. Definition of Vertical Farming

Urban farming or any other higher level definition elaborated on in the paragraphs above are not the main focus of this study, whereas Vertical farming is. Despommier (2020) wrote one of the first major books on vertical farming and potentially changed to definition to a more high-tech variant. Vertical farming is best described as an indoor cultivation method that grows food in controlled artificial environments. The the part vertical refers to the multi-layered position of cultivation, or the use of height. This is clearly visible in figure 2.2, which shows a picture taken at one of Aerofarms' vertical farming facilities in North-America.

Figure 2.2: Aerofarms; a vertical farm in the USA (Worland, 2021).

The figure shows two rows of vertically stacked baskets that operate as growing facilities for plants. Plants are placed in their growing medium, often substrate or a reusable cloth, making sure that their roots are free to collect nutrients and water. Aerofarms, like other vertical farms, feed their plants by a hydroponics technology. In lay man's terms, this means utilizing a misting system to water the roots of the plants, where nutrients are solved within the water (Aerofarms, 2021). Above the plants, and below the basket of the next layer, led lights are making sure that the plants get their optimal spectrum to gather energy to grow. The 'blank' space between the top of the plants and the led light is required to serve as cooling mechanism. A constant breeze is artificially generated to cool the air as the led lights and other systems still heat up the room.

Another detail that figure 2.2 shows, is the man in a protective suit. This aspects puts the height of the production plant into perspective, but there is a reason why protective clothing is required in the facility. As vertical farms can artificially reproduce the outside world, it is straightforward that polluting bacteria and other unwanted guests are left out. As a result, a vertical farm does not use pesticides or other harmful substances. This is, obviously, beneficial to the sustainability and circularity of the technique. However, a more elaborate details on the advantages and disadvantages are described in section 2.1.3.

As mentioned, vertical farming is connected to high-tech. The most advanced watering systems are in place, which makes sure that vertical farming requires no soil but growing mediums (Despommier, 2020). The data driven cultivation methods, implemented with vertical farming, lead to a level of precision farming that makes optimal use of resources (Kozai et al., 2019). In this way it contributes to a circular economy that is envisioned in the Netherlands (Baarsma, 2020).

Kozai (2013) is one of the first reference articles to write about plant factories in a convincing and viable way. This is similar to vertical farming as known across Europe and North-America, however, in Asia academics use plant factories more often. The author goes into more detail about the design of a single facility and elaborates on the viability and energy usage. Also, does the author provide a list of elements that should be present in a plant factory with artificial lighting (Kozai et al., 2019):

- Airtight box
- Thermally well-insulated
- Air shower
- Layered system (with artificial lighting and hydroponic beds)
- Air conditioners
- CO_2 enrichment
- Floor covered with epoxy
- Collection and re-use of water
- Circulation and sterilization of nutrient supply

Some authors are not completely consistent in their terminology (Benis & Ferrão, 2018) and others use somewhat vaguer terms (Klerkx & Rose, 2020), it can be concluded that urban farming entails more than vertical farming. These definitions are the most often used and so does this review. This work tends to focus on the vertical farming and not urban farming in its wider definition, however, the number of academic papers on the more specific topic are limited.

To give a better definition on what kind of vertical farms are included, this study uses the list of requirements drafted by Kozai et al. (2019) for selection purposes. A final definition of vertical farming therefore by this study is: **Vertical farming is the large-scale cultivation of plants in a soil-less and multi-layer indoor setting, which is kept in a fully controlled and artificial climate by cutting edge technology.**

2.1.3. Sustainable Performance of Vertical Farming

Vertical farming and other indoor cultivation techniques offer new perspectives for food production in the new age, however, more details are required to assess the resource efficiency (Graamans et al., 2018). This subsection compares the vertical farms with professional greenhouses as it is important to understand the relative potential given the broader problem statement. These two cultivation techniques have a lot in common, however, there are significant differences.

Graamans et al. (2018) defines the greenhouse horticulture as a semi-controlled environment that may use solar energy for both photosynthesis as well as heating. Ventilation may release excess energy and the greenhouses can be heated and or cooled artificially when required. A vertical farm, however, is a completely closed environment and utilizes always an artificial indoor climate for cultivation. Graamans et al. (2018) identifies another clear distinction in the multi-layered aspect of vertical farms. Whereas greenhouses only grow their products on single layer, vertical farms are designed to more efficiently use land area.

A couple of the used underlying techniques, like hydroponics, are similar in the cultivation of plants in both a vertical farm and a greenhouse (Graamans et al., 2018), innovation may improve both methods. While some techniques are similar, there seems to be a difference in the category of products that fit each method best. Experts in the business field raised this aspect, however, no academic research included such a study. The lack of academic information on this problem may be an interesting research topic for further research.

Figge et al. (2002) use in their attempt to integrate sustainable aspects with business perspectives three pillars of sustainability. It is an all-inclusive perspective to help assess a certain phenomenon on sustainable performance. Next to environmental and social aspects, to be sustainable, a phenomenon has to be economic viable. The next paragraphs elaborate briefly with this perspective on vertical farming. This creates a better understanding of the current literature and the vertical farming method for the reader.

Environmental Aspects

When going into more detail on the Kozai (2013) stated that vertical farms are far more water efficient compared to current greenhouses, however, the author did not include the Dutch high-tech greenhouses in the study. Graamans et al. (2018) did include these aspects and concluded that closed systems require less water. The almost closed-system greenhouses in the United Arab Emirates, therefor, only requires 28% more water as a vertical farms theoretically requires. This result supports the findings of Kozai et al. (2019), but it has more to do with the ventilation in greenhouses that vertical farms lack. The water usage is therefor highly dependent on the location of the cultivation of crops (Graamans et al., 2018). Shrinking the water usage of farming is contributing vastly to a future proof solution of the food system.

Another positive environmental aspect on vertical farming is that it requires less land area to grow crops with its multi-layer vertical cultivation system in place (Despommier, 2020) (Thomaier et al., 2015) (Graamans et al., 2018). There is, however, a maximum to the production layers as the ventilation and indoor environment system must have the right capacity (Graamans et al., 2018). For a business model, this land efficiency becomes important as the price of property in cities is higher. With urban cultivation there are shorter food chains possible that require less energy depleting logistics (Benis &

Ferrão, 2018). Furthermore, mega cities require these shorter food chains to become self sufficient and with less required area for cultivation of crops, more area is left for nature. (Kozai, 2013).

Despite a higher energy efficiency, due to the more efficient layer system, vertical farms require more energy from the grid as compared to greenhouses. Even with solar panels on the roof, a vertical farm is far from energy neutral (Graamans et al., 2018). The radiation from the sun and the sunlight partially fulfills the heating requirements and the photosynthesis, whereas a vertical farm copies these inputs with purchased energy from the grid. Another aspect that utilizes more energy is the ventilation and cooling. In a greenhouse ventilation is possible and less heat is generated. The LED lights in a vertical farm generate waste heat which needs to be dissipated by means of cooling mechanisms that require energy. Graamans et al. (2018) concludes that the energy requirement for greenhouses differ across the globe.

Orsini et al. (2020) add that not much research is conducted on the complete cradle-to-cradle cycle of vertical farms and with current technology and energy emissions, the vertical farming affects climate more as greenhouses. There is a need to constantly improve the spectral recipe for plants and increase LED-light efficiency. Orsini et al. (2020) conclude that vertical farming may positively impact sustainable use of resources, however, the electricity requirements must drop for it to become a viable solution.

Martin et al. (2019) concluded that circularity and sustainability of the food system improves by implementing vertical farming. This latter aspect is also repeated by Thomaier et al. (2015), however, it depends heavily on the actors involved and their goals. The precision farming and closed-system approaches in vertical farming increase efficiency of CO_2 usage (Graamans et al., 2018). Vertical farming produces less residual waste and hence enhances circularity (Martin et al., 2019). On top of that, a completely closed system, such as depicted in figure 2.2, does not require pesticides (Aerofarms, 2021)(Kozai et al., 2019).

Social aspects

The social viewpoint is a mayor one in the problem statement of this thesis. Urban farming is often linked to improve social aspects (Thomaier et al., 2015). Food security looks troublesome for 2050 with the current progress. In a vertical farm, the artificial led lighting, climate control and hydroponics system help to improve this food security as plants are able to grow all season without dependence on the outside weather conditions (Despommier, 2020). Orsini et al. (2020) include the potential of vertical farming has to increase the food system resilience.

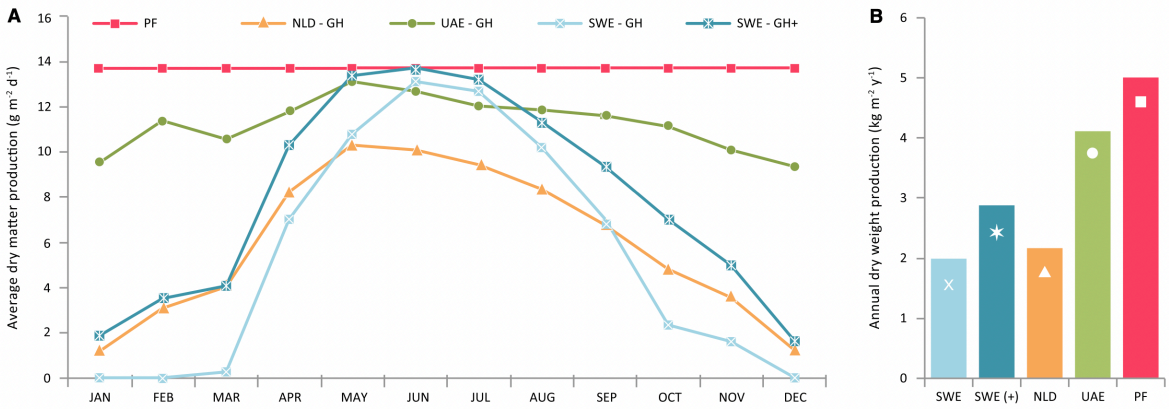


Figure 2.3: (A) The dry matter production of lettuce throughout the seasons. (B) the total annual dry matter production of lettuce. (Graamans et al., 2018)

Graamans et al. (2018) acknowledge both these statements, all-being it wrong to presume greenhouses cannot. Greenhouses produce year-round, however, this method is less consistent throughout the seasons as these semi-closed systems depend partly on the weather conditions (Graamans et al., 2018). Figure 2.3 illustrates the difference between the dry matter production of lettuce in greenhouses and vertical farms. The red top line represents a vertical farm's dry matter production, which is a hori-

zontal line with no deviation across the season. A Dutch greenhouse is represented in the yellow line, which clearly illustrates the deviation year-round.

Vertical farming has the potential to enhance the learning and increase the attention about food production among schoolchildren (Eigenbrod & Gruda, 2015). However, the large investment and more industrial orientation of vertical farms in comparison to rooftop community gardens the social impact may be less. Nevertheless, this section is focusing on greenhouses and vertical farms and due to the more efficient land-use and less light pollution vertical farms are potentially located in more urban area's compared to greenhouses. Therefore, there is more potential interaction with food production among city residents.

Business Outlook

The business outlook is a last perspective in this sustainable analysis on vertical farming. The business and commercialization is also a main perspective for this thesis, which accentuates this section's importance. However, limited literature availability on this topic resulted in research gaps as stated in 1. Nevertheless, according to Avgoustaki and Xydis (2020), an investment in a vertical farming facility is preferable to investing in greenhouses. The authors considered a variety of options in financing construction in their study and opted vertical farming in all configurations as optimum investment.

While both the NPV and IRR show better results, the comparison is not completely fair. The greenhouse configuration does not entail the latest advancements while the calculations for the vertical farm do. In addition, many of the financial configurations consist of crowdfunding, which is not often a typical investment option for large scale production plants. This affects the vertical farming opportunity more significantly as the initial investment costs are higher. In the end, however, the paper does grant an approach to compare greenhouses and vertical farms from a business perspective. When optimizing the approach and combining it with the results from figure 2.4, interesting results on the investment opportunity may arise.

2.4 depicts in figure 2.4 the relative energy use of vertical farming across the globe and the water scarcity in countries. Graamans et al. (2018) identified that across the globe there is a variety in relative electricity use efficiency of vertical farms compared to greenhouses for the cultivation of lettuce. This relative advantage can be translated to different optimal methods on a scale from semi-open greenhouses to vertical farms. Graamans et al. (2018) included only the relative electricity use advantage and the water scarcity. As the figure lacks relative electricity costs, relative water efficiency and other economical factors, it is far from complete to assess business opportunities. Nevertheless, the figure visualizes the more logical locations to start with vertical farming from an environmental perspective.

The figure shows that only a minority of habitable countries in the world have an energy advantage for vertical farming at the moment. Weidner et al. (2019) describes "it will probably take many years of development and need a larger share of renewable energy in the grid in order for vertical farming to become a serious contender for reducing environmental impacts of a city's food system" (p. 1646). This is something that Martin et al. (2019) also highlight. The energy usage and high investment costs are currently a large negative aspect (Benis & Ferrão, 2018). However, Thomaier et al. (2015) have opted the possibility of heating buildings with recessive heat.

From this elementary sustainable analysis, it is evident that vertical farming has benefits as well as deficiencies compared to greenhouses and conventional farming and a lot is unknown about the business perspective. However, as the exploitation of the vertical farming method gains momentum (Benis & Ferrão, 2018), the process will improve (Klerkx & Rose, 2020). Therefor, it is not the question if vertical farming has a role in the circular food system of the Netherlands, but rather what role it plays. In order to find an answer, an elaboration on the food system and current literature of vertical farming in the Dutch food system is provided in the next section.

2.2. Current food system in the Netherlands and its future

To understand where vertical farming fits in the Dutch food system, a high-level overview is given on its workings in the following paragraphs. The current role of greenhouses gets accentuated as this cultivation method is most comparable to vertical farming (Graamans et al., 2018). Also, a literature study describes the future of vertical farming in a circular food system in the next section. This information

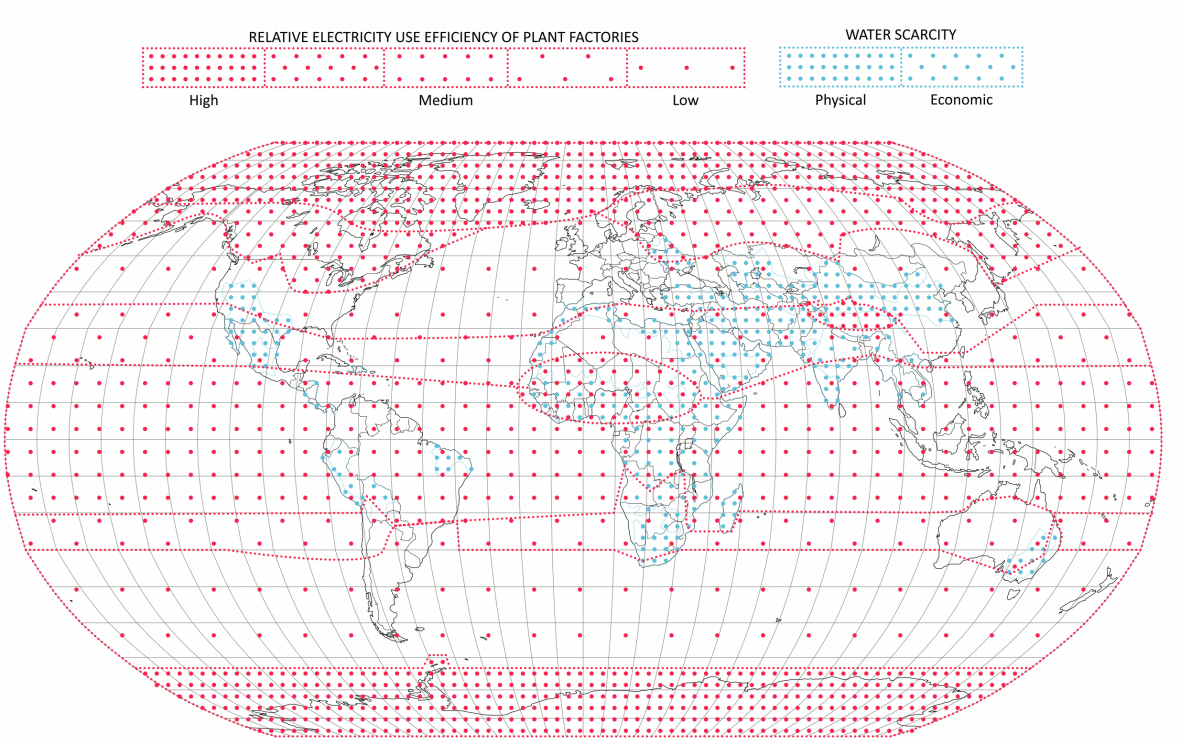


Figure 2.4: Estimation of the relative advantages of vertical farms across the globe by Graamans et al. (2018)

helps to find the gaps in the current literature and assists in finding an optimal research perspective for this dissertation.

The Netherlands functions as an important global importer and exporter of food and related products. A critical factor is the harbor of Rotterdam, which is a key player for transport to the hinterland and further in Europe (De Bosatlas van het voedsel, 2014). This information may give a wrong impression of the Dutch solely being a trading nation, as a large part of this export consists of processed food products and home-grown agricultural and horticultural products (De Bosatlas van het voedsel, 2014). Again the harbor rises as an important factor for the global distribution of these products as about 80% of the horticultural products gets exported (CBS and LEI, 2012)(Breukers et al., 2008).

For the food system towards the customers, figure 2.5 gives a conceptualization. Customers buy more products from supermarkets as before, which is in contrast with the number of supermarkets (De Bosatlas van het voedsel, 2014). As depicted in the figure, there are 5 main purchase offices of food products that distribute the majority of the food products in supermarkets. This system design gives these major firms a high leverage in the food system design of the Netherlands (Planbureau voor de Leefomgeving, 2018). In addition, the number of businesses that are between the farmer and the customer is perhaps more as one may assume, which makes the profitability for farmers lower as direct sales (Planbureau voor de Leefomgeving, 2018).

In an effort to describe the dutch food system, Baarsma (2020) describes the lengthy food chains that currently exist in the Netherlands. The Dutch live in a ”food paradise”, but still import vegetables from all over the world (mostly Europe). On the other hand, the Dutch export a lot of their home-grown products, which is rather opposing. Baarsma (2020) is proponent of smaller food chains, which must be taken into account. These smaller chains can be conceptualized by imagining another stream of products from the farmers to the customers in figure, yet this stream is marginal 2.5.

A last aspect in the general description of the Dutch food system is the policy aspect. The Ministry of Agriculture, Nature and Food Quality is the responsible instrument on the food system of the Dutch government. The main task on the agricultural aspect is to ensure food security and safety for all Dutch citizens, and to stimulate innovation that ensures a more sustainable and durable food production (Rijksoverheid, 2021). A independent team of this ministry, the Nederlandse Voedsel- en Warenautoriteit (NVWA), monitors and corrects firms in food production on rules and regulations. Klerkx and Rose

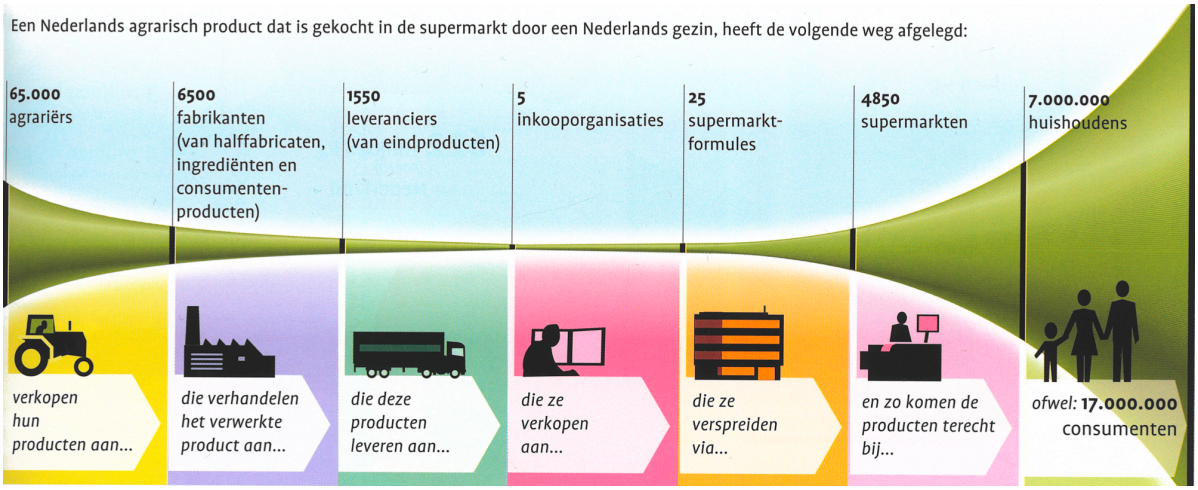


Figure 2.5: The value chain of the food in Dutch supermarkets (De Bosatlas van het voedsel, 2014).

(2020) adds that governments (or the NVWA) have the power to steer transformations in the right direction by promptly defining the boundaries, which must be done.

This NVWA team, however, focuses on the status quo of horticulture and agriculture methods. This causes a delay in proper set regulations for the vertical farming sector. Farhangi et al. (2020) elaborate that a lack of regulations currently hinders the progress of the transition and exploitation of vertical farming. Jurgilevich et al. (2016) express a more actionable statement, the authors mention the European Union's need to create policy for the coordination of nutrient flows and raw materials. So the government and other regulatory institutions can assist in the growth of vertical farming by accelerating adjustment of the regulations towards new techniques.

2.2.1. The circular vision of the food system in the Netherlands

From a perspective of the government, the vision is to stop depleting the land and improve the circular efficiency. "Kringlooplandbouw" is the terminology that the Dutch government uses (Rijksoverheid, 2021). This means to keep the food chain local where possible and regional or global where required. In addition, the Dutch government proposes three underlying goals to achieve Kringlooplandbouw. First, the food producers must be paid accordingly for their services and starters in the business must have good prospects. Second, the customers or citizens must understand what it takes to produce food in order to improve the appreciation for the farmers among the civilians. Lastly, The Netherlands must stay at the international frontier of innovation in the sector (Rijksoverheid, 2021).

The Netherlands is, one may observe, one step ahead of the European Union (EU) in terms of a circular vision. Where the EU focuses on CAP strategic plan, which entail moving towards a social, environmental friendly and economic sustainable sector. "Europe needs a resilient, sustainable and competitive agricultural sector to ensure production of high-quality, safe and affordable food for its citizens and a strong socioeconomic fabric in rural areas" (European Commission, 2021, p.1). In The Netherlands, where the complete agricultural sector compromises about 10% of the economy, the focus is more in line with achieving the Paris Agreement (Rijksoverheid, 2021).

Smit (2020) goes into more detail and describes four aspects that should be the focus for a resilient and sustainable food system in the Netherlands by 2040. These are, reduction of the external costs, no energy from fossil fuels, food security, and complete circularity of the food chain. Baarsma (2020) has also included the aspect of internalizing the external effects in the vision. Loss of biodiversity, damage to the ozone layer and contribution to greenhouse gases should be payed for, as such is the only way of making closed loop food competitive and a realistic option in the general market.

In addition, a minimal amount of import and export should become the status quo in the food system as this entails less food miles, less energy required and less land-use for agriculture in other countries (Smit, 2020). Jurgilevich et al. (2016) add that indeed shorter food chains help to solve the imbalance of circularity in the food system. Similar to Baarsma (2020), the authors urge for shorter chains where possible.

This circularity imbalance is particularly present in the nutrient availability in the land. Due to the large-scale agriculture and depletion of the fertile land, the nutrients and vitamins in the Dutch food have significantly decreased (Raad voor de Leefomgeving en Infrastructuur, 2020). Also, the current level of emissions from the agri-food sector in the Netherlands are not dropping comparing to previous years (Planbureau voor de Leefomgeving, 2018). Both these aspects evaluate that the Netherlands is not at a circular food system and the pace of implementing innovations to decrease emissions has dropped. The study is including animal farms, so may give a skewed outcome when analyzing purely crop and vegetable agriculture. However, the greenhouses are incorporated as a separate entity. The results of both these studies are shown in appendix B.

So, there is a vision set by the Dutch government that focuses on circular agriculture and horticulture. Despite the clear goals, however, the practical solution to achieve this goals is missing in the food sector. The government does stimulate new innovations by subsidizing and investing in new technologies, which in return help to achieve ”kringlooplandbouw”. To get there, a lot of work has to be done as depletion of resources and illogical food chains are the status quo today.

2.2.2. Horticulture and Agriculture in The Netherlands

The greenhouse sector, which is most similar to the vertical farming sector (Graamans et al., 2018), has evolved over the past decades (Breukers et al., 2008). Breukers et al. (2008) describe the sector to be more market-driven as before. Also, to the quality certifications in the Netherlands, give the Dutch greenhouse produce a unique selling point for international trade. The vegetable horticulture, however, only accounts for 23% of the total Dutch horticulture value (Breukers et al., 2008).

Breukers et al. (2008) continue that subsidiary programs from the government stimulated innovation in the greenhouse vegetable horticulture. ”More specifically, 10% of the companies in greenhouse horticulture are regarded as being innovators, which means that they were the first in the Netherlands to introduce a new product or process” (Breukers et al., 2008, p.9). Another interaction between the government and the greenhouse horticulture sector led to a Long-Term Agreement on energy objective, nutrients and pesticides (Breukers et al., 2008). With such agreements and investments in innovation, the Dutch government ought to reach its climate goals.

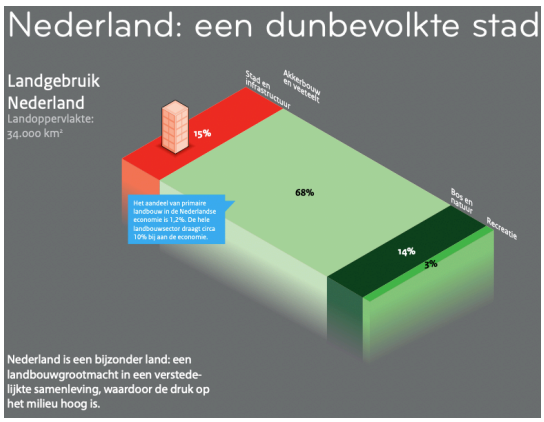


Figure 2.6: The land-use in The Netherlands (Planbureau voor de Leefomgeving, 2018).

Yet, there is much land use reserved for agriculture and horticulture that may hamper reaching these climate goals. Although figure 2.6 may be oversimplified, it shows the enormous amount of land-use that is dedicated to agriculture. This is not only in contrast with the economic importance, but also with the global average (Planbureau voor de Leefomgeving, 2018). The majority of the vegetable horticulture, however, operates from three main locations. These are the Westland and Oostland and the region around Venlo. Due to their economic importance the Government actively helped to improve infrastructure as these ’Greenports’ in return employ workers in the region (Breukers et al., 2008).

By studying the horticulture facts provided by CBS (2021), this study observes a shift in size and strategy from the actors within this sector. As from 2000 onward, there are less firms registered as horticulture producers, however, this sector occupies more land area since the start of the new millennium. Breukers et al. (2008) add that large greenhouses are more efficient and appear to have better results. Greenhouses invest in new equipment and machines to increase profitability by quality improvement and year-round production. As energy and labour costs are the most important costs in greenhouse vegetable production, firms invest in machinery to reduce the required resource intensive input (Breukers et al., 2008).

2.2.3. Current state of Vertical Farming in the Netherlands

In the Netherlands, farming indoors on multiple layers started with mushroom production in the 1950s (den Besten, 2018). Mushrooms grow in the dark and therefor no artificial light is required, which also indicates this technique is nowhere near a high-tech vertical farm nowadays. The first vertical farm with artificial light opened in the 1980s in Roermond to produce, among others, lettuce. Due to the inefficient lighting, the cooling of the indoor climate was an energy rich process that made it unprofitable.

The latest big breakthrough came when GrowX Amsterdam opened in 2017. These farms are still small scale and get turnover via education, advice, and selling equipment. Also, different actors as the current horticulture actors seem to start these early vertical farms. There is momentum in the Netherlands as both den Besten (2018) as well as Farhangi et al. (2020) concluded that the complementary technology are more than existent in the Netherlands. With firms and academic institutions such as Philips, Certhon and the Wageningen University & Research institute there is adequate knowledge available and the amount of start ups in this sector are rising.

Nevertheless, in order to stay profitable high-tech urban farms are highly dependent on governmental funds (Farhangi et al., 2020). These funds are often associated with a positive social and environmental impact, which makes high-tech urban farms adopting social cohesion and sustainability as their core business cases. Farhangi et al. (2020) concludes that this effect causes high-tech urban farms to be less focused on productivity and more on social impact.

Farhangi et al. (2020) have also studied the niche sector of high-tech urban farming in the Netherlands. The authors have outlined networks and conclude that the high-tech urban farms are slowly infiltrating in the current agri-food regime. However, the current state is still niche and the number of actors the authors have included is not more than 40. The number of vertical farms included is far less. So, it is questionable if the initiatives significantly changed the food production in Amsterdam already. Especially when taking into account the city has over 800,000 inhabitants (Statista, 2021).

2.2.4. The role of vertical farming in the vision of the Netherlands

Ministerie van Infrastructuur en Waterstaat (2018) have included vertical farming in their vision, however a clear purpose is lacking. When it comes to vertical farming, den Besten (2018) elaborates on the Dutch approach. In the Netherlands there is less awareness about 'Plant Factories' compared to Japan or the USA. This is exceptional as den Besten (2018) defines the Dutch as frontiers in the agri-food sector with their high-tech greenhouses. It seems counterproductive to invest in a multi-layer technology, while in the Netherlands the greenhouses are a proven business-model and more economically efficient in this context.

There is, however, another perspective that den Besten (2018) clarifies. Currently, the Dutch are exporting high-tech greenhouses all over the world. This vital export for the Dutch economy includes knowledge and complete growing systems. In addition, the Dutch have the knowledge to build vertical farms from a technical perspective as well as a more practical perspective. Vertical farming, therefor, has the potential to become a large export product of the Netherlands, but the business-model for building vertical farms within the country is complex.

The export economy of high-tech agriculture production facilities and knowledge is, however, only included by a few academic studies. It seems logical that this aspect must be taken into account when analyzing the role of vertical farming for the second largest agricultural exporter in the world (Farhangi et al., 2020). "The combination of green and technical knowledge and experience in this field, plus realistic business case calculations, may lead to vertical farms being a new export product next to high-tech greenhouses" (den Besten, 2018, p. 317).

This export perspective is not including the circular economy visions set out by the Dutch government. This is a perspective that Baarsma (2020) includes in a vision of a more circular and resilient food system in the Netherlands. Baarsma is, however, not including the potential of vertical farming or any other new technology in the vision, which is more focused in shorter food chains. Currently, the agricultural food from the Dutch supermarkets is often produced in other countries, while in the Netherlands enough agricultural food gets produced. This may sound illogical, but it is the effect of mass producing vegetables in a most efficient way.

With a new era of circular and more sustainable food production inbound, the question where the food originates becomes more important for the consumer. Baarsma (2020) proposes a shorter food chain which increases the connection between the farmer and the urban citizen again. Such a food

chain not only drastically decreases the 'food miles', but also increases resilience as the farmer knows the final consumer's demands better. These shorter chains are achievable with vertical farming (Despommier, 2020).

2.2.5. Holistic overview of vertical farming in the Netherlands

This literature study identifies the characteristic of vertical farming and its fit in the Dutch food system. Vertical farming has potential to boost the circularity and quality of certain plants. Despite the uncertainties connected to its prospect in the Netherlands, it is evident that this new method of cultivation has a place in the circular food system. In particular, since the Dutch government sets its focus, regarding agriculture and horticulture, on innovation, circularity and fair profit distribution. The current academic work, however, lacks studies on the business perspective and a holistic view on vertical farming.

To find a fitting research perspective, which is able to study the commercialization of vertical farming in the Netherlands, this literature study describes the relative position of vertical farming compared to the other professional methods in the food system. Vertical farming is in a niche or birth stage, so really at the start of its commercialization in the Netherlands. It currently has a negligible size compared to the professional greenhouses in the Netherlands, but it is able to extract know-how from the current horticulture in place. Vertical farms in the Netherlands need this knowledge as far from all farm founders have a background in horticulture and the transition operates from bottom-up and outside the current regime of cultivation actors (Farhangi et al., 2020).

Another important characteristic to include is technical difference between the current cultivation methods in place and vertical farming. Of course, there are many similarities, but its closed system, multi-layer design and high-tech controlling mechanisms make it a completely different method. This characteristic, together with background of the founders and the early niche stage in which vertical farming currently operates, make it interesting to study the constellation of partners and actors in this new sector. Whereas these partnerships between firms is established in the current horticulture sector, a new sector needs to built such a collaborative structure. To study such a context with a focus on business development results in utilizing the business ecosystem perspective.

2.3. Business Ecosystem Perspective

As the previous section shows, there are still unanswered questions regarding the prospect and commercialization surrounding vertical farming in the Netherlands. This section proposes the business ecosystem perspective to study the Dutch vertical farming sector. It starts with a description of the business ecosystem perspective and continues to illustrate more detailed aspects of it by various authors. By the end of this section, the reader establishes a substantial and sufficient amount of knowledge on this perspective for understanding further sections in this dissertation.

2.3.1. Details of the Business Ecosystem Perspective

The business ecosystem perspective, which is a different perspective to study complex business environments as the more traditional strategic management perspectives, finds its origin in the biological world. The perspective describes a single focal actor that orchestrates the ecosystem (Moore, 1993), and it eminently fits emerging markets with their opacity and flux environment (Möller et al., 2020). The vertical farming industry fits both these concepts and since the business ecosystem perspective has not been applied in previous research on this sector, this study opted for this perspective.

Anggraeni et al. (2007) mention economic activity is modifying towards networked relationships between firms. This requires a new perspective to study these interactions and the business ecosystem provides an interesting perspective to analyze such a network in a holistic manner. It is the perspective that focuses on the complex business network around a single focal firm. The actors inside a firms business ecosystem are assessed as loosely coupled firms that get orchestrated by the focal firm. Such a perspective accentuates different aspects compared to a more traditional strategic management perspective. R. Gupta et al. (2019) add that the business ecosystem perspective applies best to actor, network and strategy related topics.

Vertical farming utilizes multiple new underlying technologies that originate from other agricultural growing methods or even completely other sectors. Take for instance the climate control, data handling, or the hydroponic system. These aspects of vertical farming are not solely dedicated to the vertical farm-

ing technique, as their usage can be found in other sectors as well. This makes it more straightforward to collect the knowledge from third party actors, and hence, a business ecosystem emerges. Furthermore, the orchestrator distinguishes itself easily in the vertical farming business ecosystem, which helps to analyze the different business ecosystems present in the business field. Chapter 4 elaborates on the business field and the various actors present.

Table 2.1: The evolutionary stages of a business ecosystem by (Moore, 1993).

Stage	Cooperative Challenges	Competitive Challenges
Birth	Work with customers and suppliers to define the new value proposition around a seed innovation.	Protect your ideas from others who might be working toward defining similar offers. Tie up critical lead customers, key suppliers, and important channels.
Expansion	Bring the new offer to a large market by working with suppliers and partners to scale up supply and to achieve maximum market coverage.	Defeat alternative implementations of similar ideas. Ensure that your approach is the market standard in its class through dominating key market segments.
Leadership	Provide a compelling vision for the future that encourages suppliers and customers to work together to continue improving the complete offer.	Maintain strong bargaining power in relation to other players in the ecosystem, including key customers and called suppliers.
Self-Renewal	Work with innovators to bring new ideas to the existing ecosystem.	Maintain high barriers to entry to prevent innovators from building alternative ecosystems. Maintain high customer switching costs in order to buy time to incorporate new ideas into your own products.

Moore (1993) defined the terminology for business ecosystems. The perspective finds its origin in the nature sciences, where species sustain in a variety of ecosystems. In such an ecosystem, species depend upon each other and different relationships between them exist. Whenever one certain breed that positions itself centrally in the ecosystem starts to evolve, other breeds in direct or indirect relationship may start to co-evolve. This phenomenon is based on natural selection in the animal world, however, Moore (1993) explains co-evolution happens in industry as well. A business ecosystem perspective may therefore give a tool to study the complex relationships between firms in a strategic cooperative networks, more specifically, when a new innovation is brought to market.

In contrast to the co-evolution inside a business ecosystem, Moore (1993) also identifies the rivalry between business ecosystems. There remains competition between ecosystems that strive for leadership in the larger business field. This is what makes the relationships rather complex, as firms work cooperatively and competitively to strive for optimal consumer satisfaction. In addition, when radical external anomalies occur, leading ecosystems within the business environment may collapse and previously marginal ecosystems may prevail. This again stems from the nature sciences and gives reason both study the internal and external workings of a business ecosystem.

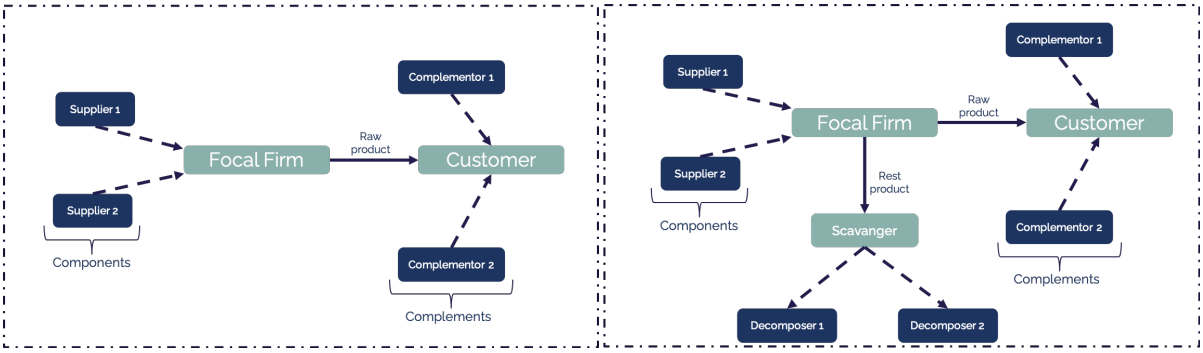
Another aspect that Moore (1993) has defined, are the four different life-cycle stages of a business ecosystem, as depicted in table 2.1. Although, in reality the boundaries between the stages are blurry, the stages do conceptualize the life-cycle of a business ecosystem in a compelling manner. Moore describes a cooperative and competitive behavior for every stage, which followed from the research.

A business ecosystem starts with a birth stage, where the seed innovation or idea must be protected and simultaneously new partners to create value must be found. The birth stage is followed by an expansion stage where competition is fierce and obtaining maximum market coverage is the goal. When the ecosystem grows to a dominant position, the leadership stage starts. During the leadership stage bargaining power must be maintained, while simultaneously improving the product or service together with the ecosystem. The last stage that Moore introduces is the self-renewal stage, where new innovations are encourage to play a role in the ecosystem. This hampers the creation of competitive new ecosystems that may challenge the leadership role.

Iansiti and Levien (2004) delivered another most cited article on business ecosystems. The authors extend Moore (1993) description by allocating specific roles of the actors within an ecosystem. These roles are the keystone, the dominator and niche player. In essence a keystone or dominator is a strategy of the focal firm, which is surrounded by niche players to fulfill and complete the value creation of the

ecosystem. A dominator strives to vertically own all of the business value creation models, where a keystone is leveraging with the niche players. Across different business ecosystems, firms and actors may have a variety of roles.

Also, Adner and Kapoor (2010) identify a strategy on value creation within innovation ecosystems and give a conceptualization of the roles and on the value creation between the those. An ecosystem consists of a focal firm, complementors, and suppliers. By merging this conceptualization with the roles division of Iansiti and Levien (2004), a more complete representation establishes. This conceptualization is illustrated in figure 2.7a and fits for business ecosystem as these ecosystems create customer value, even though, Adner and Kapoor (2010) identify their conceptual model for innovation ecosystems. This research adopts the simple structure to portray business ecosystems and justifies to do so since the boundaries are ambiguous between the different ecosystems as expressed in figure 2.10.



(a) Conceptual model (Adner & Kapoor, 2010).

(b) Conceptual circular model (own illustration).

Figure 2.7: Two different conceptual models on value creation within a business ecosystem

Tate et al. (2019) diagnose the lack of circular actor present in a business ecosystem and propose yet two other roles present. ”In particular, business ecosystems require more participants in the roles of ‘scavengers’ and ‘decomposers’ and an underlying infrastructure, that helps to manage information and material flows in an integrated way” (Tate et al., 2019, p.1). As the vertical farming business field proliferates itself as a more circular and sustainable production method, both these roles are obliged to be present in the those ecosystems. Figure 2.7b depicts the scavanger and decomposer role in the framework of Adner (2006). The scavenger’s business is to collect the rest materials and dismantle, sort and redistribute it to a decomposer who recycles this material into a new product in the system. As the scavenger orchistrates this part of the ecosystem, by Iansiti and Levien (2004) theory it is either a keystone or dominator. The decomposer fits to the niche player definition.

2.3.2. Nestedness of complex business ecosystems

Since the literature on ecosystems is scattered and fragmented, Möller et al. (2020) proposes a definition of what a business ecosystem consists of in relation to other theoretical frameworks. This thesis uses similar definitions. Figure 2.8 visualizes this concept in which Business Fields, Business Networks, Business Ecosystems and Market Systems are described relatively to each other and the different layers that exist in the socio-technical system.

Möller et al. (2020) describes the business ecosystem as purposeful coalitions of actors, where the actors are bounded rational decision makers. Bounded rationality, as Kahneman (2011) defines, helps to explain the complexity of decision making by heuristics and biases in the human brain. This makes it important to not only study the focal ecosystem, but also include the business field and the context in this dissertation.

In addition to Moore (1993) and Iansiti and Levien (2004), Möller et al. (2020) clarifies characteristics that define the four layers in complex business analysis. The figure represents these focal layers and their corresponding artefacts and grounded theory. There is the ”Actor” (micro layer), the ”Focal Ecosystem” (lower meso layer), the ”Business Field” (upper meso layer) and the ”Set System” (macro layer) as depicted in figure 2.8. Since this research has the two meso layers at its center, the next paragraphs describe both these layers.

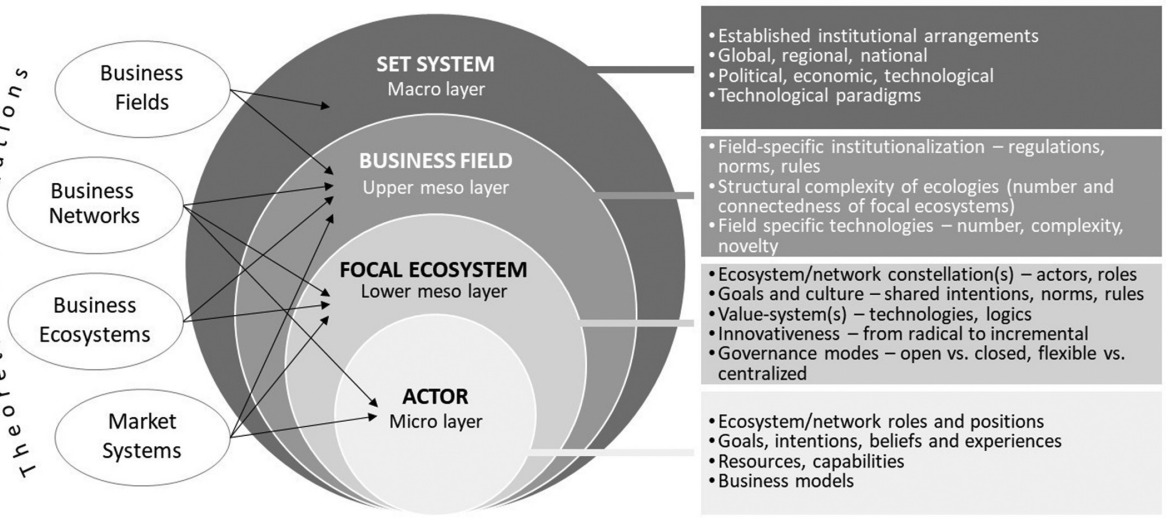


Figure 2.8: NEST - Nested business environment framework Möller et al. (2020)

Direct-relationship partners with the focal actor belong to the lower meso layer. This constellation of actors is firm specific and there are differences in the openness of these ecosystems. Möller et al. (2020) elaborates that key characteristics of ecosystems are the network structure between partners, the different roles, the goals, culture, business-models, governance and organizational arrangements. These characteristics give a sense of direction in how to describe business ecosystems in a comprehensive approach. Also, this layer links to specific processes, exploration, exploitation, system mobilizing, coordination, maintenance and competition.

The upper meso layer consists of interrelated business ecosystems (Möller et al., 2020). ”Business fields portray specific interrelated clusters of business activity, and comprise business field specific institutions (regulations, norms, and values of conduct), structures and technologies” (Möller et al., 2020, p. 385). Möller et al. (2020) make a difference between embryonic and mature business fields. Where mature business fields are more set and innovate via incremental innovation, the embryonic fields have greater uncertainty and radical innovation. This flux and opacity is extended to the constellation of actors in the underlying ecosystems. This difference between embryonic and mature business fields is better conceptualized by Walrave et al. (2018) in a MLP framework.

As this research describes the upper meso level of vertical farming operations in The Netherlands by analyzing the separate business ecosystems, the business ecosystem theoretical framework fits. However, Möller et al. (2020) point out that the nestedness of the layers, the multimodality and context dependent aspects and artefacts, and the transitional character are vital to include in any complex business environment analysis. It is therefor crucial to include part of this understanding in the research. Nevertheless, to restrict the complexity of the research interviews the business ecosystem perspective is kept. The multi-level perspective as proposed by Walrave et al. (2018) may serve as an interested view to adjust for the kaleidoscopic nature of business ecosystems.

2.3.3. Multi-level Perspective on business ecosystems

As mentioned before, Moore (1993) describes that radical changes in the external environment of a business ecosystem may cause the ecosystem to collapse. Also the call from Möller et al. (2020) to include the nestedness of a system, proves the necessity of placing the business ecosystem perspective in a wider context. (Walrave et al., 2018) position the perspective in a multilevel perspective, which accentuates the transition and merger of niches in the current regime. The authors emphasize that societal resistance from the socio-technical regime can break a business ecosystem.

In addition, information alike is essential for an analysis of the projected growth of a business ecosystem, and studying the landscape factors, regime and other niche-level initiatives gives an overview of the current window of opportunity for niche breakthrough (Kamp & Vanheule, 2015). ”A destabilized or weak regime offers windows of opportunity for niche breakthrough” (Kamp and Vanheule, 2015, p.473). It is the interaction between these three levels that affect niche up-scaling (Kamp & Vanheule, 2015).

Walrave et al. (2018) adds the terminology of external viability to help explain the success rate of an ecosystem.

A multi-level perspective analysis divides the socio-technical system into three levels: the landscape factors (macro level), the socio-technical regime (meso level) and the niche (micro level) (Geels, 2002). Walrave et al. (2018) conceptualize multiple ecosystems to create a niche and so whenever there is a niche breakthrough, it is an ecosystem breakthrough as well. This research embraces a similar construct, which is depicted in figure 2.9.

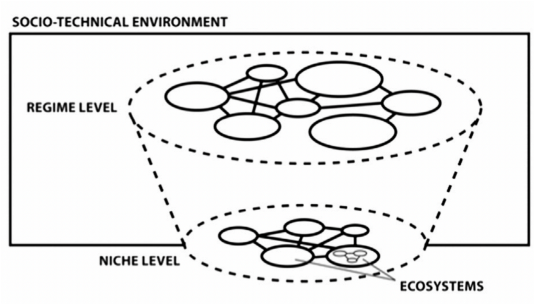


Figure 2.9: A conceptualization of the ecosystem level within the multi-level perspective (Walrave et al., 2018).

The landscape level consists of factors that are not part of the regime and niche but do influence these levels. It is a broad range of aspects that are entitled to this level, among others, deep structural trends, macro-economic factors, and cultural routines (Kamp & Vanheule, 2015). Positioned below the landscape level is the collection of currently prevailing artifacts, habits, and the rules between an actor network in a certain business environment (Geels, 2002). This level is referred to as the regime level that consists of established actors. These established actors prefer incremental improvements in their regime, which is opposite of the actors in the niche level (Walrave et al., 2018). In the niche innovations are proposed as solutions for solving issues in the regime. As these niches are often weakly structured, the actors can more easily embody changes from the landscape or regime (Kamp & Vanheule, 2015).

2.3.4. Relationship Between Ecosystems

The first and last stages of the life-cycle of a business ecosystem as defined by Moore (1993) include innovation or co-creation of innovation. However, when considering this co-creation of innovation other authors reveal that such happens in an innovation ecosystem (Adner, 2006)(Adner & Kapoor, 2010). So, the different ecosystems are overlapping and the boundaries are ambiguous, which is depicted in figure 2.10.

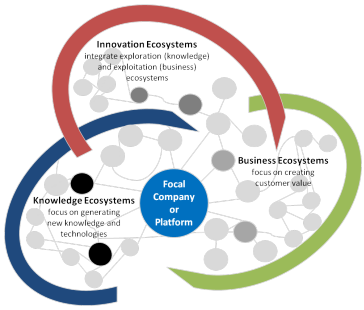


Figure 2.10: An overview of different ecosystems in the business literature (Valkokari, 2015).

Some actors participate in different ecosystems within a same business environment and take on different roles (Adner, 2006). ”In addition, on a temporal scale, the future-orientation of innovation ecosystem contrasts with the other concepts” (Valkokari, 2015, p.21). However, the different ecosystems serve different needs for firms and institutions. Appendix C contains an overview of the differences between them. Adner (2006) adds that the innovation strategy of firms should match those of their innovation ecosystems to benefit optimally.

Clarifying the boundaries of the business ecosystem is vital information as this research takes a similar perspective. Valkokari (2015) defines the baseline of the business ecosystem as utilizing resources for creating customer value. In a business ecosystem there is one main actor that operates as focal firm. This focal firm orchestrates other actors to share resources, assets, and benefits in its networked business operations. These other actors consist of suppliers, customers, and more loosely connected firms, who share a business relationship that is both competitive and cooperative (Valkokari, 2015). This research adopts the definition from Valkokari (2015) on business ecosystems as it is in line with the definition from Moore (1993) and gives a more complete overview on ecosystems.

2.4. Empirical Framework - The 6C Framework

As the this study only selected a fitting research perspective in the previous section, there is need for an empirical framework. Section 2.3 elaborates on the definition of business ecosystems and how to conceptualize them in an optimal manner for vertical farming. It lacks, however, a clear and concise lay-out for analyzing the various business ecosystems. This section explores the 6C framework for analyzing the business ecosystems by Rong et al. (2015).

The search for a suitable framework resulted in the 6C framework, as it is one of the few frameworks for analyzing business ecosystems. Nevertheless, the framework fits the purpose as it analyzes an ecosystem broadly. Rong et al. (2015) divide the various IoT business ecosystems into three categories from open to more closed patterns, which is in line with Möller et al. (2020). However, an ecosystem with the 6C framework may accentuate more underlying enabling and constraining factors (Reijtenbagh, 2020).

Reijtenbagh (2020) applies the 6C framework to discover enabling and constraining factors in the circular ecosystem of Dutch demolition contractors. As Reijtenbagh (2020) diverges from the original sector for which Rong et al. (2015) designed the 6C framework (IoT setor), the applied framework is different from the original. This is not hampering the research from getting prompt results.

The authors recommend to apply the framework to different disciplines, but difficulties may arise by doing so. It is for that reason that this research embraces the 6C framework with care and tailors it to the Dutch vertical farming business ecosystems with the help of circular business ecosystem aspects from Reijtenbagh (2020) and the context and role division as elaborated on in section 2.3. The next subsection is devoted to explaining the empirical 6C framework in more detail.

2.4.1. The 6C - Framework

As aforementioned, to gain insight in the internal workings of the business ecosystems, the 6C framework by Rong et al. (2015) is suitable. It is an elaboration of the 3C analysis of Y. Zhang et al. (2007). The 6C framework analyzes a business ecosystem by describing the context, cooperation, construct, configuration, capability and change within the business ecosystem. Such an analysis helps to gain insight in how it performs, what its barriers are and what its current value creation mechanisms are.

In order to fit the framework to this research, four of the original 6 constructs are slightly altered towards a more circular and vertical farming business ecosystem approach. The justification for this is that vertical farms proliferate themselves often as more circular as chapter 4 elaborates. Reijtenbagh (2020) proposes a circular alteration of the framework for the built environment sector. The final 6C framework that this research uses, is an optimal fit between the literature as this chapter explains, the 6C framework by Rong et al. (2015) and by Reijtenbagh (2020). The following paragraphs contain a detailed description on the six (altered) dimensions of the 6C framework, which table 2.2 summarizes.

Context

The context dimension is defined by Rong et al. (2015) as the external environment in which the ecosystem operates. For analyzing the context of a business ecosystem, drivers, barriers, and key missions are identified. In addition, since Moore (1993) defines the life-cycle of business ecosystems with the corresponding behavior of firms, and demonstrates that a firm's status changes in the business ecosystem life-cycle. Hence, it is imperative to include the life-cycle in the context.

Rong et al. (2015) adds that within this parameter, interactions with non-direct business partners is included. Due to the complexity and importance of the context for this research, a more comprehensive method is embodied to study the context. Kamp and Vanheule (2015) describe and utilize the multi-level perspective (MLP) analysis in their research to study the socio-technical context of a niche within its regime and landscape factors. This tool fits the purpose of analyzing the context for business ecosystems as well, however, a time constraint hampers this holistic method. Thus, this study includes the nested system by Möller et al. (2020).

Möller et al. (2020) describes the 4 layers within a complex business environment. As the other constructs of the 6C framework describes the focal ecosystem and actor layer, the context is there to elaborate on the business field and set system. Figure 2.8 visualizes this conceptualization. The

original 6C framework by Rong et al. (2015) lacks a summation of the field specific technologies, structural complexity and institutionalization of the business field. These are important to consider as the business field directly influences the focal ecosystems (Möller et al., 2020).

Cooperation

"Cooperation reflects the mechanisms by which partners interact (collaboration mechanism and governance system) in order to achieve the common strategic objectives" (Rong et al., 2015, p.44). The relationship between firms in a business ecosystem is complex en differs along the life-cycle of a business ecosystem (Moore, 1993). As the interview protocol of Rong et al. (2015) omits detailed questions on the cooperation dimension and more far-reaching information is wanted for this criteria.

Tate et al. (2019) further delineate this dimension as the authors define the complexity of the collaboration mechanisms by describing the density of the network, network complexity, and interdependence. Parida et al. (2019) mention risk division and granted exclusivity are strategies that influence the interdependence parameter. Risk division entails the negotiation of different revenue and risk provisions and granted exclusivity is all about making exclusive agreements with other firms or actors within the business ecosystem.

For describing the governance system within a business ecosystem, Parida et al. (2019) conclude that ecosystem orchestrators (or the focal firms) utilize negotiation, nurturing, and standardizing strategies to fulfill the construct in an optimal way. Negotiation mechanisms are about strategies to contract new partners, while nurturing mechanisms grant support to the business ecosystem for improving knowledge development, sharing of knowledge, and intellectual property. Parida et al. (2019) describe three mechanisms for the standardization aspect. These are promoting industry-wide standards, co-developing technological standards, and drafting formal and informal certification schemes.

Construct

For the definition of the construct dimension, this research adopts a more circular approach compared to the original construct dimension by Rong et al. (2015). "The construct dimension defines the fundamental structure and supportive infrastructure of a business ecosystem" (Rong et al., 2015, p.44). Rong et al. (2015) utilize a 'structure-infrastructure' model for conceptualizing the construct. Such a model has a manufacturing managing background, so this fits the analysis of this research.

Reijtenbagh (2020) researches circular business ecosystems and adapts the 'structure-infrastructure' model to fit a more circular approach. As there exist scavengers and decomposers next to the producers and consumers of a non-circular business ecosystem (Tate et al., 2019). Tate et al. (2019) elaborate that scavengers are in control of dismantling, sorting, and transporting secondary materials. Decomposers, on the other hand, make sure to transform these materials into reusable products for the ecosystem. As the vertical farming industry proliferates as a more sustainable and circular solution for the agriculture, adopting these circular construct parameters is legitimate.

As vertical farming is connected to high-tech monitoring as well, this research requires to include a information on data processing in the business ecosystem. S. Gupta et al. (2019) conclude that data management enhances decision-making, and hence, such improves the efficiency of operations. Tate et al. (2019) add that data on material flows has potential to increase circularity. Also, data platforms may increase the knowledge exchange and capability sharing (Lacy et al., 2020).

Configuration

Rong et al. (2015) explore with the configuration dimension the external relations in the business ecosystem and its configuration patterns. There are further business ecosystem activities that coordinate processes as the individual constructive elements. Rong et al. (2015) therefor ask in the interview protocol more information on the business models and business processes. This method is embodied in the research of Rong et al. (2015) as the configuration dimension is becoming increasingly important in the study of global engineering networks (Y. Zhang et al., 2007) and supply networks (Srai & Gregory, 2008).

As depicted in figure 2.7a, Adner and Kapoor (2010) identify a conceptualization for portraying the relation between ecosystem's actors. In order to include the more circular approach proposed by Tate

et al. (2019), this research adopts and tailors this concept to help visualize the configuration. Figure 2.7b visualizes this phenomenon as described by Adner (2006) and Iansiti and Levien (2004). It is the configuration aspect that describes the value creation and business processes between the actors (Reijtenbagh, 2020).

Since the vertical farming sector proliferates themselves as circular, it is interesting to verify this with their underlying configuration structure. The third sub research question of this thesis is all about the business models and processes on this circular aspect. Thus, the configuration aspect must provide a thorough understanding of this parameter. Walrave et al. (2018) adds that societal pressure can prevent a niche system from gaining ground. It is straightforward that society expects results from the vertical farming sector, however, no research has taken the physical results into consideration.

Capability

Capabilities are the key success features in a business ecosystem (Rong et al., 2015). A business ecosystem gives the opportunity for actors to cooperate and take advantage of each other capabilities. Srai and Gregory (2008) defined the capability dimension in the competence of communication and sharing, integration and synergizing, innovation and learning, and adaptation and restructuring. Rong et al. (2015) adopted these competences in the 6C framework as it was a proven concept.

The capability construct is important for this research as Rong et al. (2015) defines it as key success features. Whenever there the performance of capability factors is insufficient, the business ecosystem is not functioning optimally. As the main research question is on the enabling and constraining factors, this construct has a central focus in this study via the 6C framework. This research follows a similar approach as these key features are not sector specific.

Change

A business ecosystem has different stages throughout its lifetime (Moore, 1993). The change dimension of the 6C framework describes this adaption of configurations between the different life-cycle stages (Rong et al., 2015). ”Thus, change is the dynamic aspect of systems’ dramatic growth instead of incremental development, which generates a new lifecycle of the system evolution. Hence change would demonstrate how the configuration pattern of a business ecosystem is renewed” (Rong et al., 2015, p.45).

Since the vertical farming industry is still in a (pre-) niche state, it is understandable that not much on this construct has occurred. The way Moore (1993) describes a renewal at the last stage of a business ecosystem is completely unrelated to this study. Yet, it is an aspect to include as simple assumptions must never be taken for granted and the embryonic stage of a business ecosystem is one of opacity and flux (Möller et al., 2020). Thus, this study adopts this parameter, all-being it in a less central position compared to the version of Rong et al. (2015) and Reijtenbagh (2020).

2.4.2. The practical use of the empirical framework

There are many gaps in the academic literature on the perspective, commercialization and technology underlying the vertical farming method. As section 2.1 describes, the definition of vertical farming is scattered across the academic work. In addition, the perspective of vertical farming is unclear, yet there is a basic understanding that it plays a role within the new circular and resilient food system. There lacks, however, an understanding about how and under what circumstances the vertical farming business thrives.

This research aims to fulfill a part of this lack of understanding and applies a business ecosystem perspective as section 2.3 elaborates. A business ecosystem perspective describes the complex business environment by strategic partnerships and co-evolving among actors in the ecosystem orchestrated by a single focal firm. It is a different perspective as the more traditional strategic management perspective, which may generate new findings. This study utilizes a business ecosystem framework as it fits the new emerging markets and has not been applied on the vertical farming industry before.

As section 2.4 details, the 6C framework by Rong et al. (2015) serves as the basis for empirical framework as chosen for this study. The chosen empirical framework fits the theoretical business ecosystem perspective. Table 2.2 describes the 6C framework as Rong et al. (2015) propose and the

6C framework for this research. This adapted version includes alterations from Reijtenbagh (2020), which proves to be a working empirical framework. Furthermore, these alterations finds their origin in the circular business ecosystem theoretical frameworks. This aspect is interesting as vertical farming firms proliferate themselves as a better circular concept.

Thus, the expected results as stated in chapter 1 scope the research topic to an optimal size. These statements, however, do no define how to research the phenomenon. The theoretical framework in this chapter provides the conceptual perspective, whereas the empirical framework helps to provide an adequate and more practical structure to study the physical commercialization of vertical farming. The next chapter describes the chosen research methodology for this dissertation. It builds upon the literature, theoretical and empirical framework as this chapter depicts.

Table 2.2: The evolutionary stages of a business ecosystem by (Moore, 1993).

Dimension	Description from Rong et al. (2015)	Description as used in this research
Context	The environmental features from a business ecosystem's network: -Life Cycle Stages -Drivers -Barriers -Missions	Positioning the business ecosystem in a wider context and express the environmental features of it: -Life Cycle Stages by Moore (1993) -Drivers -Barriers -Missions -Nested System by Möller et al. (2020)
Cooperation	Collaboration and governance mechanisms in business ecosystems -Coordination Mechanism -Governance System	Collaboration and governance mechanisms in a business ecosystem from Reijtenbagh (2020). -Governance Mechanism (negatiation, nurturing and standardization from Parida et al. (2019)). -Network Charasteristics (dense and heterogeneous network from Tate et al. (2019)).
Construct	The infrastructure and structure of a business ecosystem. -Structure -Infrastructure	Infrastructure and structure of a circular business ecosystem. -Structure (actor balance from Tate et al. (2019)) -Infrastructure (Physical, virtual and data)
Configuration	The operational mechanisms within a business ecosystem and emergence of configuration patterns. -Pattern -External Relationship	The operational mechanisms within a business ecosystem and emergence of configuration patterns. -Business Processes -Business Models
Capability	The key aspects to deliver success in a business ecosystem. -Integration & Synergy -Learning Adaptability -Communication & Accessibility -Adoption & Mobility	The key aspects to deliver success in a business ecosystem. -Integration & Synergy -Learning Adaptability -Communication & Accessibility -Adoption & Mobility
Change	The continues process in evolving to different configuration patterns. -Renewal -Co-evolution	The continues process in evolving to different configuration patterns. -Renewal -Co-evolution

3

Research Approach

This chapter defines the research approach that applies to this dissertation. As figure 3.1 represents, defining the research approach is the third step in the main research process. A detailed description is important for enhancing the replicability, while a rigorous research approach enhances the reliability and construct validity of a study. The chapter starts by elaborating on the two main research methods. It continues with describing the analyzing method in section 3.3 and concludes with the a relevant analysis on the reliability, replicability and validity of this study.

Figure 3.1: The research process steps for this dissertation

The research methods are the main tools for researching the proposed research gaps, which is the missing link on how to apply the empirical framework. This study advocates in favor of a triangulation approach on the context dimension as this fits within the available resources for this research. The other dimensions are studied by means of a single embedded case-study followed by a verification interview. The desk research is the preferred method for the triangulated context approach. In addition the desk research provides vital information for the case-study selection and understanding of the technical progress of vertical farming for both the reader and researcher.

The 6C framework connects the two methods on their common grounds by means of a coding table. These objective results are presented by Chapter 6. The limited amount of resources is the reason for this research set-up. There are a limited amount of actors that wanted to participate in this research, therefore the focus is on a single focal firm.

A justification for this approach, is the more in-depth analysis that a single embedded case-study brings. Since few vertical farming actors have commercial success and no research has identified the constraining factors, it helps to scrutinize a common case.

In order to be able to generalize to other vertical farming business ecosystems, and potentially to other sectors as well, this study includes verifying interviews. In this way, the verification process takes care of the investigator's potential bias.

The next sections contain a detailed description of the methods and data collection processes, boundaries and other specific considerations of the methods. Figure 3.2 depicts the research approach in the main research process. This figure helps to visualize and keep track of the approach as the sub components get explained in more detail in the next subsections.

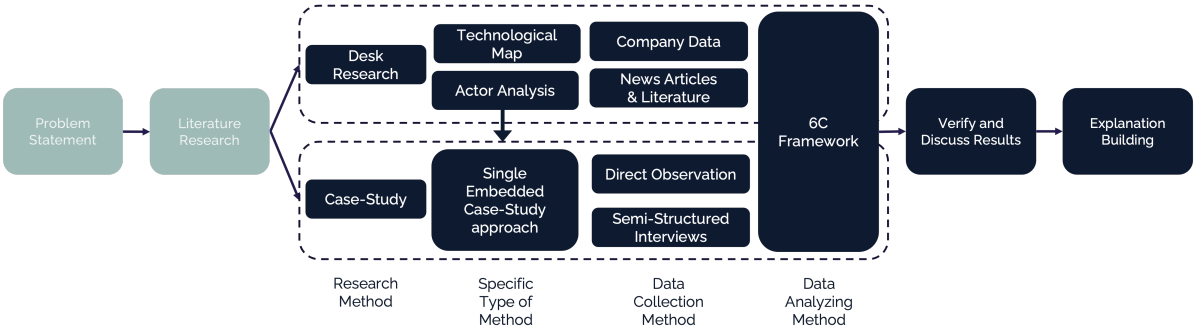


Figure 3.2: The research approach for this dissertation

The figure clearly represents the two separate methods and show the dependency between the two research methods. An actor analysis provides the potential cases for case-study selection. Without a thorough actor analysis, a single case-study is more difficult to position in the context of the sector. Also, the data analyzing method is a dependency and connection between the two methods. The 6C framework merges both streams of collected data and organizes the results for the succeeding conclusion chapter. In there, explanation building around the most impact factors provides the final conclusions of this research.

3.1. Desk Research

The desk research consists of a technological map and an actor analysis, where the main purpose is to retrieve data on the underlying technological advancements and the size of the business field. In addition, the actor analysis provides the input for the case-study selection, which is a crucial step in this dissertation. As the right side of figure 3.3 portrays, the desk research provides data input for the context, construct and configuration dimension. Thus, the desk research's contribution to this study is far reaching and is therefor included as a separate research method.

Möller et al. (2020) describe the definition of a business field and helps to illustrate the boundaries of the desk research. Figure 3.3 depicts the desk research in the context of the four complex business environment layers by Möller et al. (2020). There is the micro layer, focal ecosystem, business field, and set system in this conceptualization. Where a business ecosystem, which is the object of analysis of this study, fits in the description of a focal ecosystem. These ecosystems are a constellation of single actors and the business field is, in a similar way, the constellation of multiple similar oriented ecosystems.

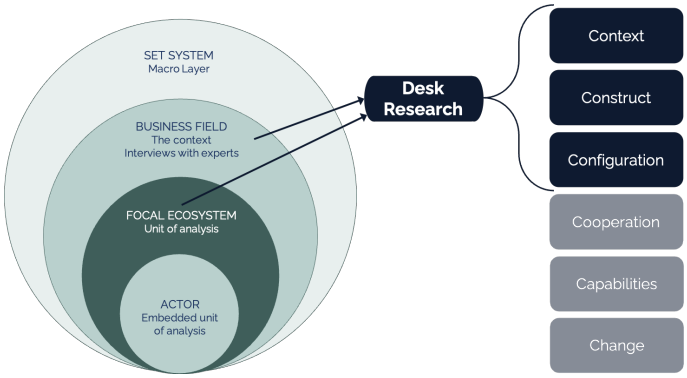


Figure 3.3: The desk research method in perspective of the research approach

The desk research focuses on the business ecosystems and the business field, as the arrow depict in figure 3.3. The specific desk research data collection tools and methods provide the boundaries in the topics to include. In addition, the desk research contributes to find the correct actors to ask for an interview. The paragraphs below describe the two specific methods and their process in more detail.

3.1.1. Technological Map

The technological map is an overview and conceptualization of the factors that vertical farming requires to function in society. It consists of an elaboration on the infrastructure, the technical components for the vertical farm itself and its surrounding technologies. Such an overview provides knowledge on the type of partnerships within a business ecosystem, the correlated business processes and the underlying

technologies. This is not only important for the construct and configuration dimension, but also gains information on the questions for the interview protocol. In addition, a technological map supports the understanding of vertical farming for the reader, because the holistic overview splits the vertical farming method into more understandable and stand-alone components.

Since the needed infrastructure gets accentuated by the technological map, it provides direct insight in the construct dimension. The other main aspect of the construct dimension are the roles of the various actors in a business ecosystem. For this 'structure' part of the dimension, the technological map also provides insight as the factors may be provided by external partners of the focal firm. Which is logical reasoning as a this new sector most probably gets its know-how from niche players in other sectors close to vertical farming. A startup simply misses the specific knowledge.

Also, the technological map provides insights on the configuration dimension as it contains information on an overview of the underlying business processes connected to the technical components, surrounding technologies and infrastructure. The information is merely an overview, yet it helps understand these processes and is able to put the data from the interviews more into place. In addition it helps the reader and researcher to prepare for this more detailed data from the case-study.

The construction process of this technological map is rather straightforward. It started with an earlier created technological map and continued with a google search. By reading literature, news articles and viewing explanatory videos on vertical farming, the researcher grows a profound knowledge on vertical farming. When new literature or articles provide no new knowledge or data, the data collection quits. Obviously, the detail of the data needs to be of a correct level. The researcher takes care of this aspect of the person leading the research is most able to make these decisions.

3.1.2. Actor Analysis

An actor analysis depicts the system of vertical farming. So, the analysis includes all main actors and describes the interaction between those actors. This data helps to put the focal firms into context of the real world and necessary resources. Next to the technical and knowledge components from the technological map, there is need to elaborate on the financial, logistic and regulatory components. It is important to understand that the main actor present in the analysis are also present in a vertical farming business ecosystem. So, this actor analysis describes the business field.

This study's actor analysis provides a more detailed overview of the focal firms and the overarching institution that are active in the Dutch vertical farming business field. Depended on the amount of actors present in the business field, the actors may be categorized and subdivided to regain a good overview of the business field. Every actor gets a short description on their current status and main vision on vertical farming.

Such an actor analysis gives insight in the context dimension of the 6C framework as it describes the business field which is the context of the case-study. The various visions on and interpretations of vertical farming gets accentuated and can be used in the explanation building process, since it may describe the variety in the business field and interaction.

The process of retrieving the data for the actor analysis is most similar to the collection of the data for the technological map. Farhangi et al. (2020) provide a starting point and scope from where an elaborate Google and LinkedIn search retrieved more actors. When new literature, articles or search entries resulted in previous known results, the search stopped. Again, the researcher decided on the depth of the actor analysis with in consideration the available resources and open knowledge.

3.2. Case-Study

In addition of the desk research, this study proposes a case-study method to obtain an answer to the main research question. "Case studies focus on collecting information about a specific object, event or activity, such as a particular business unit or organisation" (Sekaran and Bougie, 2016, p.98). In this definition, a business ecosystem is suitable to research as a case study. Moreover, the researcher is in contact with the online community of 'Indoor Farming Nederland', which serves as a knowledge business field that connects a variety of vertical farming actors in The Netherlands.

The justification on why a case-study is the main research method starts by mentioning that a case study fits the exploratory research question and character of this study (Yin, 2014). Yet, there are various method that suffice. A case-study, however, accentuates the context, which is important to

include in this study. Furthermore, the commercialization and initial growth of vertical farming happens in the here and now, which makes a case-study method even more valuable as data can be obtained from experts who are working on the matter this very moment (Yin, 2014).

The case-study method requires more details to describe as there are many different formats. The next subsections discuss the reasons for a specific case-study design that suits this study. It starts by elaborating on the details of the single-embedded case-study, from where it continues to the selection criteria and data collection methods. All of these aspects are important to design before starting the case-study as these aspects may point the research towards various directions.

3.2.1. A single embedded case-study design

There are two main categories to choose from when performing a case-study. There is the single case-study and the multiple case-study, with its definitions that are both self-explanatory. Although a multiple case-study is more compelling and has a higher external validity, it serves as replication logic. This entails that the cases must provide similar or contradiction results, which the study determined on beforehand (Yin, 2014). Moreover, Yin (2014) states that multiple case-study methods require extensive resources in time and available cases. As the aim of this research is to provide propositions and the resource availability is low, this study rejects the multiple case-study method and opts for a single case-study method.

In addition, the presence of a theoretical framework strengthens the external validity of this research, even in a single case-study method. As aforementioned, this key performance indicator is important for this research as it strives to present an all-inclusive perspective of the vertical farming business ecosystems. Yin (2014) describes another rationale to consider when including a single case-study method. Such a method is appropriate if a case focuses on observing a critical, unusual, common, revelatory, or longtitudinal phenomenon. Since this study aims to built academic work on the complete vertical farming industry, a common case is a right rationale to include.

In the single case-study method, there is yet another split in designs. A holistic design studies the case as single phenomenon, whereas an embedded design divides the case into integral sub-parts. Each sub-part represents an embedded unit of analysis as figure 3.5 depicts. The holistic design is more prone to shifting in direction of the main research objective. Academics both see this flexibility as a positive and negative aspect depending on the context of the study (Yin, 2014). An embedded design holds its focus better. However, by analyzing the sub-units, the researcher must be careful not the shift the main unit of analysis, which are the business ecosystems (Yin, 2014).

Since business ecosystems are a constellation of actors, the various actors of a single ecosystem may function as embedded unit of analysis. This makes an embedded design possible for practical reasons. Also, the focus of this study is set by the theoretical and empirical framework. Therefor, the flexibility of a holistic design is not desired and the focus of an embedded design fits the research better. Thus, this study applies a single embedded case-study design to its method.

With the guidance of Möller et al. (2020), figure 3.4 depicts the boundaries of the case and embedded sub-parts. The business field and set system represent the context in which the focal ecosystem operates. This business ecosystem represent a single case, whereas the single actors of this business ecosystem represent the embedded units of analysis. So, while the case-study researches the business ecosystems, its main focus is the actors.

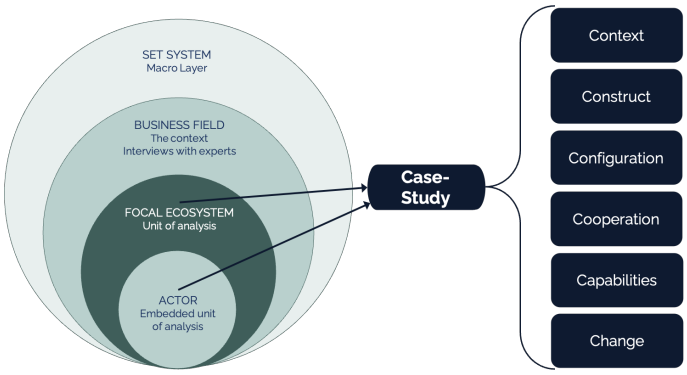


Figure 3.4: The case-study method in perspective of the research approach

However, the research must prevent to dive into detail about the single actors. Both the empirical framework by Rong et al. (2015) and the definition of ecosystems by Möller et al. (2020) assist in this. It is inevitable to avoid some ambiguity, as the actors define the ecosystem themselves. However, a focus on the network constellation,

goals and culture, value systems, innovativeness, and governance model, sets the scope and boundaries for the case.

A focus on the single actors still provides relevant results as all the single actors together form the business ecosystem. By asking relevant questions and obtaining relevant data to the business ecosystem and not focusing solely on the single actors, an embedded design accentuates the various perspectives of the single actors. This leads to a higher reliability as research artifacts are limited. Thus, the use of an embedded approach keeps the focus and provides relevant data.

3.2.2. Selection criteria for case studies

The vertical farming business field is in an early niche stage, which sets serious boundaries on the amount of available case-studies. The selection criteria are therefor not as specific as with other case-study research. Yet, this research adopts three main selection criteria. It is a combination of how apt the business model of the business ecosystem is, how common or representative the case is, and how inclined the business ecosystem actors are towards a research.

Thus, a first straightforward selection criteria is that case-studies must be actively participating in a vertical farming business ecosystem in the Netherlands. Chapter 2 defines a definition of vertical farming. However, as the vertical farming industry has a niche status, most focal firms do not consider all the requested definition aspects. That's why the selection criteria directs this definition to the vision of the focal firm. The fast pace of development in the entrepreneurial setting justifies this criteria.

Also, chapter 2 presents a definition of a business ecosystem. As a business ecosystem framework is merely reviewed as a perspective (Möller et al., 2020), most cases suit this criteria. However, there are still boundaries to what extend it fits in a case-study research for practical reasons. The single actors of the business ecosystem, or the embedded units of analysis, must consent with taking part in the research process. Most available cases do not allow a researcher to study their business ecosystem or are busy, but two cases responded positively.

A final selection criteria connects the five case-study rationales from Yin (2014) to the research. Yin (2014) identified five case-study rationales of which the common case-study fits this research. A common case objective is to capture the conditions of a prevalent situation. This rationale serves as the main criteria. As this study aims to clarify the enabling and constraining factors from the everyday situation, this research requires a common case.

In order to be informed about the presence of potential case candidates and to obtain the required contact information, this study performs a desk research as described in the previous subsection. The actors and business ecosystems that the desk research provided is the final list of potential candidates. In a following step, this study performed the selection criteria, as described in this section, on the final list of candidates. Chapter 4 describes the process of finding these potential candidates.

Thus, as this study conducts exploratory research and wants to define the general enabling and constraining factors, the selected case must function as a general example. This is what Yin (2014) defines as representative case, which is not unique or critical in its context. When combining this criteria with the definition of vertical farming and the willingness to take part in a study, there is one case selected that fits this study most optimal. The next paragraphs introduce the selected case.

Glowfarms

The selected case is the business ecosystem around Glowfarms. Glowfarms is a startup that utilizes a vertical farm to grow crops and envision a fully automated vertical farm. Their primary business model focuses on the sale of pre-packed herbs that have a longer shelf life relative to the current products for sale. Glowfarms claims this is possible due to the clean and precize production. So, the farm uses no pesticides and optimize the growing environment to a perfect condition for the herbs.

Since Glowfarms is a startup, the facilities are not similar as Kozai (2013) defines for a vertical farm. The vision of Glowfarms, however, is including the definition, and as aforementioned, this suffices the selection criteria. Also, since the vertical farming industry is in a niche state, the focal actors are either startups or spin-offs. Moreover, the majority of the vertical farming actors internationally grow similar products as Glowfarms and its founders have no history in agriculture or horticulture. This makes Glowfarms a common case and with an ecosystem that is willingly to embrace and cooperate in a research, this study opts for the business ecosystem of Glowfarms as the single case.

Glowfarms cooperates with a variety of actors and separates the straightforward suppliers from the cooperation partners. Obviously, Glowfarms collaborates with all actors, however, with a select number of actors Glowfarms shares a more intense cooperation. As there are more intense cooperations or partnerships as embedded units of analysis this study can include, it chooses three partners to embrace in the interview. The number of three embedded units of analysis comes from the total number of partners of Glowfarms that are willing to participate in this study. Furthermore, a total of four in-depth interviews provide sufficient coverage of the business ecosystem and depletes most bias of the single actors. Chapter 5 elaborates on the selection of the included collaboration partners and contains a comprehensive description of the case-study.

3.2.3. Case-study Data Collection Methods

The data collected for the case-study method is of qualitative nature, yet it uses multiple data collection methods. Such a design improves the reliability as Yin (2014) acknowledges. The subsections below elaborate on the justification of the chosen data collection methods and their specific analysis methods. It starts by describing the process of obtaining the direct observation and why this method is apt for this case. The next subsection entails information on the main source of data collection, which is the semi-structured interviews. A corresponding interview protocol is briefly described below, however, appendix D contains a more elaborate version.

Direct Observations

Direct observation is qualitative data on the experience of an observant in a real case (Yin, 2014). Yin (2014) adds that direct observations may contain additional information that assists in complementing or preparing interviews. Since a single observant experiences and defines this set of data, it is not the main source of evidence as this data is prone to bias. Yet, this data assists in describing three of the six dimensions of the framework. It describes the cooperation, capabilities and change dimension as the observant researcher was in the position to collect data on these dimensions with the available resources and permissions.

The observational researcher that collected the data went to the case-study location about one day every week. Glowfarms employs the researcher for designing, manufacturing and monitoring a network of sensors in the vertical farm. Although this task is on a different organizational layer as this study, the researcher is able to collect relevant information by the weekly meetings and conversations on the location. In this way, the employment has little effect on the research as the observant is not interfering with the formation of the business ecosystem, excluding the search for a data analyzing niche player.

From the technical-sensor-design-role, the observant joins the weekly meetings from the start of February up until the beginning of August and notes down sets of information that either connects to the 6C empirical framework, or contains interesting information for further research. A case-study database shapes this information in the six dimensions of the empirical framework and other relevant information. Chapter 6 contains more elaborate information on the final observational data.

Semi-structured in-depth interviews

Interviews deliver the main source of data for the case. Yin (2014) expresses the value of interviews in an exploratory case-study. Since the case operates at the present moment, interviewing experts or employees of the case adds value as these people are perhaps unavailable or have a scattered knowledge on what happened in this very moment. Also, interviews assist in suggesting explanations of key factors, and present the participants perspective. This is vital as most decision-making, envisioning and networking still happens by humans.

This study chooses to include an in-depth interview as the selection criteria and enthusiasm among the case participants limits the amount of available resources. Furthermore, the embedded design assists in providing single key informants a balanced impact on the research results. If a single key informant provides solely a large portion of the information, the data may be skewed or biased. By verifying this among other sub-parts, this study protects itself against such. An in-depth interview then suits apt to this study as many topics of the empirical framework get covered.

As explained by Sekaran and Bougie (2016), semi-structured interviews are an excellent choice for an exploratory study and beginning interviewer. Moreover, another advantage from semi-structured

interviews is the unobstructed setting for interviewees to tell the complete story. The partly unstructured settings allows for diverging from the questions if the researcher collects other interesting data. The interviewer makes the selection on when to probe and when dive into a sub-topic on the spot, so it is difficult to explain the triggers as the qualitative data from the interviewee may have an ambiguous character. The interviewer is the researcher of this study and therefor, understands the topic sufficiently.

Since the interviewer is the sole researcher of this study, the amount of interviews conducted has a practical constraint. Due to time boundaries and consent from the participants in the case study, this study conducts a single interview per embedded unit of analysis. It justifies for the construct validity as this study carefully considers who to interview as object of observation.

Employees from a focal company (keystone or dominator) or niche player in the business ecosystem serve as interviewees and deliver qualitative data on their business ecosystem, which is the unit of analysis. Figure 3.5 depicts this situation, where the red / darker squares within the embedded unit of analysis represent the interviewees. The interviewees from the focal firm is preferably one of the founders as the position has the most knowledge on the complete business ecosystem and its vision.

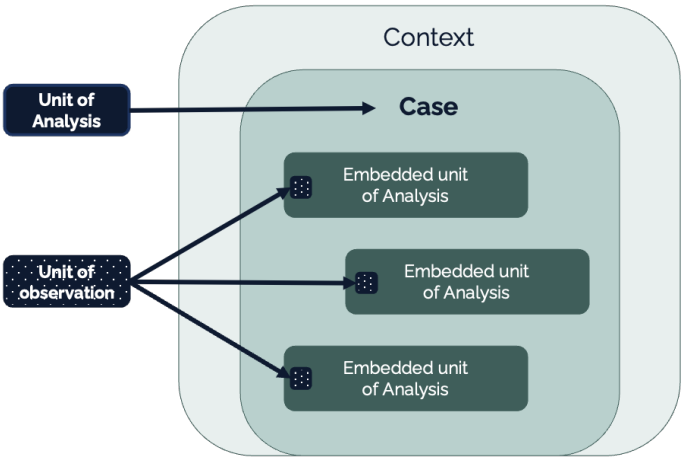


Figure 3.5: The single embedded case-study design (adapted version from (Yin, 2014)).

For the niche players in the business ecosystem, there are two other selection criteria. As such an actor is not automatically focused on the vertical farming industry, interviewing an employee that is directly involved with the ecosystem is more appropriate. The interviewee must have gained sufficient knowledge and so this study asks interviewees to have at least one year of work experience. A manager is the preferred source of data, as this position is most aware of the existence of a business ecosystem.

The interview protocol assists in acquiring, storing, and utilizing the data in a correct scientific method. Appendix D contains the complete version of the protocol that the interviewees received via email. All the interviewees and firms are anonymized, as this may prevent any unwanted affirmation and connection to this research. The data storage is in line with the TU Delft Data Management Plan and to TU Delft standards, which appendix D describes in more detail. This is valid for written notes as well as any audio from the interview.

The empirical framework, as described in chapter 2, takes a central role in the interview. The interview bases its question on the six dimensions. In this way the interview provides data that suits the theoretical perspective. The interview protocol divides the questions per dimension of the empirical framework, which may assist the coding process. Every dimension gets an estimated time relative to its importance and the focus of this study. The interview protocol grants most time to the Context, Configuration, Cooperation and Capabilities dimension as Change is not expected to have taken place and Construct is partly answered by the desk research. The questions for the niche players differ from the questions for the focal firm.

3.3. Explanation Building

Explanation building as Yin (2014) defines as providing a concluding set of causal sequences. The expected results serve as main arguments from which the explanation building designs propositions for further research. Its main focus is to discover if the expected results emerge and if so, why or how these results arise. Besides the expected results, this process includes other interesting findings by the collected data. These other findings focus around the business ecosystem and 6C framework as

described in chapter 2.

Yin (2014) describes the explanation building in more detail. It starts by making a basic and tentative statement. The expected results that this study clarifies in chapter 1, function as these basic and tentative statements. Next, Yin (2014) advises to compare the collected data with these statements. It may be required to adjust and revise the statements when comparing these with the collected data. In order to test these revised statements, these revisions needs other details from the case. There may be details from other embedded units of analysis, observations or interviews that are able to test these revisions.

Also, the coding scheme, as presented in this chapter and in figure 3.7, provides a sound practical vehicle to connect similar findings in the case as well as in the desk research. This entails that this study uses its coding scheme not only for the interviews, but for its complete research. Whenever there are multiple similar findings, the coding scheme connects these findings to each other. This leads to the construction of new tentative statements that are up for further causality research. Thus, the main difference between newly constructed statements and the expected results is that the expected results may be proven wrong and the final proposition varies from the earlier constructed expected result.

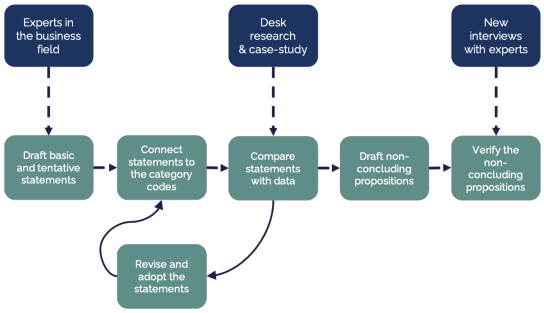


Figure 3.6: A visualization of the explanation building process

3.3.1. Coding Scheme

Coding schemes function as analysis tool for the qualitative interview data. This study uses a similar 'hybrid coding approach' as used and proposed by Reijtenbagh (2020) and Rong et al. (2015). This approach is a mix of deductive and inductive coding. Where the deductive part fits the 6C framework to direct and scope the coding process accordingly. Yet, the inductive or open coding may deliver some non-prior-anticipated results. Also, since the 6C framework originally studied business ecosystems in the IoT sector, it may require adaptions and improvements in the coding.

The process of finding the correct coding scheme consists of three steps. First, this study scrutinizes the code schemes from earlier research (Rong et al., 2015) (Reijtenbagh, 2020) and the categories that fit this study's topic are copied. Second, the literature study and expected results identifies new categories. Third, the open or inductive coding process as described by Saldaña (2021) may discover new categories.

This study accepts the definition of Saldaña (2021) of a code. "A code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldaña, 2021, p.13). This definition directly affects the process of open or inductive coding as this entails that the regularity and similarity of codes form the categories. The coding process consisted of transcribing the complete interview and attach a code to every identified block of text. These blocks of text exists are sized between complete sentences and paragraphs. Chapter 6 elaborates on the process coding.

Figure 3.7 represents the included code categories. Each dimension splits into multiple 2nd order categories, which split into multiple 1st order categories. The 1st order categories are the categories that the coding process associates with specific sentences from the interviews. When this study completes the coding process for all interviews, the 2nd order categories and dimensions help to cluster the results. In that way, it is possible to clearly describe the business ecosystem by the 6C framework.

This coding scheme includes many recycled 1st and 2nd order categories, and obviously the six dimensions, from earlier academic work (Rong et al., 2015) (Reijtenbagh, 2020). This study justifies this action as the included studies are in a similar research field and obtained valuable results. In addition, both included studies are exploratory in character and researched the business ecosystem of certain focal actors by analyzing interviews.

In addition to the recycled categories, this literature study identified a handful of categories. These categories are the nested systems by Möller et al. (2020), the ecosystem's perspective in a multilevel

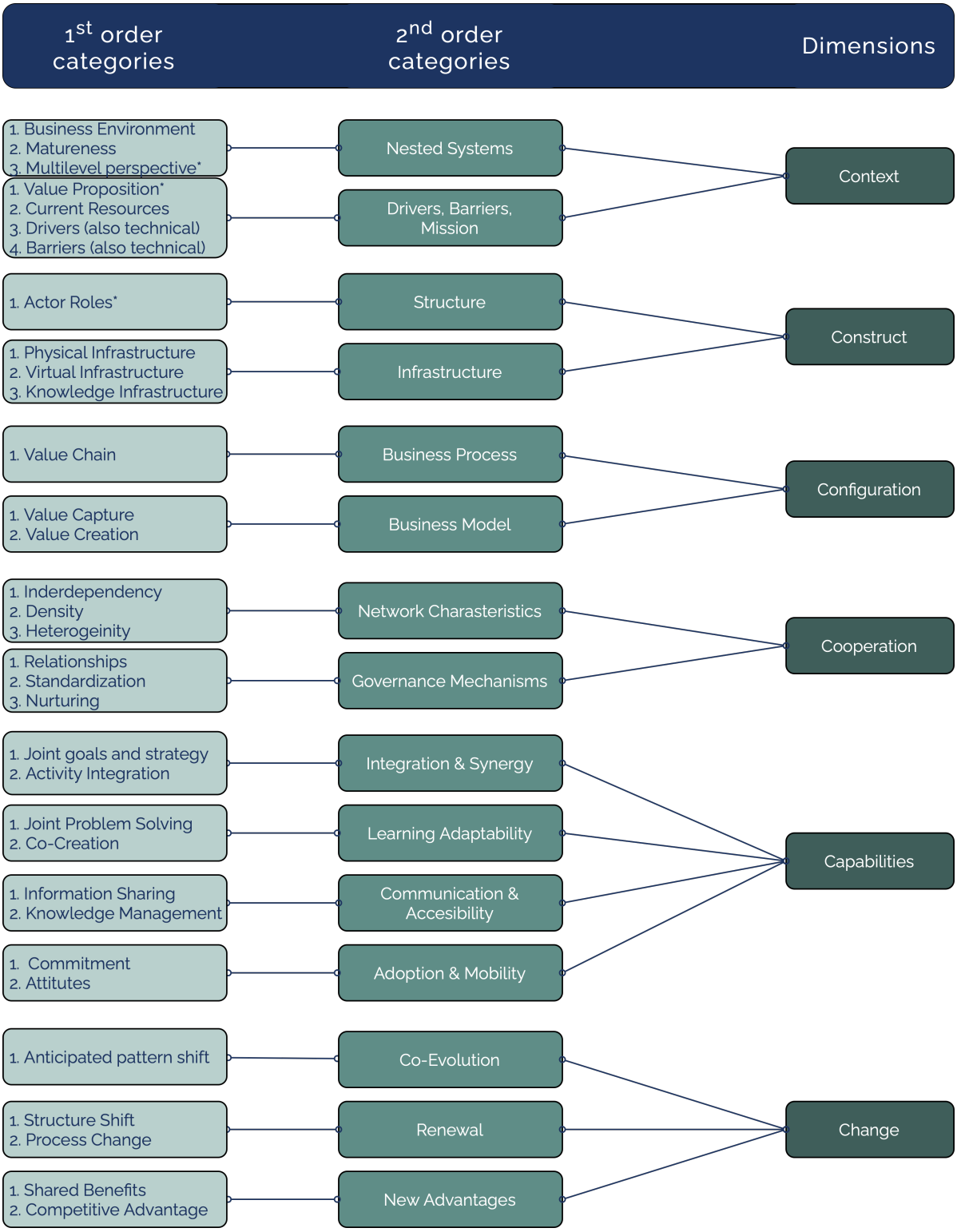


Figure 3.7: The final coding scheme for the interview data analysis

perspective by Walrave et al. (2018), the data infrastructure by S. Gupta et al. (2019), the actor roles by Adner and Kapoor (2010), Tate et al. (2019) and Iansiti and Levien (2004), and the business ecosystem's value proposition by Moore (1993).

There are three coding categories formed by open coding procedures. These are the knowledge infrastructure, the actor recruitment, and the knowledge management. Table 3.1 contains the details on the descriptions of all codes and dimensions, also the newly open coded ones. It were these three codes that repeatedly occurred during the interviews according to the researcher. For that reason these are included in the research coding scheme.

3.3.2. Concluding Research Remarks and Verification Process

A single case-study can only form non-conclusive propositions. These non-conclusive propositions are more elaborate and definite as the expected results, but these propositions can by no means be accepted as the complete reality. This study aims to verify these newly drafted proposition by conducting an interview with other focal firms and experts from the business field. In this way, the propositions are less biased towards a single case, however, all propositions formed by this study need further research in causality to be accepted as phenomena.

So, a desk research covers the most general information from online sources on the complete vertical farming business field. The desk research makes an actor analysis and a technological map to create an overview. The actor analysis provides most actors and their business models, while the technological map helps to identify any technical boundaries. In-depth interviews provide the data for the separate business ecosystem case-study. This study opts for a single-embedded case study, where its embedded units of analysis are the main actors in the business ecosystem case-study.

There is overlap between the desk research and case-study, yet this overlap limits itself to the technological boundaries and viable business models. The main purpose of the desk research is to clarify the chosen case-study and identify any technological boundaries to include in the interview proposal. A case-study on Glowfarms' business ecosystem must provide clear data to construct proposals from the expected results and other interesting similarities. These proposal may be input for further research. A final check by interviews with key informants and other focal firms together with a good interview process validated by academic supervisors provides an adequate amount of reliability and neutrality.

3.4. Reliability, Replicability, and Validity

In addition to the research methods, there are other parameters of the research approach that must be included. These are the reliability, replicability and validity of the research approach and the planning. To describe the reliability, replicability and validity is a necessity as it helps to assess the research approach. Sekaran and Bougie (2016) describes the hallmarks of scientific research, which these three concepts include.

In order to describe and assess the quality of a research design, there are 3 main aspects to include. These are the reliability, replicability, and validity (Bryman, 2016). Where reliability defines the repeatability of results from the research, replicability describes the repeatability of the method used. The last factor, validity, can be subdivided into three categories: construct, external, and internal. Yin (2014) describes the construct validity as retrieving the correct measures from the case-study. The internal validity is not of any importance for exploratory studies and the external validity is about the wider applicability of the specific research context.

Reliability

Yin (2014) indicates that case-study research gets rarely repeated, however, other researchers may get suspicious if the cases are poorly documented. Documentation must make it possible to repeat your own work and get similar results, with the context in consideration. It is therefore important to describe the context for the case, which this study does automatically via the 6C analyzing framework and triangulation on the context dimension.

Table 3.1: The coding scheme categories explained

Dimension	2nd Order Category Codes	1st Order Category Codes
Context: The environmental features of the complex business network and its maturation.	**Nested Systems:** The business field and set system that interacts with the business ecosystem and its single actors.	**Complex business environment:** The environment in which the business ecosystem operates. (The SET system and business field by Möller et al. (2020). **Matureness:** The stage of the business ecosystem. **Multilevel perspective:** How the business ecosystem fits in the current regime and its connection to other business ecosystems in the vertical farming sector.
	Drivers, Barriers & Mission: Identify main aspects on the vision and current obstacles of the business ecosystem.	**Value proposition:** The value proposition of the business ecosystem and its actors. **Current resources:** The resources available to conduct operations and create value. **Drivers:** Aspects that thrive the business ecosystem. **Barriers:** Aspects that hamper growth.
Construct: The connections within the business ecosystem and its required infrastructure to support these connections.	**Structure:** An elaboration on the 'organizational chart' of the Business Ecosystem.	**Actor roles:** All business ecosystem actors and their roles. **Actor recruitment:** How the business ecosystem recruits actors..
	Infrastructure: The necessary foundations of the business ecosystem required to maintain relations, develop en prosper.	**Physical infrastructure:** Perceptible objects in a real-world setting that support the business ecosystem. **Virtual infrastructure:** The use of IT applications and other online tools on the PC that support the business ecosystem in any way. **Knowledge infrastructure:** The amount of knowledge available to the business ecosystem.
Configuration: The forming of configuration patterns in the complex business environment and its value creation models.	**Business Processes:** An overview of the different operations within the business ecosystem.	**Value chain:** The sequence of activities or processes that create value in the business ecosystem and the understanding and planning of these activities.
	Business Models: The main financial incentives and operations of the business ecosystem.	**Value capture:** The money management and collaboration methods within the business ecosystem, an overview of the method on how the firms make money and share the financial benefits of the business ecosystem. **Value creation:** A description of the main method of value creation in the business ecosystem.
Cooperation: Collaboration within the business ecosystem and its governance methods.	**Network Charasteristics:** The distinctive and unique features of the business ecosystem (internal context).	**Interdependency:** The dependency between actors in the business ecosystem. **Density:** Spatial geographical distance and the number of actors in the business ecosystem. **Heterogeneity:** The variety among actors.
	Governance Mechanisms: The underlying process of orchestrating the business ecosystem.	**Relationships:** The quality and type of relationship in the business ecosystem. **Standardization:** Required activities that realize industry requirements. **Nurturing:** Early investments and guidance between the actors in the business ecosystem.
Capabilities: The required and used capabilities in the business ecosystem network.	**Integration & Synergy:** The level of teamwork and symbiosis in the business ecosystem.	**Joint goals and strategy:** The goal development. **Activity integration:** Processes of multiple actors that work on a similar step in the supply chain.
	Learning Adaptability: The 'extra' beneficial outcomes of the integration and synergy in the ecosystem.	**Joint problem solving:** Multiple actors that work together to find solutions to rising problems. **Co-creation:** Long-term value creation by interaction of multiple actors with open innovation.
	Communication & Accessibility: The level of communication and contact between the actors and the openness to external new actors in the ecosystem.	**Information sharing:** Transparency on data and business information among actors in and outside of the business ecosystem. **Knowledge management:** Tacit and implicit knowledge distribution among actors.
	Adoption & Mobility: The necessary change in attitude of actors and their commitment to achieving the vision of the business ecosystem.	**Commitment:** The enthusiasm among actors to engage in the business ecosystem. **Attitudes:** The change or similarity in culture or philosophy of the actors to sufficiently support each other.
Change: The process of transformation from a niche structure and configuration into a matured business ecosystem.	**Co-Evolution:** The progression of the business ecosystem that similarly affects actors.	**Anticipated pattern shift:** The naturedness of the business ecosystem directly affects the cooperation.
	Renewal The change in actors and value creation of the business ecosystem.	**Structure shift:** The change in the organizational chart of the business ecosystem that comes with progress. **Process change:** The change in value creation methods and / or activities by the actors.
	New Advantages: Additional benefits that provide reasons to join or keep involved in the business ecosystem.	**Shared benefits:** The mutual benefits among actors in the business ecosystem. **Competitive advantage:** The expected advantages of operating in a business ecosystem, also for niche players in the business ecosystem.

Replicability

Carefully describing and outlining the proceed steps in the research improves the replicability of it. Although only a small part of the research conducted is repeated, researchers do value the replicability of it (Bryman, 2016) (Yin, 2014). It is often originality that gets most attention in the scientific world and so is this work. Nevertheless, the research methodology described in this chapter and the further thesis make sure that this study is highly replicable.

Construct Validity

The construct validity is one of the main arguments against the use of case-study research. The experts or other interviewees may have a bias in what the individual positions as enabling and constraining factor. Thus, it is beneficial for this research to collect multiple sources of evidence (Yin, 2014). Yin (2014) remarks that the construct validity improves by a review by key informants or multiple sources of evidence. This study solely obtains data from experts with experience in the business.

External Validity

The use of a theoretical framework helps to keep the external validity sufficient. Chapter 2 scrutinizes the theoretical frameworks used and makes the study appeal for a wider context. Also, Yin (2014) identifies that a good process logic behind the formation of the research questions is vital for external validity. The research question in this work originate from the research gaps identified after a literature review on the problem statement. By taking these arguments into consideration, the external validity is estimated as being of a sufficient level.

Internal Validity

The internal validity is not of any importance for exploratory research as this aspects concerns the interference of a third factor in explanatory research (Yin, 2014). The internal validity is important when further research ought to find causal relationships with the proposed proposition by this study.

II

Second Part

4

Desk research

This chapter elaborates on the desk research. It starts by describing a technological map that provides insight for the reader and researcher on the underlying technologies for the vertical farming method. This makes sure that the technology is better understand and helps to structure that interviews. Next to this map, an actor search describes the business field or sector of vertical farming in the Netherlands. Next to the data on the context of a single business ecosystem, the actor search assisted in the selection process of the case. Figure 4.1 positions this chapter in the research process.

Figure 4.1: The research process steps for this dissertation

4.1. Technological Map

A technological map assists in identifying the underlying technological context and infrastructural construct. The observations of the researcher in combination with the literature on vertical farming shaped the technological map. Figure 4.2 depicts the results in a clear format, which this study borrowed from Benke and Tomkins (2017) and Group L (2019). There are three main layers to describe: the infrastructure, the technological components and functions, and the surrounding technologies. In addition, this technological map accentuates the controlled environment agriculture (CEA) technology. The upcoming section elaborates on its importance to the vertical farming business ecosystems.

A vertical farm utilizes a vast amount of energy, it therefore requires a robust energy infrastructure (Benke & Tomkins, 2017). In the Netherlands food transport is carried out by trucks, so also the road infrastructure is needed for a vertical farm to operate (Ergin Birinci and Alexandra Virlan, 2017). Another important infrastructure component is a robust internet connection. As vertical farming entails high-tech farming, there is need for smart systems which are interconnected via internet (Chin & Audah, 2017). Water supply is a final infrastructure component that vertical farming requires (Stein, 2021). Plants are fed by nutrients in the water and in order to be independent of a water supply, vertical farms require an unrealistic size of rainwater collection.

Group L (2019) identifies two more infrastructure components. These are, however, related to waste water and waste products. In a circular vision, there is no waste and all products are either re-used in the facility or sold. Vertical farming has the possibility to respond in an optimal way to this circular vision due to its constant output and clean facility. Therefore, the waste infrastructure is not a required component in the definition set by this study.

The technical components and functions are all in place to facilitate a controlled environment agriculture (CEA) technology. This is the official name for an indoor cultivation facility that adjusts its climate in order to optimize growth, which takes place in various levels of intensity in technology (R Shamshiri et al., 2018). Thus vertical farming refers to the use of CEA in a large-scale urban setting with the best

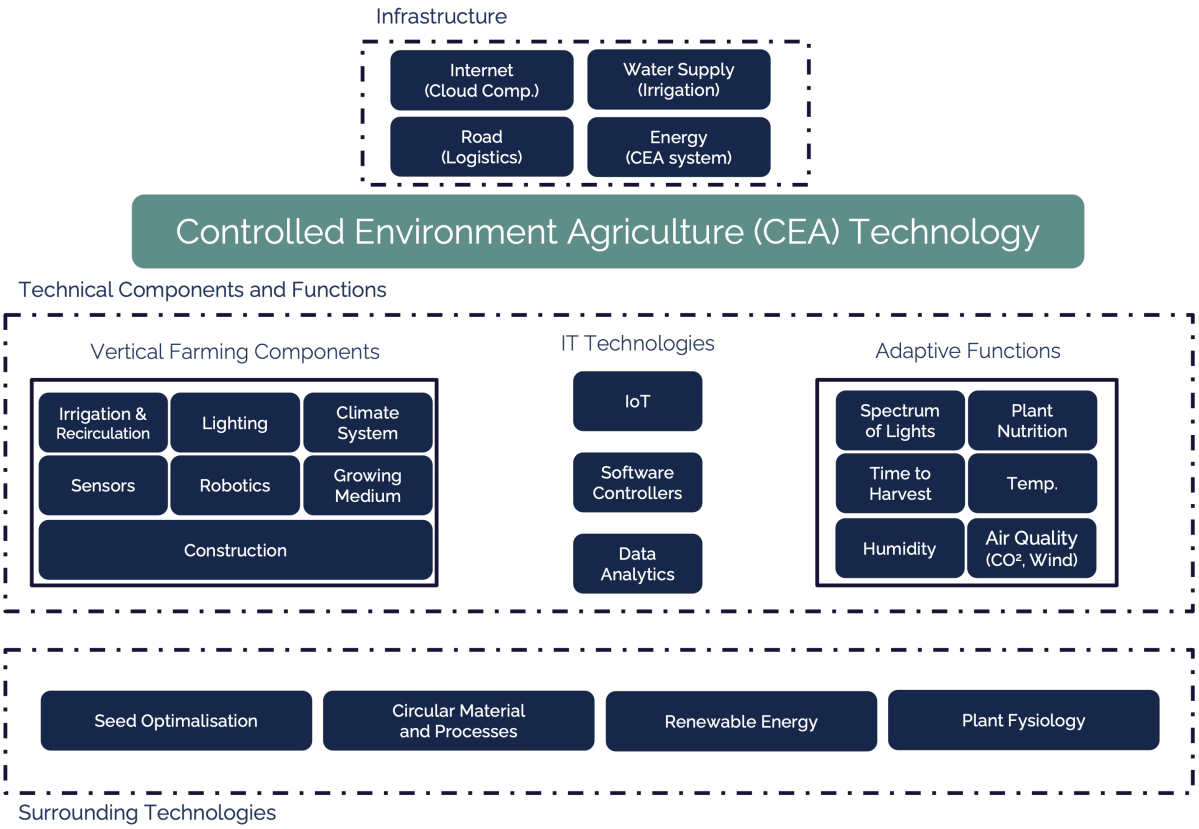


Figure 4.2: Technological map of the Vertical Farming Technology (own illustration).

available high-tech technology. The CEA technology consists mostly of components that are capable of controlling the light, temperature, humidity and carbon dioxide.

This study differentiates between the components, functions and the IT technologies that adjust the functions. It is different from the technological map from other authors as this study beliefs that the technical components and functions must both be included to describe the vertical farming's perspective on CEA. The figure summarized and divided the components that must be in place for vertical farming to be operational in the following categories:

- Irrigation & Recirculation: Plants require water and nutrients to grow.
- Lighting: Plants use photosynthesis to grow which is powered by (sun) light energy.
- Climate Control: Plants use carbon dioxide and have an optimum climate in which they grow.
- Sensors: To set the CEA system in an optimal condition, sensors read the current condition.
- Robotics: For more automation, consistency and less manual labor, robotics must be included.
- Growing Medium: A growing medium facilitates a condition in which seeds can grow.
- Construction: A construction makes sure that all components are kept in position during operation.

All these components can be adjusted in their output and functions. For example, the amount of irrigation and nutrient supply can be adjusted to suit optimal plant growth. In a similar manner, the climate is adjustable as well as the spectrum of the lights and time to harvest (R Shamshiri et al., 2018). In a fully automated or hybrid control mechanism, IT helps to adjust and optimize these adaptive functions. IoT sensors deliver data input which algorithms analyze and adjust the input for the software control mechanisms (Chin & Audah, 2017).

A last aspect of the technological map by Group L (2019) are the surrounding technologies. Next to the technical components, there are indirect technologies that influence vertical farming. Plants grow from seeds, so the seed optimization for indoor cultivation has impact on the performance of vertical farms. Next to this seed optimization, new materials and processes impact the vertical farm by new packaging methods, improved growing media, easier cleaning options, etc.

Also, as vertical farming proliferates as sustainable and circular, renewable energy is a surrounding technology that enables this classification. A last components in the figure is plant physiology, which is not a technology. However, this study claims the importance of the understanding how plants can optimally grow is critical for vertical farming. Therefore, the technological map includes this 'technology'.

With this technological map depicted in figure 4.2, the reader can easily observe the various components that vertical farming needs. These different technical specialties may require different external actors in the business ecosystem. Therefore, the technical map portrays the potential size of the business ecosystem from a technical perspective.

4.2. Actor Analysis

In order to find a suitable and optimal case for the case-study analysis, this study performs an actor analysis. In addition, the actor analysis provides insight in the context and configuration dimension of the 6C framework. The following sections elaborate on the actors and organizations that are present in the Dutch vertical farming industry. Most actors present are portray as an entity , so not on the level of a single firm. However, each focal actor is distinguished in the actor search for the case-study selection.

Farhangi et al. (2020) present in their work the actors present in the transition toward high-tech urban farming. Vertical farming, in its definition by this study, fits in this broader definition. Farhangi et al. (2020) accentuate the important role for the private sector in the development of innovations. The authors see that the high-tech urban farming sector disentangled itself from the existing regime of incumbent firms. This causes a decentralized network forming between consumers, incumbent firms, policy regime and the niche developers or focal firms.

These four main entities are connected through local and national government according to Farhangi et al. (2020). The governments also support the bottom up approach as the top sector policy in the Netherlands stimulates innovation in agriculture and horticulture by tax reduction schemes. Such policies help to connect incumbent firms with new startups. In addition, funding is available for new innovative research on which many startups function. However, a further detailed understanding of the growth of the commercialization is missing in the analysis of Farhangi et al. (2020).

Another expected entity which is excluded from the study of Farhangi et al. (2020) is the food system. However, since the vertical farming sector is still a niche state without much commercial success, it is difficult to make a thorough actor analysis. The network forming is still in an ongoing process, which hampers a holistic actor analysis. Still, the study from Farhangi et al. (2020) presents a high level entity overview and the hybrid network forming between new actors and incumbent firms.

The case-study selection needs a complete insight in the actors present as focal firms. This study facilitates this view by a thorough actor search as described in Chapter 3. Two main focal actors are distinguishable as one focuses on the vertical farming machinery and the other kind of focal actor focuses on the complete operational performance. This differentiation helps to understand the vertical farming sector and its organizations. In the Dutch vertical farming business field, as defined by Möller et al. (2020), there are a couple of overarching organizations that connect these various focal actors. These overarching organizations are either a knowledge ecosystem or innovation ecosystem.

4.2.1. Overarching Knowledge and Innovation Organizations

Although the overarching organizations are not a suitable option as a case-study in this research, including these organizations enhances the understanding of the connection between the focal firms and provides a wider understanding of the business field context. By a straightforward google search on vertical farming organizations and with the help of the interviewed experts, the next paragraphs present five organizations connected to the vertical farming industry in an alphabetical order.

Fieldlab

Fieldlab is a research focused overarching organization that facilitates teamwork between knowledge institutes in the province South-Holland and firms that focus on vertical farming. The main goal is to create and maintain an innovation ecosystem that encloses state-of-the-art knowledge on vertical farming and promotes business research for focal firms. With this goal, Fieldlab contributes to the

Dutch vertical farming sector and helps it to sustain at the global frontier of knowledge. The teamwork and cooperation between institutions and firms is new in this sector and differs fundamentally from historical innovation process in the sector.

Fieldlab's main activities are subdivided into four packages, numbered 1 to 4 and following each other chronologically. The first step is to generate more familiarization about vertical farming among consumers. Together with Wageningen Economic Research and fueled by consumer and market research, Fieldlab aims to spread the advantages of vertical farming. The second step is to enlarge the current knowledge on vertical farming and a third step is to analyze and adapt the current education programs for operators and other necessary jobs. The fourth step is to alter the created innovation ecosystem to a robust and continuous platform where cooperation is more easy to access.

Greenport West-Holland is a triple helix organization, which entails it aids entrepreneurs, governmental institutions and knowledge institutions to cooperate efficiently. Teamwork is their main strategy to achieve collaborative progress among the vertical farming actors. There are different projects compared to Fieldlab and the focus is more diverged from solely horticulture actors. The belief of Greenport is that together more can be achieved by sharing tacit and implicit knowledge which in return originates fruitful cooperations. Greenport is actively recruiting actors in and out the region of South-Holland.

Figure 4.3: The logo from Greenport West-Holland (Greenport West-Holland, 2021)

On the LinkedIn online platform **The Indoor Farming Nederland Community** is found. This community shares knowledge, contacts, and opportunities surrounding vertical farming for Dutch firms. Their main strategy and motto is share knowledge to grow faster, and focuses on the entrepreneurs. The community describes indoor farming as a new sector in its birth stage that develops continuously for both business opportunities as well as research and education opportunities. The community welcomes most with a relevant background and invites to ask questions and start discussions.

Everybody that is a member (about 125 single LinkedIn members) may post any interesting information and/or ask any interesting question. However, far from all members are active. The members do share interesting new articles and business opportunities, but new cooperative projects seem to start on different platforms. Perhaps members contact each other outside of the LinkedIn page. Every 4 months the community organizes an event to meet each other and discuss new findings. So, this knowledge ecosystem may support the development of new projects and products but seems to be too idle for this goal.

Figure 4.4: The logo from The Indoor Farming Nederland Community (The Indoor Farming Nederland Community, LinkedIn, 2021)

The AgTech Institute is a research group connected to the TU Delft and focuses on agricultural innovation. "TU Delft AgTech Institute promotes research- and innovation in AgriFood technology. It fosters public-private partnerships by connecting the industry to TU Delft's world-class engineering- and systems knowledge and expertise. The unique R&D portfolio that is emerging from these partnerships addresses societal and industrial demands to the sector, and will be instrumental in driving the transition to a sustainable future in AgriFood with novel high-tech solutions. We invite you to innovate our future together" (Agtech Institute, 2021, p.1).

The institute takes on a technical perspective as the new agriculture 4.0 requires a technology-driven strategy. The sector is therefore in need of collaboration between the agrifood industry, horticulture and knowledge institutes. A focus is on a more efficient production method and improved sustainability for the food system. Other sectors in place, among others Robotics, Sensor physics, Computer Vision, Communication Technology, Geothermal engineering, Material Science, Artificial Intelligence, Genetics, and Crop Modelling, have ready-to-use products and services that may have advantages when applied on the agricultural sector.

Figure 4.5: The logo from Wageningen University (Wageningen University, 2021)

Wageningen University is a worldwide renowned and respected university in the agricultural sciences. Located in the east of the Netherlands, it is some distance away from the main Horticulture area in the Netherlands. Nevertheless, there is much innovative research ongoing encompassing the vertical farming sector. The main goal of the university is to explore the potential of nature to improve the quality of life. Together with over 10000 students from all over the world, the university performs research in the field of healthy food and environment not only for their own knowledge hub, but also for governmental institutions and businesses.

There is also the Wageningen University & Research (WUR), which is a collaboration between Wageningen University and Stichting Wageningen Research. The WUR stimulates and supervises entrepreneurs on different areas. Together with firms, investors, juridical and financial advisers they strive to radically change society for the better. A sustainable world where human and animal live in harmony and food is secured must be a main goal for the participating firms.

4.2.2. Focal firms in the Dutch vertical farming industry

Finding the optimal common case is one of the goals of the actor analysis. As the case-study is set to be a Dutch vertical farming business ecosystem, this study needs to have a sufficient overview of the actors that are present in the Dutch vertical farming sector. This section provides a list of the focal firms that operate within this sector. The vertical farm definition by Kozai et al. (2019) helps to make a category for this list as there are many high-tech firms that offer a partly vertical farming solution.

However, if a firm does not live up to the definition, this study may still include the firm in the list. Such a deviation is justifiable as the other main goal of the actor analysis is to provide insight in the broader context of vertical farming. So, if an actor is on the boundary of being accepted by the definition, but the actor has an interesting twist to the other present actors on the list, this study includes information about this focal actor. This does not imply that such an actor can be selected as a case, it only serves as broader information. The last section in this chapter elaborates on the selected case.

This part of the actor analysis has a slightly different process as the overarching organizations lookup. First, the overarching organizations provide partners on special projects, who may be active in the vertical farming sector. Second, a well-known social business platform (LinkedIn) contains a recommendation engine that provide other interesting actors. Third, a google search with the terms ”Vertical Farming Nederland”, ”Indoor Farming Nederland”, or a similar phrase, provides interesting links and web-pages. This resulted in a number of actors that are potentially active in the vertical farming sector.

A next screening must shorten this list. This study search for online information and assumed in its best ability whether a firm fits the definition. Also, as to speed up the process, this search provided new more detailed information for this chapter. Again LinkedIn provided the founding year of the firm, the number of employees, and a link to its official website. Over there, this research extracted the stage of the company and its main business. This information is sufficient to make an assumption whether to include a firm and when to exclude.

These five main information classes present the information on which the common case gets selected. However, the actor search revealed two distinguishable business models. In the Netherlands there are two types of firms active as vertical farming companies. There are the firms that sell the complete ready-to-use vertical farms (or modular components) and the firms that sell fresh produce by utilizing vertical farming. As the latter type encompasses a larger spectrum of the vertical farming business and may therefore present completer and more interesting results, this study selected this type of focal actor.

Firms that utilize the vertical farming technology

Figure 4.6: The logo from Future Crops (Future Crops, 2021)

Future Crops has 17 employees and started in 2016 as the first soil-based vertical farm in Europe. Its main office is in Poeldijk, which is in the Westland. The Westland is an area in the Netherlands that hosts the largest connected greenhouse area in the World. Future Crops strives for automation to help sell their herbs to the wholesale. The University of Wageningen is one of their main collaboration partners.

"Our philosophy is producing fresh, delicious produce, as nature intended. The state-of-the-art technology in our vertical farm enables us to do just that. The soil is where it all begins. It empowers us to produce consistent, sustainable, superior quality produce, completely clean and pesticide free. Thanks to our research and quality-driven mind-set and our entrepreneurial agronomists' passion that inspires us to innovate, we continue to seek perfection and never, ever settle for less" (Future Crops, p.1, 2021).

Future Crops mentions soil based vertical farming as the best option. It is interesting as most literature and actor propose soilless methods. Also as appendix B shows, the degradation of soil and the decline of vitamins and minerals in the cultivated product. Also, the literature explains the circularity of phosphorus and nitrogen to be a problem. Yet, Future Crops provides a different theory, as they propose vertical farming 2.0 with soil.

Figure 4.7: The logo from Glowfarms (Glowfarms, 2021)

Glowfarms is the focal actor and main actor in this research. The firm started previous year, with a team of five. The team has set-up a fully functioning business ecosystem and created a running prototype that supplies supermarkets at the moment. Its core business is the sale of fresh herbs and various kinds of lettuce that has an improved shell-life compared with traditional products in the supermarket. This is possible by the vertical farming technique in combination with an improved and more circular packaging method. This chapter provides other more detailed information in earlier sections.

Figure 4.8: The logo from GROWx (GROWx, 2021)

GROWx created their own brand called "Chefs farm". With this brand they sell microgreens to Dutch fine dining restaurants. The company started in 2016 in Amsterdam. Because of several big challenges, the company had to close in 2018. However, they successfully restarted their company in 2019 with a new business model.

At this moment GROWx is the first commercial Vertical Farm in the Netherlands and employees 15 people. They even "developed the first vertical farm in the world that is fully automated, AI-driven, almost completely circular and with a cost price that can compete with regular farms". (GROWx, 2021)

They start to build their automated vertical farming system on a large-scale plant. With their positive operational result, they want to explore the needs of consumers, keep innovating with new knowledge and continue their experiments. Apart from selling to restaurants, their vision is to go to developing countries and to locate their growing pod in a distribution center of a supermarket.

Figure 4.9: The logo from Infinite Acres (Infinite Acres, 2021)

Infinite Acres "is a sustainable food system company with proven engineering, scalable operations, and food industry expertise" (Infinite Acres, 2021). They design, build and operate vertical farms that provide high yield, nutritious, and delicious produce year-round. They aim to sell fresh produce for the wholesale market. They are especially pioneering in tomatoes.

At this moment they have a hundred commercially grown crops and eight indoor farms in operation. They just started to build their first large scale facility. Their head office is located in Delft, but they are also operational in USA. The company started in 2019 and has 19 employees at this moment.

They are gaining (online) interest, which can be seen in the several publications in news channels, as the New York Times and BCC, and 1600+ followers on LinkedIn. They even started the Infinite Academy, which is a platform where you can follow several programs and courses to become a growing operator.

Koppert Cress started in 1987 in Monster, in the west of the Netherlands. However, the major growth and success of the company were initiated when Rob Baan took over the company in July 2002. Rob was able to link his business knowledge from the seed industry with the culinary treasures he encountered on his travels. Koppert Cress started producing microgreens for professional chefs from that moment.

Figure 4.10: The logo from Koppert Cress (Koppert Cress, 2021)

The company now holds between 200-500 employees. And is besides the Netherlands, also operational in different countries in Europa and the USA. This study assumes Koppert Cress uses vertical farming on a smaller scale and tries to find a best fit for the company. They did not start of as a vertical farm, but as a greenhouse in the Westside of the Netherlands. At this moment they are doing both.

Koppert Cress specialized in cresses; seedlings of unique plants, which each have their own specific effect on the senses. Flavour, fragrance, feel and presentation, are their key ingredients. Koppert Cress is constantly looking for natural, innovative ingredients that chefs can use to intensify the taste, aroma and presentation of their dishes. As they are growing, they are also widening the assortment. Every year at least one new item is added to the collection of Microvegetables. A collection, which is presented as 'Architecture Aromatique'.

OneFarm started in 2017 and designs full scale farms in several countries in Europe. In this moment they got three farms under construction in Great Britain. Their headquarters is based in Amsterdam and had seven employees at this moment. Their aim to deliver circular food products in fresh herbs, various kinds of lettuce by 2050.

Figure 4.11: The logo from OneFarm (OneFarm, 2021)

Their main goal is to provide affordable fresh healthy food and plant pharmaceuticals to local communities on a global scale to mitigate the upcoming food crisis. Therefore they roll out large scale vertical farms together with local partners to ensure food security for all parts of the population.

"OneFarm combines knowledge about food and plant pharma, technology, infrastructure and data to enable local communities with their own secure food supply. The data produced will reinforce the open-source feedback learning system. This will reinforce selection of seeds, new product development and long term control of the growing environment leading to first-mover advantages" (OneFarm, 2021, p.1).

Phoodkitchen is the world's first aquaponics restaurant. They took over "Duurzamekost" in 2018. They aim for healthy meals and lifestyle, by selling meals with their own produced fish and herbs in their restaurant. The farm is in Eindhoven and can be watched from outside.

Phoodkitchen tries to set up a fully circular aquaponics system. This system uses fish to feed the plants. In an optimal aquaponics system, the fish feed from the plants and the plants feed from the fish. It seems not to be possible at the moment as phoodkitchen is feeding the fish, however, if they manage to feed the fish this would be a perfect example of a short food chain.

Figure 4.12: The logo from Phoodkitchen (Phoodkitchen, 2021)

Besides the restaurant it is possible to take a tour in the farm and buy the products. At this moment, Phoodkitchen has three main employees, a restaurant and farm staff. They also employ people with a distance to the working environment (social workers).

Figure 4.13: The logo from PlantLab (PlantLab, 2021)

Plantlab is the largest vertical farming firm in the Netherlands. They started in 2010 and received a funding of 20 million. They have a cultivation of flowers and fresh herbs in stacked boxes, so kind of modular in size. At this moment Plantlab has 60 employees and their main office is located in Den Bosch.

Their ambition is to develop and operate vertical farms called 'Plant Production Units' (PPUs) worldwide. These PPUs deliver fresh produce that is safe, affordable, tastier and more nutritious. In addition, less inputs are required compared to the current cultivation methods.

"Growing plants is our nature. We are firm believers in being the change for the global food chain. At PlantLab we produce fresh food locally, without pesticides, using 95% less water and less land. Developing and operating custom-built indoor farms at a commercial scale is our core business. We are already making an impact in the Netherlands, USA, and the Bahamas. We bring together highly motivated engineers, researchers, entrepreneurs, and global leaders to strengthen this movement (**Plantlab**, p.1)."

Figure 4.14: The logo from SMARTKAS (SMARTKAS, 2021)

SMARTKAS "brings a globally deployable, infinitely scalable and energy & waste neutral smart agricultural solution to feed the world. Our solution is a AI-run, drone & robotics assisted, fully automated and unmanned structure, that can be deployed and installed anywhere in the world."

SMARTKAS started in 2019 and has 17 employees at this moment. Their headoffice is located in Amsterdam. They operate in the Netherlands, Great Britain, Germany, although not all large scale. It is also not clear from their website if this contains vertical farms or regular greenhouses. However, they are building a new huge self-sustaining vertical farm factory in the middle east.

Firms that sell the vertical farming technology

Figure 4.15: The logo from Artechno (**artechnologo**)

Artechno is an engineering company specialized in the development and realization of modern hydroponic cultivation systems. Their main business model focuses on the irrigation techniques and watering systems of agriculture and horticulture, and also on harvesting and cleaning equipment. Vertical farming is relatively new in their assortment.

Artechno has 21 employees, started in 1988 and has its roots in Dutch horticulture. The main office is located in De Lier. They aim to empower their customers in cultivation from start to finish, so they are able to integrate the entire cultivation process within their investment and be profitable. Part of their business is to sell solutions in vertical farming. They sell farms which are scalable for large and mega solutions, however their farms are not fully automated. Germination is separate from their solution.

Artechno offers tailor-made horticulture techniques with extensive experience in project management of small to very extensive projects. Because of their diverse team with different backgrounds they are able to customize designs with functions that meet the client's needs. One of their strengths in this is flexibility and the ability to realize large projects within a very short time.

Figure 4.16: The logo from Codema (Codema, 2021)

Codema Systems Group offers a large scale of products and services related to agriculture and the corresponding technologies. Codema Systems Group believes in its ability to create a healthier and more sustainable world for future generations. Codema develops essential, custom-made horticulture solutions. Providing technological solutions, to improve processes in greenhouses. They design, develop and deliver tools and services for greenhouse operations.

Codema Systems group started in 1958 and has 125 employees at this moment. Their main office is located in Bergschenhoek, but they also have offices in Germany and China. They are active in water management, climate management, cultivation systems, power & lighting, construction & engineering, software & web solution, and vertical farming. Vertical farming is a relatively new aspect and service which they deliver.

Figure 4.17: The logo from Light4Food (Light4Food, 2021)

Light4Food is an innovative company that focuses on the design, production and assembly of sustainable closed cultivation systems for the horticultural sector. This is also known as City Farming and multilayer cultivation. They sell smaller mobile vertical farming cabins.

The company started in 2014 and has 22 employees with different backgrounds at this moment. " Together on a mission to provide every place in the world with sustainable, local and fresh food" (Light4Food, 2021, p.1). Their main office is located in Horst, Limburg. They have international project throughout Europe and North-Amercia.

The cultivation system includes the cultivation of crops without daylight in a closed space, where optimal growth can be achieved 24 hours a day, 365 days a year. The cultivation takes place under the ideal climate conditions and light recipes of the LED lighting and with a minimal input of resources. They operate as a technical supplier and as a knowledge and development partner.

Figure 4.18: The logo from Own Greens (Own Greens, 2021)

Own Greens started in 2018. Their main office is located in Burgh-Haamstede, Zeeland, and they have 8 employees at this moment. Own greens grows ferns with the help of vertical farming equipment. In addition to this business model, they sell vertical farming solutions to B2B.From very small scale to larger scale and from manually to fully automated.

Their aim is to change global food production drastically. "The rapid loss of biodiversity, the polluted soil and water reservoirs and all the other effects made us realize the gigantic impact that agriculture has on our planet. These thoughts turned into action when Own Greens was founded" (Own Greens, 2021, p.1).

This start-up was founded upon a solid technological basis, since the technology that Vitro Plus uses to grow ferns could be applied to growing edible crops too.

The 30 years of fern-growing experience from Vitro Plus and 6 years of research into the Own Greens product has led to a several vertical farming solutions. The Own Greens grow-set enables consumers, restaurants and shops to grow their own greens when and wherever they want.

This has many advantages: "People get transparency, since they will know exactly what happens to their food and how it grows. They also get an extremely sustainable system that cuts out transportation in the entire supply chain, that does not need pesticides and only just enough water and minerals. The combination of a special film, specially developed minerals, LED grow-light panels and individual water containers for the plants makes this solution so easy and clean" (Own Greens, 2021, p.1).

Figure 4.19: The logo from Ridder (Ridder, 2021)

Ridder started in 1953 in Harderwijk. The company has over 180 employees and focuses on multiple aspects of indoor agriculture. Ridder has grown into a large international company with customers in more than 100 countries, who receive support from international offices and a stable and global partner network. They focus on drive systems, climate screens, water management, management systems, process automation, fresh produce, floriculture, vertical farming, intensive livestock, crop storage, medicinal crops, climate computers, labour registration and inside greenhouse technology.

In recent years, Ridder and a number of other pioneers have gained knowledge and experience in vertical farming. This has led to the development of a number of practical technical solutions that will enable the vertical farming sector to optimize and achieve sustainable growth.

"Farmers and growers worldwide need to be able to adopt their own individual approach to efficient and sustainable controlled environment agriculture. This is the promise that Ridder, as an international family-owned company, fulfils by translating more than 65 years of Dutch agri-food expertise into adaptive technology and know-how that is tailored precisely to local needs and conditions" (Ridder, 2021, p.1).

4.2.3. The Common Case Selection

Table 4.1 presents the actors that sell the fresh VF produce and it assists in the decision-making process. This section elaborates on this selection process and justifies the decisions made by this study. A final result of the selection process is to continue this research with Glowfarms. Although Glowfarms started in 2019 and has only 5 employees, the firm fits this study best as a common case as this section explains. The table includes a number of crossed-out actors, which this study could not select as case study objects.

A first reason for the crossed-out actors is a different perspective on vertical farming. Both Future Crops and Phoodkitchen do not cover the definition of vertical farming this research uses. However, this study accentuated these cases since it are interesting and unusual cases that still connect to vertical farming sector in the Netherlands. Future Crops uses a soil based vertical farming method and Phoodkitchen uses an aquaponics technique without a multi-layered system. The actor analysis in this chapter elaborates in more detail on the extraordinary details of these actors.

A second reason is based in the inability and secrecy of actors. There are actors who are more secret about their used technology or version of vertical farming. Whenever this research failed to feel confident enough the firm fits the definition of this research, this firm drops from the potential case-studies. These firms are SMARTKAS, Plantlab and One Farm. This confidence level assessment is based on the extracted information in this chapter and the webpages and posts of the specific actor. As these actors may become more transparant in the near future, this study leaves them on the final list, but excludes them from a potential choice as case-study.

These factors leave only a handful of candidates from which this study selects Glowfarms as the common case for the case-study analysis. Glowfarms proves to be an sufficient common case by the stage in which the firm operates and its small size in employees. In addition, Glowfarms is open for taking part in this research and is transparent in describing its exact vision and use of technology. Furthermore, Glowfarms' business ecosystem is vibrant and transforming at a fast pace since the firm is finding and fighting for its existence. These aspects make it extra interesting for research as little is known about these opacity and flux stages.

The study does understand that a business ecosystem of a startup / scale-up is different in comparison to an established firm like Koppert Cress. Also, the number of actors is low, which makes it difficult to select a common case as all cases are quite different in their character. Chapter 7 elaborates on this aspect of selecting a right case, where it provides a more complete discussion on the topic. The next chapter describes more details on the selected case for the case-study: Glowfarms.

Table 4.1: An overview of the actors in the Dutch vertical farming sector who sell leafy greens or raw products

Focal Firm	Start Date	Nr. of Employees	Business Model	Customer	Stage of the firm
~~Future Crops~~ *Soil-based VF is not the definition as in this study*	2016	17	Sell microgreens	Wholesale supermarkerts	Not clear, assumed that a farm is operated
Glowfarms	2019	5	Sell microgreens en leavy greens	Wholesale supermarkets	Designing a first large scale farm
GROWx 2018	2016	15	Sell microgreens	Catering industry	Building a first large scale farm
Infinite Acres	2019	19	Sell microgreens and tomatoes	Wholesale supermarkets	Building a first large scale farm
Koppert Cress	2002	200-500	Sell microgreens	Catering industry	Experimenting with VF
One Farm	2017	7	Sell microgreens	Wholesale supermarkerts	Designing a first large scale farm
~~Phoodkitchen~~ *Not a multilayer VF, so not the definition as in this study*	2018	6	Restaurant	Sell meals	Just opened the restaurant with aquaponic-products
Plantlab	2010	60	Sell horticulture products and microgreens	Wholesale	Got a 20+million investment for a second large scale plant in the USA
Smartkas	2019	19	Sell various argicultural products	Wholesale supermarkets	Building a first large-scale farm in the UAE

5

Case-Study

After an actor search, this research choose a best fitting case on the arguments as presented in chapter 3. This chapter elaborates on the chosen case and presents detailed information on the focal firm and its business ecosystem. Also, it specifies the embedded units of analysis from which interviews and observations secure the qualitative data for this research. In figure 5.1, which depicts the main research process in a chronological order, the box with the darkest color represents the current position of this chapter in the complete research. This entails that obtaining the data is an important aspect of this chapter. Section 5.2.2 present the global data collected.

Figure 5.1: The research process steps for this dissertation

5.1. Elaboration on the case: Glowfarms

As Glowfarms is the selected case for this case-study analysis, it is important to include some detailed background information. This information contains, among others, the business model, the culture, and the background of the case. Furthermore, it provides an overview of the business ecosystem of Glowfarms. This information makes sure the reader better understands certain aspects and decisions in the research. Furthermore, it is necessary information for the researcher, who otherwise is unable to identify the boundaries of the case and the case specific phenomena. Both these aspects directly improve the research with a better validity.

5.1.1. Glowfarms in General

Glowfarms is a startup that tries to disrupt the AGF market by producing fresh herbs, lettuce and spinach with a fully automated vertical farming philosophy. This philosophy grounds itself by including modern data analytics, self learning algorithms and IoT systems in the agricultural sector. The ambition of Glowfarm is to generate an algorithm that understands crop cultivation better as the current human knowledge in this field. In particular, Glowfarms intends to improve the production of fresh herbs and various types of lettuce in terms of durability, shelf life and taste. In addition, Glowfarms ensures that all kinds of herbs grow all year-round, regardless of the climate outside. With the help of this automated vertical farming philosophy, Glowfarms aims to obtain a firm position in the consumer market with their Glow brand.

There are two main founders who have known each other for years, but have a completely different professional background. In November 2019, Mr. Pieterse attended a conference in Wageningen which hosted a presentation of a new Vertical Farming system by the Frauenhofer Gesellschaft (”FhG”). This institution invented, tested and patented a new vertical farming system that utilizes a similar

principle as a conveyor belt. Figure 5.2 provides a schematic visualization of this patented system, where the crops grow on one side of the conveyer belt in a substrate and are fed on the other side by an aeroponics technique. Glowfarms concluded a licensing agreement with FhG in May 2020, and in this way, Glowfarms is entitled to continue development and usage of the patent.

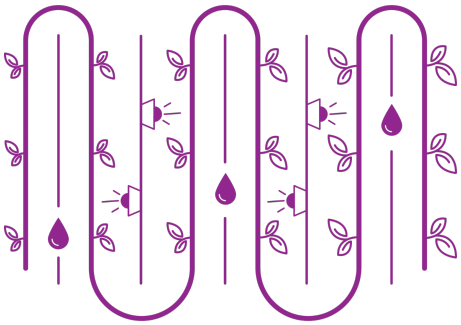


Figure 5.2: The autonomous vertical farming system by (Glowfarms, 2021)

After attracting its first shareholders in August 2020, Glowfarms officially started as a company in September 2020. Glowfarms achieved a number of significant milestones since its inception. The team finished the design phase of the cultivation system by November 2020 and construction of the plant started afterwards. In mid-March 2021, the design team finished the construction phase and tested the various parts. After the successful completion of the testing phase, the company officially started growing different types of fresh herbs by April 2021.

Currently, Glowfarms employs five people and as it is a young and relatively small company, the organizational structure is flat and there is hardly any hierarchy. Apart from the fact that both directors-major shareholders ("DGA") are ultimately head of responsibility, almost all decisions are made by the entire team. The team schedules a meeting every Monday to discuss the developments for the coming weeks. In more detail the agenda contains, among others, short-term plans and recently taken decisions or decision deadlines that are coming up. Each meeting ends with a brief glimpse into the future, prompted by one of the two DGA's.

This is not only beneficial for the environment, but it also helps to meet a relatively new desire of most consumers who prefer locally produced food. In addition, Glowfarms envisions a self-learning algorithm that is able to increase yield, enhance flavor and shelf-life and produce cheaper as current professional agricultural methods.

Kozai et al. (2019) provides a list of elements and a definition that this study applies to a vertical farm. Glowfarms does not utilize all these elements at the moment, however, the design of a next large-scale factory does include all the elements. It is for that reason that the selection criteria for the case selection encompassed Glowfarms as chapter 3 presents. From the list of elements, the vertical farming system designed by Glowfarms uses air conditioners, layered system, collection and re-use of water and circulation of the nutrient supply.

This entails that the large-scale factory design from Glowfarms includes in addition, an airtight box, thermal insulation, air shower, CO_2, and an epoxy floor. As the literature study in chapter 2 identifies, it is important that this study verifies the intentions of Glowfarms with respect to vertical farming. The difference between a greenhouse and a vertical farm is less straightforward as one might expect and building a case around a non-vertical farm is destructive for this research.

Figure 5.3 shows the logo of the business to customer brand of Glowfarms. Glow sells pre-packed fresh herbs and various types of lettuce in a packaging that contains 90% less plastic as the status quo. This is in direct contact with the business model of Glowfarms, which is quite simple. Glowfarms sells products to supermarkets or other distributors that sells the product in wholesale format. Currently Glowfarms sells in 5 different supermarkets, with the prospect of a contract with a large export firm.

Figure 5.3: The brand from Glowfarms (Glowfarms, 2021)

5.1.2. The business ecosystem of Glowfarms

As aforementioned by previous academic work, Moore (1993) describes a business ecosystem as a constellation of actors that are loosely connected to each other. Within this group there is a single focal firm who orchestrates the various niche players to a clear vision. This study selects the business ecosystem of

Glowfarms as example case for the other vertical farming business ecosystems. The name of the business ecosystem carries a similar name as the focal firm of that ecosystem. This makes it clear for the reader as each business ecosystem has a different focal firm, but may have similar niche players.

Figure 5.4 presents a overviewable visualization of the business ecosystem of Glowfarms. The academic work of Adner and Kapoor (2010), Iansiti and Levien (2004) and Tate et al. (2019) support the configuration method that this study uses. There are six main categories of actors in the case, where each category performs a distinguishable role in the business ecosystem. The categories are the focal firm, the customer, the suppliers & partnerships, the complementors, the scavengers and the decomposers. The arrows in the figure shows the relationship among the actors in the business ecosystem of Glowfarms.

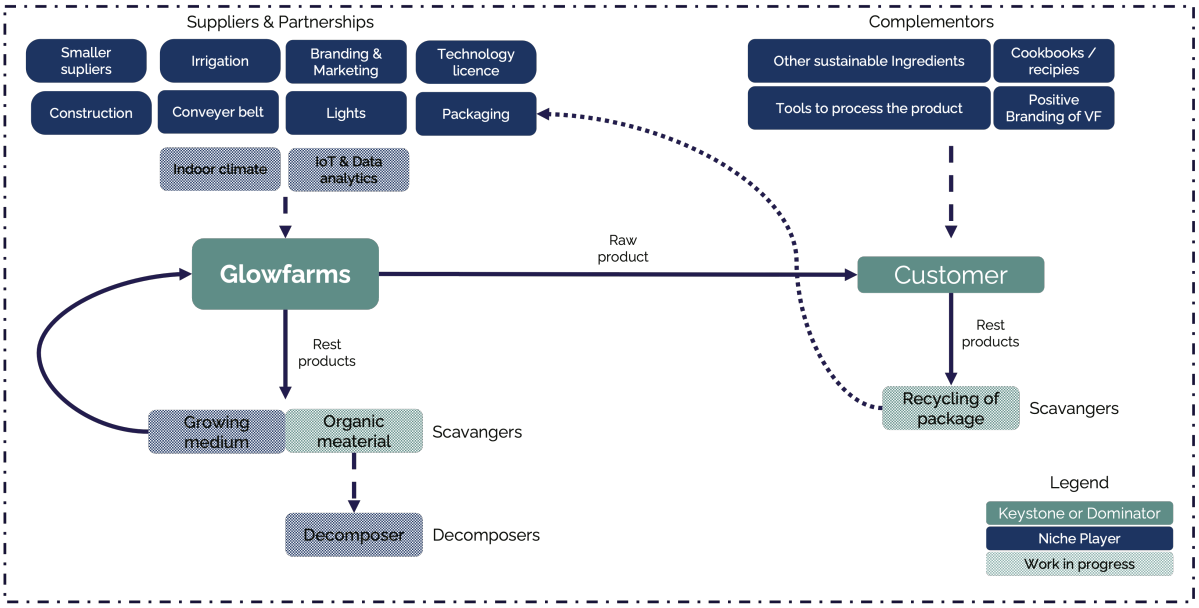


Figure 5.4: The visualization of the main business ecosystem of Glowfarms

Glowfarms acts as the focal firm and orchestrator, which is rather clear from a first glance at the figure as Glowfarms is in direct contact with most actors. The largest part of actors fall below the category of suppliers & partnerships, who are the main assistants in creating the raw product. Without the suppliers & partnerships, Glowfarms is unable to produce pre-packed fresh herbs. Glowfarms accentuated the difference between a supplier and a partnership. A supplier is the best choice in quality, price and assurance, where a partnership focuses more on the long-term relationship and connects on more aspects to Glowfarms as a supplier.

Obviously, there exists a soft transition between supplier and partnership in the context of Glowfarms' business ecosystem. Nevertheless, this research finds it important to establish a sort of split as the cooperation between the various roles differ largely according to Glowfarms. Thus figure 5.4 depicts the actors fitting the supplier role best on the most top left and the actors fitting the partnership roles more to the right. The bottom two boxes in the figure represent an actor in the indoor climate and IoT & data analytics sector, but Glowfarms has not established a clear relationship with the actors at the moment.

The figure positions the scavangers and decomposers below Glowfarms. There are two main rest products that are not re-transferred back into the cultivation system. These are organic material, like roots and the organic remains, and the growing medium. The producer of the growing medium is in a special position as it envisions a circular system with their product. The final destination of organic material has several options, which section 5.2 describes in more detail. Figure 5.4 assumes that the organic material gets collected and pre-processed by a scavanger, whereas a decomposer uses this pre-processed product again.

The business ecosystem of Glowfarms also entails complementors and customers. The customer

is in direct contact as Glowfarms sells their product to the customer. The complementors, however, are not in a similar direct contact with Glowfarms. The complementors add value to the product of Glowfarms by delivering a certain product or service to the customer that connects to the product of Glowfarms. This study identifies 4 different classes of complementors for the product as the figure depicts.

Moore (1993) describes in his elaboration on business ecosystems four stages that any ecosystem experiences. The business ecosystem of Glowfarms positions itself between the birth and expansion stage. The focal firm, Glowfarms is actively enlarging its ecosystem, which figure 5.4 depicts, and tries to cover maximum market share. On the other side, Glowfarms sets its value proposition not that long ago and is still protecting its knowledge and idea at the present moment. These aspects set for a transition from the birth stage into the expansion stage.

Thus, the business ecosystem of Glowfarms sets for a good case as it fulfills the criteria. Glowfarms can be seen as an example case as chapter 4 describes. Furthermore, the business ecosystem fits the theoretical framework as chapter 2 proposes. Also, the vision of Glowfarms is in line with the vertical farming definition of Kozai et al. (2019). As the selected research approach includes a single embedded case study, this study selects the four actors to scrutinize in the next subsection.

5.2. The embedded units of analysis and data collection

The embedded units of analysis give more depth to a case-study (Yin, 2014). However, adding the embeddedness to a case-study requires a logical split between units of analysis. With a business ecosystem the split by actors of the business ecosystem is logical and straightforward. Chapter 3 elaborates on the reasons for selecting an embedded case-study. This subsection contains the information on the selection criteria and detailed information on the selected embedded units of analysis.

There are a total of 5 actors that this study selects to include as embedded units of analysis. Obviously, this study includes Glowfarms, as the orchestrator and main party in the business ecosystem. For the other options, observing a variety in actor roles is the main selection criteria. Unfortunately, the complementors are not yet in contact with the business ecosystem of Glowfarms. Also, a first real customer is only taking part recently, which causes a lack of real involvement in the business ecosystem. Therefore, this study excludes these categories from the embedded units of analysis.

The growing medium actor is the only actor that is present at the moment in the business ecosystem on the scavenger & decomposer level. For that reason this research includes this actor as embedded unit of analysis. As this study with its theoretical framework focuses more on the co-creation and evolution, it makes sense to include actors from the partnership class. The contacted actors are the irrigation actor, lights actor, branding & marketing actor, and the packaging actor. Unfortunately, the packaging actor could not participate in the research due to business circumstances.

In order to give more detailed information on the selected embedded units of analysis, the paragraphs below contain specifics on the actor. This study conducts a similar internet search as presented in chapter 4 for the actor analysis. So, a look in the kvk registry finds the 'age' of the actor, a search on LinkedIn find the number of employees and general information, whereas its web-page identifies its core business. The selected actor are listed below starting with Glowfarms and the others follow in alphabetical order.

Figure 5.5: The brand from Glowfarms (Glowfarms, 2021)

Glowfarms is the focal actor and main actor in this research. The firm started previous year, with a team of five. The team has set-up a fully functioning business ecosystem and created a running prototype that supplies supermarkets at the moment. Its core business is the sale of fresh herbs and various kinds of lettuce that has an improved shell-life compared with traditional products in the supermarket. This is possible by the vertical farming technique in combination with an improved and more circular packaging method. This chapter provides other more detailed information in earlier sections.

A freelancer in the branding & marketing strategic advice is the branding & marketing partner of Glowfarms. This actor has over 20 years of experience in providing help for firms, and in particular start-ups, with the positioning of products. The experience consists of earlier projects in the food and vertical farming sector.

The irrigation system is from a worldwide market leader in high-tech irrigation solutions for sustainable agriculture and horticulture. Excluding the pumping mechanisms, this actor is able to provide ready-to-use irrigation systems in for indoor and outdoor farms. The interviewee is an experienced sales manager in the Netherlands who is in contact with Glowfarms.

The LED-light used at Glowfarms are delivered by an established lighting firm. The firm is not specifically designing and manufacturing horticulture lights, but a wide-range of lighting products. It is an international firm that is starting to focus more on horticulture and vertical farming in general. The interviewee is the manager in business development and innovation for vertical farming and is in direct contact with Glowfarms.

The growing medium actor delivers rockwool products for horticultural cultivation. The firm is specialized in precision applications of rockwool for indoor cultivation and innovates continuously with their products. Vertical farming is one of their tier visions for future cultivation. The interviewee is the account manager for vertical farming from this worldwide operational firm.

5.2.1. Interview Case-Study Data

The interviews data covered the complete coding scheme as the questions for the interview are based on the six dimensions as appendix D describes. One of the main goals for the data collection from the interview is to gain insight from different perspectives in the business ecosystem. These different perspectives are the embedded units of analysis. Whenever multiple actors in the business ecosystem provide a similar line of reasoning or answers, the result is more rigor.

Table 5.1 provides an overview of the interviews for this study including the interviewees, length and date. All interviewees are in direct contact with Glowfarms and often are taking initiative on vertical farming in their firm. The various lengths of the interview is a constraint in time of the agenda's of the interviewees in combination with the hybrid interview. Whenever an interview included interesting new aspects the interviewer probed for more information. This resulted in sometimes lengthier, but also more interesting interviews. The names are anonymized, but are known by the researcher.

Table 5.1: An overview of the conducted interviews

Anonymized Name	The corresponding actor and role	The position of the interviewee	Date of the interview	Length of the interview [min]
The founders	Glowfarms The focal firm	The founders and simultaneously managing directors	02 - July - 2021	56 minutes
Interviewee B&M	Branding & marketing strategy A freelancer	A freelancer with over 20 years of experience in supervising startups	05 - July - 2021	42 minutes
Interviewee IRR	Horticulture irrigation systems A worldwide market leader	Sales manager	08 - July - 2021	29 minutes
Interviewee LED	Horticulture lighting systems A large European firm	A manager in business development and innovation	08 - July - 2021	48 minutes
Interviewee GM	Growing mediums for indoor cultivation - A global leader in its type	An accountmanager	13 - July - 2021	55 minutes

All interviews had a 'relaxed vibe', there was no show of constraining elements for the interviewees. Even when probed, the interviewees replied with in-depth answers. The tone was serious, yet some occasional funny stories and jokes helped to make the setting comfortable for both the interviewer and interviewee. In addition, at the end of the interview the interviewees replied positive to the interview.

This combination of components makes it doubtless that the collected data is sufficient quality to be analyzed in this dissertation. The type of data is hard to explain as it includes both broad information as well as in-depth information. Nevertheless, the cooperation, capabilities and context dimension delivered most in-depth information from the interviews.

For an analysis according to the 6C framework, the complete interview related to the business ecosystem is transcribed. Chapter 6 elaborates on the collected data. Next to the number of times a topic is discussed, the depth, understanding and enthusiasm about a topic all interfere with the final conclusions.

Unfortunately all interviews are in Dutch, however, the language does not influence the coding process at all. The researcher is bilingual and therefore is able to translate the interviews into the coding process at the spot. So, there are no translations of the interviews kept, only the original language to hinder any translation adaptions on the original emotion and feeling of the interview. All the interviews combined resulted in a 68 page document.

The researcher split all answers in a way that every merged section of sentences fit a specific 1st order category code from the coding table as presented in chapter 3. In the excerpt in the figure there are six different merged sections. In the comments section on the right, the researcher adds to which category code the section fits best. After all the transcripts are coded, the researcher merges all the category codes belonging the a specific dimension and summarizes the most interesting data per 2nd category code in chapter 6.

5.2.2. Observational Case-Study Data

During the period of the research from February until August, the researcher worked part-time as software specialist at Glowfarms. From this task, the researcher was able to observe the progress and struggles that Glowfarms encountered as the researcher worked on site once a week. Most data collection from the observations is on the focal firm, yet a particular set of data is on the embedded units of analysis. The amount of data on these embedded units of analysis is, however, minimal in comparison with the interviews.

The researcher, which performed the role of observant, attended the weekly meetings, important presentations, and coffee-break and lunch talks with the employees. On average Glowfarms organized a meeting or presentation once a week, which the researcher either joined online or physical. The other observations from the normal workday process were observed about once per week. In total the observant worked for 24 days on site and attended 15 weekly meetings and important presentations.

There are two main data collection methods for the researcher regarding observations. The weekly meetings provided an excellent summarizing agenda which discussed all important tasks and progress of the past week. These agenda points were both on technical progress as well as on business progress of the firm. In addition, the researcher observed the process of solving problems on site, the changes in the business ecosystem, and the contact with niche players in the business ecosystem. Also, the availability of resources and working atmosphere for the software tasks are important observation to include. In this way, the researcher observed various components of the inner workings of the business ecosystem of Glowfarms.

The final collection of documents consisted of 40 pages, which were mostly the minutes of the weekly meetings. To these minutes the researcher added the observational data of that week from the coffee and lunch breaks. However, there are also presentations and posters included in the observational data. Only the personal notes of the researcher are included in the 40 pages, the figures and agenda slides are excluded.

The observations mostly provide information on the cooperation, capabilities and change dimension of the 6C framework. In addition, the observations allowed the researcher to describe the case in more detail, which the section earlier in this chapter presents.

Since the data from the observations is written in text format, the researcher used a similar coding process as with the interviews. The different lines of code are connected to a 1st order category code from the coding table as presented in chapter 3. In the excerpt of the figure, a total of six different fragments are connected to different category codes. Together with the interview data, the researcher merges the codes of a similar dimension. The next chapter contains the most interesting results from the case-study.

6

Results

This section describes the general results form the desk research and the case-study. It provides no conclusions, but simply states the collected data per dimension of the 6C framework. This means that all collected data for each dimension are merged, so the desk research, observations and interview data are described per dimension. The last section elaborates on the verifying interview with a comparable start-up in the vertical farming sector to Glowfarms. Figure 6.1 shows where in the research process this information belongs.

Figure 6.1: The research process steps for this dissertation

6.1. Key Findings on the 6C framework

The key findings of the 6C framework are listed below per second order category, because it provides some more depth to the data collection. The descriptions of the second order categories and dimensions are given in Chapter 3, where a coding table is provided near the end of the chapter.

All data got coded and the codes that belong to a similar second order category were merged into one coherent story. The researcher tried to write the results as interesting a possible without adjusting the qualitative data. The next chapter establishes an impact factor per second order category to give priority and collect the most important factor from these results.

6.1.1. Context

Nested systems

Glowfarms builds its business ecosystem around the underlying technological principles and branding actors. Two years ago, the firm started to estimate what vertical farming could bring extra to the Dutch market. The basis of this new method is still an indoor cultivation method that is similar to other vertical farming firms as chapter 4 identifies. It is the branding and specifics of the technology that differentiates Glowfarms from other focal firms.

Interviewee BM tells the worldwide movement towards better sustainability and circularity. Interviewee BM adds that from a financial point of view, investors have shifted to invest more on scale-ups instead of start-ups. The business model must be operational before investment. Such an shift makes it more difficult for start-ups to collect financial resources, unless there are investors with a certain vision on the world.

Interviewee LED includes that more people in the Netherlands understand that indoor cultivated product have more nutrients and their flavor is better. In addition, 'Made in Holland' is an export brand

as Interviewee IRR notes. Dutch greenhouses are the top in their class and get exported all around the world.

The founders started Glowfarms since they firmly believe that the current agricultural methods in place can be improved. In particular on the circular and sustainable aspects, but also the use of artificial intelligence (AI) lacks quality at the moment in the sector. However, the founders are aware that it takes another 5 to 10 years before this new method of vertical farming can compete with the larger agricultural actors in place.

The large incumbent actors make progress in the improvements towards sustainability, yet the smaller actors that are new in the field often have more radical new potential. Glowfarms is one of those as interviewee BM mentions.

Interviewee GM provides growing mediums for the regime, greenhouses. The interviewee also mentions that vertical farming founders and early employees are different from the older established greenhouse working crew. The plant physiologic knowledge is far less and it is often about collecting investments and making money, where the plant gets lost out of sight.

In addition, there is no communication between vertical farms focal firms. Everything is secret and nobody wants to share knowledge and information according to Interviewee GM. This vagueness also hinders the widespread technology of the knowledge infrastructure available in the Netherlands. Also, the greenhouses, the largest competitors in the regime, have already lots of technology in place.

These start-ups do interfere with incumbent and knowledgeable firms as the networking takes place from bottom up. This makes more resources available to them. Also, the overarching organizations provide help in obtaining more resources. Both financial resources from often governmental funding and network resources are provided by these overarching organizations. Yet, it is also clear that there exists rivalry and secrecy between the vertical farming focal firms.

Some firms are vague about their understanding of vertical farming. It may be green washing or a marketing trick where the firms are not really performing automated vertical farming, but this vagueness may also emphasize the secrecy about their process. From the focal firms that are clear about their understanding, this study notices many variation on the practical use of the vertical farming technique. Most actors do utilize vertical farming in their own way as there is no dominating single design.

Another observation on the context is on the matureness of the vertical farms in the Netherlands. The desk research detects that most focal firms are in a early stage of moving towards a first real large-scale farm. This accentuates, one more time, the early niche state of the vertical farming sector in the Netherlands. It is far from an established sector in which start-ups disentangled from the existing regime connect the innovation to a working business model.

Interviewee BM defines the stage as 'puberty'. Birth has already taken place, however, the sector is still protected by funding and needs to fight its existence in the regime. The current developments undergo a fast pace, but the vertical farming sector is far from an 'adult' phase. Interviewee GM adds that the greenhouse sector has ages of advantage in plant physiology compared to the vertical farms that just started.

Drivers, Barriers & Mission

Glowfarms its main mission is to avoid spilling and enhance circular and sustainable aspects in the current food system. This broad value proposition is based on many underlying advantages of vertical farming.

Glowfarms makes a difference with their distinguishable brand in the supermarkets on herbs. All interviewees share this vision of disrupting the food system in a positive manner. Moreover, Interviewee LED focuses on a vision of food sovereignty, which is providing food in a sustainable and secure way where every actor earns a decent share in the food system.

In order to move towards this vision, Glowfarms collected limited resources, which causes the main focus to be on the working principles and industrial prototype. Interviewee LED adds that investments in the indoor farming sector are growing each year. This is because of wealthy countries want to be independent of external factors and produce year-round. In particular, to secure food in extreme weather conditions.

Another driver on the investments is that food is a primary need for people and its an understandable concept. Also, Interviewee LED includes that in case of trade sanctions in the world, the food sector is often left untouched. Glowfarms mentions that the market is 5 billion at the moment and expected to grow towards 30 billion in 7 years.

The amount of knowledge resources is an important aspect of the success of the start-up. Interviewee IRR tells that it is only because Glowfarms is a system integrator that the actor may cooperate with them. Normally the firm only sells through retailers with less detailed knowledge on the design. This provides extra resources for Glowfarms to excel.

There are also other factors in place that thrives the vertical farming sector. Glowfarms mentions that Vertical farming has a lot of potential in comparison to the more traditional methods. There is need in technology that VF offers to make cultivation more sustainable and stop spoilage of rest-streams. There are no real technical obstacles as Glowfarms mentions.

Interviewee BM mentions that with the design that Glowfarms uses, the plant and their progress is easier to measure and obtain data points. It is the 4.0 version of vertical farming. Also consumers are more sustainable minded and well-being market is exploded. Also local produce and ease are wishes that we see more often as being chosen by the consumer. There is already a lot of knowledge from the greenhouse sector.

Interviewee IRR adds that it helps the overall brand and perceived image of your firm if you are able to mention the collaboration with interesting innovative and sustainable start-ups. Its new and innovative processes attract many people that find such interesting like Interviewee GM. On the growing medium anything can grow.

Next to the drivers, there are barriers to consider. A first identified barrier by Glowfarms and Interviewee LED is that the consumer is unaware of the potential advantages that vertical farming offers. Interviewee LED adds that consumer behavior and the spendable income hampers the firm to grow larger fast. It takes time for people to get familiar and understand the better performance of vertical farming products.

Interviewee BM accentuates that panic about new thinking hampers vertical farming introduction within the food system. The vertical farms need to make their way in this existing system, yet retailers are unaware of what it is and perhaps there are some pricing obstacle for wholesale and retailers.

Glowfarms identifies a lack of volume in internal business ecosystem projects is hampering circularity. Also, the technology for circularity is expensive, which may obstruct a successful business model in vertical farming. Interviewee LED adds that the starting investments are large compared to current business models.

The birth stage hampers a complete 100% complete design. There is much more to learn and to improve, so there are small technical obstacles during the process up until now. Also the energy demand is high as well as manual labor. With an automated farm, this latter one gets canceled, yet the energy must be taken into account.

From an irrigation perspective, space is required in the vertical farm, which makes a farm less efficient. Interviewee IRR adds that there are vertical farming projects that do not make it as the greenhouses have been able to be developed and engineered for over a long period of time and simply provide a standard in the current food system.

Although the growing medium Interviewee GM provides is most probably optimal for vertical farms, the lack of knowledge among the vertical farmers and the absence of active informing them from Interviewee GM blocks the spread of this growing medium.

6.1.2. Construct

Structure

The actor roles come in different gradations. Interviewee GM explains these actor roles present in the vertical farming sector. There is the turn key supplier, who creates value around the ability to built a vertical farm for third parties. The operator is the third party that only focuses on the successful operation of a vertical farm. This actor is not involved in any technical innovation, but simply aims to optimize the business model and performance output of a farm. For innovations the operators are able to interact with R&D facilities, who offer help for improvements to the product.

These aforementioned actors are not running everything themselves. Third party suppliers provide specialized knowledge and offer assistance in smaller detailed aspects of the complete process. A last distinguishable actor role is the firm that focuses on branding and is designing, operating and innovating vertical farms together with third party suppliers. Among other firms, Glowfarms is such an all-inclusive actor with a different value creation than the more traditional actor roles.

Within these third party suppliers or niche players of the business ecosystem, Glowfarms differentiates between partnerships and suppliers. Glowfarms selects a suppliers based on the price and quality. These actors are prone to interchangeability as other suppliers may improve their price and quality in a next quotation. Partnerships, on the other hand, focus on the long-term relationships and involve more co-creation. There are already a number of partnerships in place and some potential supplier that can change into partners with the next step towards a large-scale factory. Yet the co-creation aspects is something that forms later in the relationship according to Glowfarms.

The technical components that facilitate vertical farming exist in other more established sectors. This causes a business ecosystem to be potentially more important and workable, where each actor provides a specialty to the focal firm. The various potential actor roles on a technical perspective become clear in the technological map and there is a lot of potential cooperation possible as there are many components. Interviewee IRR acknowledges this observation and the supplier definition of Glowfarms. The firm delivers products and brings experience without selecting what Glowfarms requires. That is up to the focal firm.

It is important to notify that suppliers or partnerships are not only of technical of nature. There are also actor roles on supervision of Glowfarms. This is the field of Interviewee BM. In the case of Glowfarms there is a complete branding and marketing mechanism required for full operation. However, since the technology is a first step to prototype, in a next phase more actors must be recruited on this other field.

Most cooperation with partners is in a supplier format, where a firm offers a certain product or service that best fits the needs of Glowfarms. This is in direct relation with the actor recruitment as the suppliers are selected on price and quality. Glowfarms recruits most actors by their ability to deliver a product that the farm requires. If the product fits the financial resources as well, GLowfarms initiates a supplier relationship.

The actor recruitment takes place via the own network and knowledge pool. Interviewee IRR and Interviewee GM confirm this manner of actor recruitment. Glowfarms knew about these actors on beforehand via the network of the earlier business ecosystem. The actor recruitment is mostly performed on the difficult or essential products and services. Most of the design and management is tried before asking help from others. The available resources limit this in the early start-up phase. However, with a next step towards a larger volume in orders, this is up for change according to Glowfarms and Interviewee BM.

Infrastructure

The technological map provides input on the Infrastructure dimension. Most technologies and infrastructure components are available in the Netherlands. There is need for state of the art IT tools and other high-tech components to run the vertical farm in an optimal way This may be costly, however, the basic infrastructure that a vertical farm requires is present in the Netherlands on business locations.

From all interviews it became clear that the business ecosystem uses online tools to interact with each other. In particular due to the Covid-19 measures. The virtual infrastructure is all very basic and makes sure there is no discrimination on actors by using complex virtual systems.

There is a lot of knowledge in the Netherlands, due to a rich history in the horticulture. Wageningen University provides essential new knowledge on cultivation and the greenhouses enjoy tacit and implicit knowledge on the operational parameters of a greenhouse, which comes close to a vertical farm. This knowledge is spread across niche players in the food system as Interviewee GM analyses.

The Netherlands houses the top of firms in greenhouse irrigation, and cultivation techniques as Interviewee IRR mentions. However, also the lighting supplier in the business ecosystem offers an immense knowledge. Interviewee LED offers since four years horticulture lighting, but for over 100

years other forms of light. On a non-technical perspective, Interviewee BM has knowledge on start-ups and scale-ups. So knowledge infrastructure is existing in the Netherlands on horticulture but also business management.

This is not implying that all vertical farms have access to this knowledge. There is an absence of knowledge in growing mediums among vertical farms, which hinders the widespread use of Interviewee GM's products. In addition Glowfarms admits there is a gap in knowledge on the practical aspects of circularity in the process. Yet, there are firms that try to develop services that improves or even closes the loop of vertical farms in the Netherlands according to Glowfarms.

6.1.3. Configuration

Business Processes

Interviewee BM developed in cooperation with Glowfarms a road-map to commercial success. Glowfarms has created an industrial proof of concept with the help of the third party supplier and other knowable actors. At the moment, it focuses on efficiency improvements, fully automatic design and the new factory design. This next step requires new resources.

To suppress the costs and save resources, the industrial prototype design is mostly done in-house, with assistance of manufacturing tools such as a 3D printer, welding machine and other tools. Also, in the marketing and branding field, Interviewee BM and Glowfarms created most content. Still the focal firm requires products and services from third party suppliers as cheap as possible. This may be up for change, due to increased maturity for a next step according to Glowfarms.

Business Model

Inside the business ecosystem, Glowfarms divides the profit and risks among actors depending on the amount of involvement and type of relationship. Often the partner or suppliers needs to adjust the price for the start-up due to a lack of financial resources. Glowfarms mentions that all long-term promises with partnerships are made on trust. All interviewees indeed claim that trust is an important element in a business relationship. Interviewee LED mentions that people buy from people, so establishing trust and understanding supports the interaction with the firm.

The value capture of the niche players center around the prospects of Glowfarms and vertical farming. These firms aim to conquer larger projects in the business ecosystem when it matures. Interviewee IRR and Interviewee LED mention the ability of their firms is more than the projects with Glowfarms at the moment. This is not only in volume, but also in variation and complementary products and services. With trust, or legal contracts these firms secure value capture in the future. Interviewee GM includes that the growing medium sale among vertical farms is an interesting business case already.

The main value creation method of Glowfarms is the sale of fresh herbs with a new innovative cultivation method. By launching a new brand that promotes these fresh products and educates the consumer and retailers on the quality and improvements, this value creation differs from the value creation of most greenhouses. At the moment this is the only business model that Glowfarms aims to fulfill, but the interviewees accentuated the openness for change.

The actor search also identifies this value creation method. There are two classes of focal actors distinguishable from each other, the ones selling the fresh produce and the ones selling the technology. So, there are two value creation methods that each requires a different business ecosystem and processes to operate. Interviewee BM supervised in the value capture models for Glowfarms.

6.1.4. Cooperation

Network Charasteristics

All interviewee expressed the independence from their side towards Glowfarms. Due to the size of the firms, the projects with Glowfarms are small and focus on the future. This small volume in the projects makes the firms not dependent on the profits at the moment. Glowfarms communicates a similar independence, where the interviewees express the momentum and willingness of many actors to become involved with vertical farming.

In the business ecosystem there are national, regional and international partners. Due to the virtual infrastructure it is not difficult to communicate with actors further away. Yet the observant identified that the more regional partners have the ability to visit the site. This helps with the problem solving ability. In addition, as mentioned people buy from people and the actor recruitment process makes that most actors are regional and national.

Next to the geographical perspective there is also a lot of heterogeneity in the functions and specialties among niche players in the business ecosystem. In addition to the technical development, there is also the development of the brand, the biological field and the operational aspects. This variance is directly observed in the different Interviewees, but also the observant spotted this heterogeneity, which sometimes makes it difficult for Glowfarms to grasp the right level of detail and function optimal on all elements.

Governance Mechanisms

The intensity of the relationships differs with each actor role. Partnerships are more intense and suppliers less. The quality of relationships, however, is equal among the niche players as all Interviewees are in good contact with Glowfarms. The best description of the relationship is perhaps positive and casual, with formal comments where required. The quality of relationship is important for Glowfarms as it is a demand for giving commitment for a long-term relationship.

The nurturing between actors is an element that the results observe on the complete spectrum of the business ecosystem. From the perspective of Glowfarms there is nurturing for new actors that assist in facilitating the built of a new large vertical farm. The focal firm started early with asking for quotations and help from specialists they can only afford when a new financial round is successful. There is also nurturing on co-creation possibilities in the circular field.

Nurturing is also visible from the third party suppliers as they see vertical farming play a bigger role in the future. This is identified by all interviewees. Also, Interviewee IRR accentuates that you also have to support the smaller firms as selling products is Interview IRR's main business model. What may start as a project that only sells one article, may grow to the complete irrigation system. In addition, Interviewee GM acknowledges that the firm is pioneering in the vertical farming business since there is an interesting business model and there is believe in the vision and mission. Similar counts for Interviewee LED and Interviewee BM.

6.1.5. Capability

Integration & Synergy

Glowfarms indicates that many firms believe in their concept of a new automated and more sustainable cultivation method. The founders of Glowfarms started their adventure to contribute to the world in the first place and hope to become successful entrepreneurs in the second place. A most repeated statement in the interview with Glowfarms was the vision to radically change the food system for the better. All actors share this ultimate goal of Glowfarms.

Interviewee GM adds that this goal is the reasoning for getting in touch with the new sector. The vision of the firm of Interviewee GM beliefs in these new innovations and so there are resources put to use. This makes it possible for Interviewee GM to visit and help vertical farm start-ups.

Interviewee LED elaborated on 'Food sovereignity', which the firm of Interviewee LED aims for. This goal goes one step further as the goal of Glowfarms. It is about creating food security while simultaneously creating a sustainable profit division, to make sure all contributors or actors in the food system make a living. With this in mind, Interviewee LED is convinced that Glowfarms' vertical farming technique is a next step in the food system.

The activity integration is dependent on the type and intensity level of the cooperation, but foremost, the amount of activity integration depends on the volume of the cooperation project. Interviewee IRR and Interviewee LED mention that because of the minor size of the Glowfarms project, there is no possibility for more activity integration at the moment. When the focal firm scales up and the order size as well, this requires more man hours from the third party supplier to make it successful.

Another aspect on the activity integration comes from the observations, as the observant recognizes that visits of potential suppliers have an overall enthusiastic vibe. This leads into a spark of excitement

in the focal firm and business ecosystem as new ideas are generated during these visits and passed on in the business ecosystem.

Learning Adaptability

The on site visits also affects the learning by joint problem solving. Interviewee IRR mentions the technical supports helps with problem solving and designing. This knowledge exchange is most efficient when visiting each other on location as this exchange contains a lot of tacit and implicit knowledge. It is really helpful for the engineers to see how the design is built as that may cause trouble. The observations lead to a similar perspective as the observant witnessed differences in the phone interactions and face-to-face interactions between the engineers from different actors.

This problem solving service is also provided by Interviewee GM. Where cultivation specialists assist with the use of growing mediums for better results. Yet, Interviewee GM notes that this service is almost not used with the vertical farmers, even though this service is mostly there to speed up new innovations and help new players to overcome basic issues.

In addition and prior to the problem solving, there is the possibility of co-creation between actors in the business ecosystem. Co-creation is the development of products or service for the focal firm. Thus instead of using a product or service initially designed for other purposes, co-creation is about creating a special design that optimally fits the needs of the business ecosystem.

It is observed that the packaging and the conveyor belt are co-created for Glowfarms. So technical products or services are up for co-creation, however, most technical components are pre-designed products from the current collection of a retailer or firm. Next to the technical components, also branding and biology may involve co-creation according to Interviewee LED. Plants that are genetically modified to fit the vertical farming concept, are likely to improve the commercial success. Yet, the observant noted that this is not being investigated by Glowfarms.

Interviewee explains that a significant volume in intra-business ecosystem projects automatically lead to co-creation. At the moment there is a lack of dependence and volume which obstructs co-creation for Glowfarms. In addition, the current range of product designed by the irrigation firm sufficed the needs of Glowfarms, so the effort for co-creation is not balancing the improvements that it will bring.

Interviewee GM explains the growing medium in use by Glowfarms already existed for other purposes. Due to the business model and prospects on vertical farming, the GM firm started to develop a wider line of products, specially developed for vertical farming. This information is distributed to Glowfarms, yet this has no priority for the focal firm. Interviewee GM also mentions it received limited requests for co-creation from vertical farms. The observant witnessed the lack of biological knowledge at Glowfarms that makes it impossible for them to ask for specific growing mediums.

Glowfarms mentions that long-term relationships, in which trust is established, facilitate co-creation optimally. They add that in the birth stage of an ecosystem you do not want much co-creation. This phenomenon happens at a later stage.

Communication & Accessibility

Glowfarms is careful in sharing information with relevant parties and signs non-disclosure agreements with the actors in the business ecosystem to prevent the spread of advantageous information to competitors. Most careful is Glowfarms on the distribution of know-how of their vertical farming set-up. Yet, there is also secrecy on business aspects and value management in the business ecosystem.

This secrecy is also present via the actor search. Many firms do not elaborate on the exact cultivation technique, which makes it difficult to assess whether the firms actually perform a kind of vertical farming. There is little information found on the websites, except for the websites of Glowfarms and GrowX. Also the request for interviews is often neglected.

Although these aspects on the environment result a rather closed sector, this is opposed by Interviewee LED. He explains that the openness of a sector is dependent on the culture and country. The Dutch horticulture sector is perceived as open and there is willingness to exchange knowledge.

This knowledge exchange takes place via cooperative projects and from face-to-face. There is not any online drive for the actors of the business ecosystem. The exchange of knowledge is dependent

on the type of cooperation and on the trust between partners according to Glowfarms. It often starts with initial knowledge from a third party supplier and than Glowfarms adds their perspective until there is sufficient knowledge exchanged for the project to become successful.

In this way, the optimal spectrum of the lights is transferred to Glowfarms, whereas Glowfarms distributed the optimal configuration of the lamps in their system to the lighting firm. In a similar way, the packing firm distributed know-how of production possibilities regarding the package to Glowfarms. In return Glowfarms provided know-how on the current wish from consumers to the packing firm. So, there is knowledge distribution between actors with the start of intra-business ecosystem projects.

As aforementioned, also the problem solving transfers tacit and implicit knowledge. Most knowledge is transferred during the visit on the locations of the actors according to Interviewee IRR. This is confirmed by the observant who witnessed many successful visits after communication difficulties on the phone. For example the lengths of the LED strips was different as expected due to communication obstacles via phone and mail. The engineers described that with a site visits these problems would not have occurred.

An interested perspective is given by Interviewee GM. He mentions that the firm does not differ in knowledge management and exchange between large and small customers. Also, the service of information from cultivation specialists, which is without additional costs, is for all clients. This spreads the tacit and implicit knowledge across the sector according to Interviewee GM as it creates more knowledge for the cultivation specialists and for the firm in question.

Adoption & Mobility

The interviewer observed commitment with the interviewees due to their willingness to take part in the research to improve the business ecosystem. The interview with Interviewee IRR even took place in the evening due to the busy agendas. All interviewees mention that commitment it is an important attitude in the business ecosystem. There has to be eagerness and belief to make the value creation of the business ecosystem successful. Also, a shared vision increases commitment according to Interviewee IRR.

Next to commitment, the trust between partners is a very important attitude. People buy from people as Interviewee LED mentions, and therefore trust needs to be built. This is an important feature as all interviewees repeatedly mention trust as an important attitude. Other important attitudes are listed below, yet these are less repeatedly mentioned as trust and commitment.

- Enthusiasm (Glowfarms)
- Shared vision (Glowfarms)
- IT savvy (Interviewee LED)
- Technical knowledge (Interviewee IRR)
- Entrepreneurial (Interviewee BM)

6.1.6. Change

Co-Evolution

Co-evolution plays an important role in the business ecosystem as it is firmly present in the interviews. A lot of the current focus is on the anticipated pattern shift and future role of Glowfarms in the food system. Next to the connection with sustainable food cultivation, the expected growth in business model played a role in the recruitment of Interviewees LED and GM. The third party suppliers nurture their way in to secure future payout. So, the anticipated pattern shift is important for actor recruitment and so for the business ecosystem growth.

Glowfarms anticipates on building the larger factory with the nurturing of new potential partners that fit the upcoming needs and requirements. This is also taken into account with the actor recruitment, firms must be able to grow with Glowfarms. With the observations in mind, it is difficult to verify this statement as the choice of actor recruitment is mostly based on the quotation.

Since most partners focus on the co-evolution, there are also expectation in the process or activity change. Interviewee LED and IRR mention that a larger volume in projects results in more intense teamwork. When the volume increases, there are more resources available for the third party supplier

who are able to assign more people on the project. There will be more activity integration according to Glowfarms.

Interviewee LED hopes that more intensive teamwork results in taking on the role as ambassador of each other's firm. Where ambassador means promoting the actors from your business ecosystem to each other and to other contacts outside the already loosely coupled actors. Another direction for change in the teamwork comes from Interviewee GM. He adds that a research lab where the two parties combined take part is something that could be viable with more resources and volume in sales.

Renewal

On the renewal category not many data is collected as there is not much change in structure or processes due to the birth stage of the business ecosystem. The interviews and observations lead to expected changes in the structure and actor roles of the business ecosystem.

In addition, Glowfarms admits that when partners perform well and trust establishes between the two firms, more services or products are bought from a single partner. This will lead to a different business ecosystem, with relatively fewer suppliers.

Next to the changes in structure, there are changes expected in the value creation. The observations show a final value creation is not set, as there is discussion in which direction Glowfarms settles in the future. Just as the cultivation system keeps on evolving from a technical perspective, the business model gets similar attention.

New Advantages

There are already advantages that stand out in the business ecosystem. The observant witnessed new investors and retailers that Glowfarms recruited via one of the actors in the business ecosystem. A Larger network of actors makes it easier for actor recruitment, which Interviewee LED calls an ambassador function.

Interviewee LED mentions that creating content impacts both parties positively due to the sustainable character. This acknowledges Interviewee IRR in a similar way, as he mentions it always improves the portfolio of the firm when they cooperate with new innovative actors. Thus, everybody in the business ecosystem can this cooperation, which improves their branding and exposure when actively communicate this cooperation.

Other form of new advantages are competitive advantages, which are advantages that improve a firms inimitable knowledge. Interviewee LED claims that co-creation always lead to such competitive advantage, but this is not occured with Glowfarms and his firm up to date. The lighting firm does expect that creating competitive advantage from the relationship with Glowfarms is just a matter of time.

Glowfarms mentions that third party suppliers already have benefits from the relationship with Glowfarms. As the cultivation method of Glowfarms spread around the globe, more expertise on this system is required. When suppliers or partners cooperate with Glowfarms from the beginning, they have the largest impact and knowledge about this system. In a more wider perspective, Interviewee BM mentions that innovators will always help you further according due to their out of the box thinking. Yet, the exact details on this progress are not given for the relationship with Glowfarms.

6.2. Verifying Interviews

For verification purposes, this study conducts an extra interview on a similar like focal firm such as Glowfarms. Both similarities and differences are discovered. The interviewee is a manager of a vertical farming production plant. First a list of similarities between the business ecosystem:

- Similar value creation method
- The focus is on circularity and improved products
- Identify energy as main business model problem and the large investments.
- The stage of vertical farming is similarly described as an early stage.
- There is no circularity yet with vertical farms
- Also most is designed and produced in-house before third party suppliers
- Identifies the lack of resources with private investors.

Find a list of differences below:

- Have considerable more IT professionals in-house
- Government funding made the firm survive
- Covid-19 measures have boosted vertical farming
- Focus on developing countries and cheap good food
- Collaborate a lot with universities

Also the conclusion are tested:

- Admits there is no cooperation and secrecy, especially among incumbent firms
- Identifies the synergy
- No information on co-creation problems. Only that the firm recruited IT professional for co-creation on the software.
- Have a similar business model and value creation

Interesting point that the interviewee mentioned that there are incumbent firms that are secret about vertical farming progress while the actor search and case-study did not identify many. Perhaps this was about the Plantlab firm.

The approach was to include verification interviews with both experts and other similar focal firms. The experts did not respond, hopefully after the greenlight a last interview can be added if required.

III

Third Part

7

Discussion

As the previous chapter describes the results objectively and in a theoretical way, it is this chapter that provides empirical insights from the researcher. The chapter discusses the results, the research process and the research approach. It ends with the limitations of the study that emerge from the discussion and expertise of the researcher. Figure 7.1 depicts the position of this chapter in relation to the research process.

Figure 7.1: The research process steps for this dissertation

7.1. Discussion of the Results

This chapter starts with a section devoted to the discussion of the results. The results are scanned and a impact factor is applied for identifying the factors with most impact. These impact factors are then later used as basic input for the explanation building in the next chapter. Also, interesting or non-expected results are discussed by the researcher. What follows is a comparison with the expected results from Chapter 1.

7.1.1. Impact Factors

In order to find the most important factors for this study, an impact factor is established. This factor is based on two aspects, the time an interviewee gives answers on a category and the language and expression that is used while providing answers on the questions regarding a specific category.

Since the interview was semi-structured and the interviewer gave room for the interviewee to provide his or her most insightful information, it is justifiable to include the amount of time an expert talks about a category in the impact factor. This cannot be the only parameter on which to base the impact factor. An interviewee may provide long and vague answers when a topic passes that does interest the interviewee but is not impacting the interviewee enough to understand the details. Therefore, another parameter that helps to provide the impact factor is the expression and use of language.

Table 7.1 presents the results from constructing the impact factors. Per interviewee the amount of time is noted as well as the expression. This expression ranges from weak, medium, to high, where a single plus-sign is the lowest amount of observed expression in the language and interview.

Next to the interviews, observations and the desk research are also important to consider. Since the desk research only focuses on the context parameter and the observations also do not cover all dimensions, these are analyzed in a different manner. The researcher provides his own objective view on the three factors with most impact. These are described below.

Table 7.1: The impact factors for the second order categories form the interviews.

2nd Order Category Codes	Interviewee IRR	Interviewee LED	Interviewee GM	Interviewee BM	Glowfarms
Nested Systems: The business field and set system that interacts with the business ecosystem and its single actors.	2.14 min +++	10.0 min +	7.49 min +	4.53 min +++	1.30 min ++
Drivers, Barriers & Mission: Identify main aspects on the vision and current obstacles of the business ecosystem.	2.20 min ++	7.13 min ++	1.26 min +++	3.46 min +++	6.10 min +++
Structure: An elaboration on the 'organizational chart' of the Business Ecosystem.	3.28 min ++	1.08 min +	5.50 min ++	1.48 min +	2.26 min ++
Infrastructure: The necessary foundations of the business ecosystem required to maintain relations, develop en prosper.	2.09 min +++	2.57 min ++	5.37 min +++	1.38 min +	0.50 min +
Business Processes: An overview of the different operations within the business ecosystem.			1.01 min +++	2.10 min ++	2.04 min +
Business Models: The main financial incentives and operations of the business ecosystem.	0.20 min +	2.13 min +	1.02 min ++	1.29 min +++	4.09 min +++
Network Charasteristics: The distinctive and unique features of the business ecosystem (internal context).		0.54 min +++		0.37 min +++	1.04 min +++
Governance Mechanisms: The underlying process of orchestrating the business ecosystem.	0.32 min +++	2.48 min ++	0.36 min ++	1.13 min +++	2.22 min ++
Integration & Synergy: The level of teamwork and symbiosis in the business ecosystem.	1.30 min ++	2.57 min +++	1.36 min +++	0.47 min +++	1.53 min +++
Learning Adaptability: The 'extra' beneficial outcomes of the integration and synergy in the ecosystem.	2.51 min ++	1.54 min +++	5.12 min ++		6.38 min +
Communication & Accessibility: The level of communication and contact between the actors and the openness to external new actors in the ecosystem.	1.16 min +	1.58 min ++	0.57 min +++		1.37 min +
Adoption & Mobility: The necessary change in attitude of actors and their commitment to achieving the vision of the business ecosystem.	2.04 min +++	2.20 min +++	3.06 min +++	3.10 min +++	1.58 min +++
Co-Evolution: The progression of the business ecosystem that similarly affects actors.	1.09 min +	1.36 min ++	1.37 min ++	0.53 min ++	2.29 min +++
Renewal The change in actors and value creation of the business ecosystem.		0.30 min +		0.49 min +++	0.30 min +
New Advantages: Additional benefits that provide reasons to join or keep involved in the business ecosystem.	0.24 min +	1.22 min +	2.13 min +	0.11 min +	0.17 min +++

Desk Research

From the desk research there are three categories that are most repeatedly mentioned. First the actor search presents information on the maturity of the sector and business ecosystems. It are by far mostly new actors that take the role as focal firm. There are some older more established firms, but these are not solely focusing on a vertical farm. They merely try to adapt and use the technology for a specific process step in their current cultivation process.

Second, the Technological map identifies the various actor roles and infrastructures from a technical perspective of a vertical farming business ecosystem. The researcher describes the various technologies and infrastructures from other sectors are present in the Netherlands. This is confirmed by the case-study.

Third, the actor search also provides information on another category in the context dimension. On the Multilevel perspective it is clear that most actors are vague about their underlying vertical farming technology. The firms that are describing their technology are all using a different technology.

Observations

From the observational data it became clear that synergy exists in the business ecosystem of Glowfarms. The partners are enthusiastic about Glowfarms and start to spread the goals and mission to other interested actors. Also, the interaction between the actors and Glowfarms sparks enthusiasm at both parties. This catalyze the information exchange and joint problem solving as relationships improve. In a business where people learn from people, this is an important feature that repeatedly occurs in the observations.

The new value creation that Glowfarms aims to fulfill, gets mentioned during the working hours. Often a new logo, packaging format and website is shared by the founders. The information about the mission of Glowfarms and why they differ from other players in the food system is distributed at the same time to the employees. It is therefore considered an important factor of impact.

A last important factor to consider from the observations is the joint problem solving that enables the engineers from Glowfarms to rapidly gain new tacit and implicit knowledge from experts on a specific technical system. It happen more than often that the engineers from different sides of the business ecosystem established a quick phone-call or other form of contact. This is therefore considered an important factor of impact.

Factors with most impact

Combining the above state impact factors and factors with most impact the following categories are accentuated and are a starting point for the explanation building in the next chapter.

- Context - Nested Systems - Secrecy in MLP
- Configuration - Business Models - Value Creation
- Capabilities - Learning Adaptability - Co-creation
- Capabilities - Integration & Synergy - Joint goals

7.1.2. Comparison of the results with academic literature

A first result that is also found in the literature on business ecosystem is the secrecy there is between focal actors. Moore (1993) describes the ecosystem stages and in the birth stage it helps to protect your ideas according to Moore (1993). This makes the secrecy explainable with the first academic literature on business ecosystems.

Weidner et al. (2019) repeatedly mention that improvements can be made by cooperation of interest groups, government, academia and industry. There is, from a technical and policy perspective, a lot of work to be done. The results do not agree on the policy perspective that needs a lot of work, there is less policy required for clean production. On the technical perspective is does agree with Weidner et al. (2019), there are many minor problems that need to be solved. There are overarching organizations that link the various actors to each other. So, on a technical perspective the results agree with Weidner et al. (2019).

Similar to the literature on vertical farming, the literature on defining business ecosystems is scattered (Möller et al., 2020) (Anggraeni et al., 2007). Thus, there is a need to regroup the literature and define a workable theoretical framework. Rong et al. (2015) emphasized the interesting perspective of combining the roles as defined by Adner and Kapoor (2010) and the system lay-out as conceptualized by Moore (1993) and Iansiti and Levien (2004). The researcher from this study acknowledges the scattered literature on business ecosystem and proposes academia to regroup it and find a practical manual for using the perspective.

7.1.3. Comparison with the expected results

At the start of this dissertation, the researcher drafted five expected results. These expected results gave some indication of what to be expected as conclusion. However, now that the data is obtained, a similarity check can be performed with the expected results. This reveals the propriety of the conducted experts. This subsection compares each expected result in a similar order as in Chapter 1.

There is a different business model on the rise among vertical farms in the Netherlands. Instead of selling white-label fresh produce to retailers, Glowfarms creates value with its brand Glow. This allows them to sell at a premium price as vertical farming proliferates itself as circular and sustainable, which are aspects that consumers like to choose due to climate change. This created awareness is increasing sales in more sectors at the moment and by accentuating the positive annotations on the packaging, Glowfarms aims to convince consumers to buy their products.

Therefore, the expected result of a business model that lacks improvement is not found in the results. The verifying interview with a similar start-up vertical farm gave similar results. It is, however, a new strategy in the Netherlands and the future will tell if it is an improvement to the white-label sale strategy, but for sure it is different. In hindsight, the researcher drafted the expected result wrongly as it should have been about the differences in the business model. In a new sector it is impossible to acknowledge whether a business model improved as there is not much evidence.

It is true that vertical farming is protected by funding at the moment. The overarching organization help the focal firms to access governmental funds and investors are keen on investing in the vertical farming sector as it is a vital sector (not many trade wars) and proliferates as high-tech. These resources are still required, due to lack in volume and sub-optimal growing conditions. However, investors grant enough resources and the sub-optimal profitability is logical given the niche state of the sector. If there is no case for vertical farming, there is most probably no economic incentive to invest.

An interesting finding with respect to the value process in the business ecosystem is about sustainable business models. Despite the sustainable character and principles, there are no service models established or documented. This is somewhat strange as all interviewees communicated the sustainable vision of their firm. It leads to the thought that the actors might be more interested in green washing for profitability as they are for really making an impact to the world.

A next expected result was about the unwillingness of the business ecosystem to recruit new actors and share information. This closed character of the business ecosystem would make it difficult for co-design and open innovation, which constraints the attraction of new actors and thus the growth and success. Again it is not easy to provide a simple yes or no answer to this expected result.

From the obtained data, the researcher makes two observations. It is not true that the focal firm is unwilling to recruit new actors. It is more the limited financial resources and the limited amount of volume that prevent new actors from joining. From this perspective it is not true. However, the focal firm is strict concerning the sharing of information to third parties. In particular with other focal firm in the vertical farming sector. Therefore, the answer to this expected result is not definite. Whereas the founders do recruit actively new actors, they are hesitant in exchanging information.A third expectation concerned the underlying technologies. The study expected to find a sufficient level of development of the underlying technologies, such as the irrigation, the lights, and climate. A technology is sufficiently developed when a business model is viable. This makes sure the vertical farming sector keeps on evolving and growing.

From the results, it is not straightforward to give a decisive answer simply because the business model is not tested for a longer period in time. The desk research did provide insights in the required technical and infrastructural components and observed that most underlying technologies are in use in other sectors. This perception does conclude that most underlying technologies are being used

and developed. Another detail is given by the interviewees who all mentioned that no obstacles are foreseen with the technology.

The researcher does understand that the interviewees always are positive towards their service and products and may never accentuate any hesitation. Also, the interviewees are sales engineers or managers, so may not have all technical knowledge to answer this question. However, in combination with the researchers own observations on the technology in use at Glowfarms and the unanimous direction of answers of the interviewees, it is expected that the underlying technologies are sufficiently developed.

Another expected results was the governmental support for a circular food system, which thrives the business ecosystems of vertical farming as funding is available and legislation is up-to-date. This aspect is not convincingly present in the results. In particular, the legislation parameter lacks. There if more to mention about the governmental support via the verifying interview, as Glowfarms' financial resources mostly originate from private investors.

On-site observations provide details on the legislation that seems sparsely defined by the Government. Since vertical farms do not use pesticides and do sell fresh plants, there is no legislation that impacts the commercial success. Legislation concerning pesticide use and processed food is in place and gets more often checks by the Dutch food security institute (NVWA) as described in Chapter 2.

The verifying interview provided more insight in the governmental support. The firm was reliant on the governmental funding for innovation in the food system. Together with the Covid-19 funds, this firm survived the past year on a financial perspective. Thus, there is certainly government funding available. This is also acknowledged by Glowfarms, however, these funds are limited and not providing enough resources for rapid growth.

A last expected result concerned the synergy among actors in the business ecosystem. The global transition towards circular and sustainable systems sparks the momentum for vertical farming. The study expected that this results in enthusiasm among the loosely coupled actors that energizes more actors to join the business ecosystem. Also a better cooperation between the firms was expected to be present.

The results conclude that there is synergy among actors in the business ecosystems. All actors in the ecosystem see the importance of a sustainable and circular food system in addition to the financial benefit. This is important and enables commercial success as the financial benefit for third party suppliers is still a minority in their complete range of projects. Since the start-up does not produce in economies of scale, the actors accentuated that belief in their mission from third party suppliers is necessary.

7.2. Discussion of the Research Perspective and Framework

This section reviews the business ecosystem perspective and 6C framework. Also, the researcher describes recommendations for the further development and use of the perspective and framework. The business ecosystem perspective was selected since the start-up builds its own new network of actors and since vertical farming 'borrowed' many technologies from other sectors. A the business ecosystem perspective focuses on the complete system of loosely coupled actors where one single focal firm coordinates the cooperation. In addition, Möller et al. (2020) describe that the perspective fits the emerging sectors as it is a holistic design to fit the opacity and vagueness of the birth stage.

There are not many options in order to analyze a business ecosystem. The 6C framework by Rong et al. (2015) is the only viable analyzing method found in literature. Since Reijtenbagh (2020) used the framework as well in a study concerning circular waste streams in the building environment, this study chose to use the 6C framework and altered it slightly to fit the vertical farming sector.

Reijtenbagh (2020) also designed a coding scheme to analyze the data, which Chapter 3 describes. This coding scheme helped to alter the already designed interview questions and process. In addition, it proved to play a central and significant role in this study as it merged the various data sources. Therefore, this section assumes the coding scheme is part of the 6C framework, while it is not in the original design as by Rong et al. (2015).

7.2.1. Review of the Business Ecosystem Perspective

The business ecosystem perspective allows to study complex business environment in a new and holistic manner. Current literature is not using such a perspective to analyze the vertical farming sector or single focal ecosystems. Although it was expected to fit, this can only be discussed after the research took place. Similarly the ease of use and recommendations for further development are unknown at the start. The following paragraphs contain the researcher's vision on these parameters of the business ecosystem perspective as Moore (1993) described.

Appropriateness to Vertical Farming

The case, Glowfarms, consults and utilizes products from third party suppliers due to limited resources and the available knowledge infrastructure in the Netherlands. In addition, the start-up is building its own network of actors that enable a viable business. For these reasons, which were also expected, the perspective fits the study perfect. Glowfarms really acts as system integrator of various components and a lot of third party suppliers are present in the business ecosystem of Glowfarms.

The perspective helps to conceptualize and understand that the complete business ecosystem affects the commercial success of the focal firm. One may say that you are as strong as your weakest link. This became rather clear when the packaging actor was not able to timely present a quality product, which affected the sale of products negatively. Although most actors in the business ecosystem are suppliers that already finished their project, these actors did join for the potential of the final retail product. In a way, the complete business ecosystem got negatively affected by this packaging actor.

Established firms in the business ecosystem hope for commercial growth and are ready to anticipate on this, however, there is no dependence from their side. The orders are relatively small in comparison to other projects. This makes them truly loosely coupled actors. The researcher does conclude that the business ecosystem perspective fits the vertical farming sector.

Ease of Use

A recent and holistic review paper on the business ecosystem lack in academic literature. The current literature is scattered and not consistent with each other. There are authors who describe a business ecosystem as a platform on which various actors may add and develop their products. Others describe it with a supply chain character. Also, the scoping of the business ecosystem is not straightforward. Literature does not prescribe which level of actors have to be included and who can be excluded. A final observation in the literature is from Valkokari (2015), who describes the soft boundaries between a knowledge, innovation and business ecosystem that Appendix C explains in more detail. These aspects make it rather difficult to define the business ecosystem of a focal firm.

Möller et al. (2020) helps to present the business ecosystem in its context. It was after reading this paper that the researcher felt confident in his ability to understand the business ecosystem literature. When also including the business field (sector) and focal firm in the configuration, it becomes easier to describe the relation between the business ecosystems. Also the visualization of business ecosystem in the context of a regime and niche by Walrave et al. (2018) helped to understand the relation between the settled firms and the new actors.

In the end, it took quite some time for the researcher to become acquainted with the business ecosystem literature. Since it is an all-inclusive perspective without much academic literature devoted to its use, it is difficult matter to practically use. The largest obstacles was the relationship between actors and the scope of the business ecosystem. After establishing a sufficient level of knowledge it did fit the vertical farming sector, which made it easier to configure the business ecosystems. From there it felt natural to use the perspective.

7.2.2. Recommendations on the business ecosystem perspective

The researcher has three recommendations for further development of the business ecosystem perspective. First, and as aforementioned, the current literature on business ecosystems is scattered (Anggraeni et al., 2007) (R. Gupta et al., 2019) (Möller et al., 2020). This stand alone experience motivates to regroup and utilize this framework.

Second, with more practical guidelines on the use of the perspective, more researcher may become triggered to use it in their research. These guidelines differ per sector and maturity stage of the business

ecosystem, but may assist a new researcher or manager to understand its use-case. This guideline must also contain the various actor roles that are present in a business ecosystem, which results in a better understanding of the scope.

Third, analyzing more emerging sectors and sectors establishes better examples for scoping the business ecosystem and may induce inter-sector leanings. These three aspects are summarized in bullet points below:

- Regroup the business ecosystem literature and its context.
- Add more practical frameworks and guidelines for analysis.
- Analyze more emerging sectors with the framework.
- Identify more actor roles in the business ecosystem.

7.2.3. Review of the 6C Research Framework

In order to analyze a business ecosystem, the 6C framework was the best options available. Yet, there was not much early work performed with the framework, which resulted in some obstacles on the way. Next to the academic research, the 6C framework and the corresponding coding scheme may also be used by high-level managers or consultants that are tasked with observing and improving business ecosystem elements.

Research Competence

The 6C framework is better for comparing focal business ecosystems with each other. The suitability for a single case study is marginal due to the limited amount of academic work that is conducted on the 6C framework. A researcher without experience in the field has difficulty to assess the impact of the various dimensions. There is need to set a neutral impact level either by more academic work, which is able to indicate which dimensions have a high impact and the standard of each dimension. At the moment it is hard to assess whether the synergy in a business ecosystem is higher or lower as in other business ecosystems and what the impact of a better synergy is on the actors. The desk research gives some insight, but for most the researcher had to use its experience to draw conclusions.

This research does present a different method to asses the impact per category as there is no established literature present. It focuses on the interviewees, who are experts in their own field. By keeping track of the relative time spend on each category and scrutinizing the word use, the impact factor is established. This method is not completely fail-safe, but it does provide direction.

The researcher beliefs this method improves by the use of inductive coding with respect to the coding scheme in place. The current or an improved coding scheme does assist in designing the interview process. However, as the answers from interviewees may contain more detailed and different elements, it helps adapt the coding scheme to this level of detail. For instance the volume of projects was often mentioned as barrier to improved cooperation. It may help the research to use this as a separate coding category to keep track of what actor agrees and what actor disagree with this statement.

On the other hand, the broad character of the 6C framework did help to assess the start-up business ecosystem as it was able to position all the relevant information. The researcher sees potential in this framework, yet it needs more practical understanding and exemplary research to become a valuable research tool.

Practical Managerial Use

Another use-case for the 6C framework is the use by high-level managers. After academia succeeds in presenting a robust 6C framework with coding scheme or indicator for specific sectors and maturity stages, it is a useful addition to a manager's toolbox. If the vision of a firm can be translated into specific balanced levels of the coding scheme categories or indicators, a high-level manager can use this to optimize its business unit in a new emerging sector.

The indicators can be part of a balanced scorecard. By knowing where to go and how the current business ecosystem scores, a high-level manager may attract and release actors to balance his business ecosystem. The researcher beliefs that the 6C framework fits new innovations best as these often enjoy rapid change to their environment and the framework assists in directing this change towards the vision of the firm.

Recommendations on the 6C framework

Since it is such a new framework, it logical that there improvements to make. The researcher proposes the following aspects further research on the 6C framework.

- Construct a complete analyzing guide on how to use the framework for both research and business.
- Identify optimal dimension scopes for the 6C framework per sector and maturity stage.
- Perform research with the 6C framework in other sectors with the preset scoping.
- Use a iterative coding scheme for coding the qualitative data.

7.3. Reflection on the Research Process

This section describes the research process that resulted in this dissertation. For a period of 8 months the researcher focused on vertical farming in the Netherlands and participated as a software specialist at the start-up Glowfarms. the researcher had no prior connection to the agriculture sector and gained a lot of knowledge on this sector as well as tacit knowledge on the use of the business ecosystem perspective in combination with the 6C framework. In order to give more context on the process towards the readers of this thesis, this section elaborates on the chronological research process from February 2021 till mid-September 2021. Also a personal reflection is included on the various research qualities.

Before the study started, the researcher assisted Glowfarms with software related services. This sparked the enthusiasm to devote a dissertation study to this new technology. Since the management focus did not interfere that much with the software related services, the researcher concluded that his presence did not influence the nature and process of Glowfarms' operations while working and studying the enabling and constraining factors of this vertical farming start-up.

After a first literature search on the topic and a preliminary scope of the research, the researcher searched for fitting supervisors at the TPM faculty. This proved to more difficult as expected, as the topic has not gained that much legitimacy at the TPM faculty. In combination with the huge workload of the academic personnel, it took the researcher more time as other students to find two supervisors. Looking back, the supervisors were in the review of the researcher the best fit to this topic.

Although the observations on site by the researcher and the network connections of Glowfarms provided a treasure of information, finding a balance between work and research proved to be more difficult than anticipated on beforehand. From this perspective, the work and research division was a new and interesting opportunity to research the internal activities of a start-up focal firm and clarify the opacity of the fast moving stage. On the other hand, this caused some delay in the research as Glowfarms depended on the researcher for software related services.

The literature research on the vertical farming cultivation technique and its position in the Netherlands was a successful process without to much obstacles. However, the process on finding a correct perspective and framework in the current academic literature was difficult. The scope was to broad in the beginning, that constrained to find a optimal research framework. A lack of experience of the researcher caused this struggle in setting to an optimal scope from the very start.

The researcher's enthusiasm resulted in his eagerness to study as much aspects of the businesses operational in the vertical farming sector, yet this proved to be impossible given the amount of resources available. After considering many perspectives and frameworks, the business ecosystem perspective in combination with the 6C framework was selected. This perspective and framework helped as well to size the study optimally and demonstrated to be suitable for the vertical farming sector. Section 7.2 describes the review of this perspective and framework.

Interviews as a data collection method was already intended from the start, however, the researcher had to select a single embedded case study of a single business ecosystem due to limited available resources. A multiple case study lacked the cooperation of the start-ups in the vertical farming sector, which in hindsight may be due to the secrecy that exists among these focal firms. Also, a multiple case study may produce more complete and credible results, there is need of trustworthy proposition that are then in an experiment format either accepted or refuted. The inaccurate visions of experts in the business field made the researcher belief that such a format would add less to the academic knowledge as proposition would get refuted.

In the end, the drafted methodology created grit for the dissertation. However, the new 6C framework with limited academic research did restrict the parsimony of the research. Unfortunately, there were some unknown unknowns in the process which were mainly connected to finding what aspects of the dimensions to include and how to translate that into interview questions. This caused a delay in finishing the design of the research method. The researcher acknowledges that the design of the research method could have been finished earlier in the process, but with limited experience beforehand it was difficult to anticipate on this. Section 7.2 elaborates and reviews the use of the 6C framework and Chapter 8 contains recommendations for other researchers who want to use this framework.

Also, the interview setup could be better. Due to the fast pace in interviewing directly after the design of the methodology, no interview training or trial could be performed, which could have optimized the interview and coding process. Yet, the coding scheme was used to draft the interview process which worked rather well. For a next study, first make a coding scheme, then designing the interview process and alter the coding scheme and interview process after every interview. Also, a first test interview could prove new insights to alter both.

The researcher started early in the process with contacting influential people and experts in the business field. The reasoning behind this was the thought of better being early in finding interviewees and contacts to guarantee a smooth research process. Whereas the first expert interviews gave no reason to expect any difficulties, the delay caused a break in actively communicate with the contacts as not much data collection could be performed. Therefore, this early contacting, caused a loss in momentum that ebbed away the contacts. Another reason for rejecting participation could be the secrecy which is found in the results.

Glowfarms provided help in finding enthusiastic interviewees from their business ecosystem, which did impact the case selection. By selecting Glowfarms the researcher was able to find the required resources for this study. Furthermore, this process started at the time the interviews process design was ready, so actors could be interviewed right away. The actors were cooperative and did help to obtain rich data. There were limitations as all actors signed non-disclosure-agreements with Glowfarms, however, this was only mentioned a single time to obstruct data collection.

Also, due to corona measures, the video conferencing is normalized. This made it easier to interview as distance between the actor and researcher was not an obstacle. In addition, the recorded audio was better as the interviewees in a video call would secure a quality microphone. There was also a downside to these video interviews, which became evident after a physical interview. It is easier to experience the context of the location and the emotions of the interviewees that enable the interviewer to steer the interview in an optimal way. Yet, the researcher got the feeling that he was able to experience the emotions sufficiently by the video call.

After the data collection, the researcher used the 6C coding table to analyze the results. Although all data could be connected to categories, it was difficult to find a structured method in retrieving the factors with most impact. A best method with the available data and resources was created, but the researcher recommends to use other impact methods. Although it will always be difficult to measure impact as there are many variables. For example, counting the amount of repeated factors or timing the interview does not simply give the most important factors as very definite factors get mostly mentioned one single time (e.g. there is no co-creation) and the interviewer may steer the interview into his biased opinion.

In the end, by grouping all the categories codes, the researcher was able to find commonalities and differences between the actors. With the help of a dimension-impact-factor the researcher provided the most important factors in the conclusion. Since the researcher became an expert in vertical farming and worked at Glowfarms for over 6 months, it was not that difficult to tie the knots. Yet, it is a biased opinion and a lack of resources does limit the impact of the study.

Overall, the researcher advocates for more use of the 6C framework, to make it more robust for business ecosystem research. Although the validity of this study may be limited, it does contain interesting recommendations for the vertical farms from an outsider who became an expert. Such is always interesting. Also, the recommendations for further research and the perspective and framework are elements of this study that potentially create impact. A next research may verify the concluded propositions.

7.4. Limitations of the study

There are limitations to the research approach that need to be considered.

- Use of only Dutch actors
- Focus on start-ups (different to the incumbent firms that try to adapt)
- Results may not apply to other cases
- Elements outside of the perspective and framework are not included (unknown unknowns)
- The data collection represents only a part of the actors in the business ecosystem
- New literature may change the prospect of vertical farming
- The interviewer is open to bias
- There were a limited amount of resources available that impacts the quality of the study.
- The interviewee may have ’green washed’ their answers

8

Conclusion & Recommendations

This final chapter, as Figure 8.1 illustrates, describes the empirical results from this study. It starts by summarizing the problem statement from where it continues with elaborating on the answers from the results on the main and sub research questions. The chapter ends with the recommendation for the vertical farming start-ups, further research and the research implications.

Figure 8.1: The research process steps for this dissertation

The expected global population increase, together with an unsustainable food system in place, puts further development of circular food production on the national innovation agendas. In addition, more extreme weather conditions cause depleted harvests around the world. This threatens food security for more countries in the world compared to today. The developed world needs to take its responsibility to take action and search for potential solutions.

A cultivation method that potentially brings improvement to the circularity and food security is vertical farming. Vertical farming is the large-scale cultivation of plants in a soil-less and multi-layer indoor setting, which is kept in a fully controlled and artificial climate by cutting edge technology. With its year-round production, clean facilities and urban farming principles, vertical farms proliferate themselves as circular and sustainable providers of food security.

Despite its potential upsides, vertical farming has not gained commercial success in the Netherlands. There are start-ups that work with the technology, but most are still unprofitable and protected by funding from government or private investors. This study focuses on the factors that enable and constrain the commercial success of a vertical farming start-up in the Netherlands.

In order to provide insights on these factors, this study analyzes a vertical farming start-up from a business ecosystem perspective. This perspective analyzes not only the focal actor, which is the start-up, but considers a constellation of actors that work towards a single goal by means of this focal firm that orchestrates those loosely coupled actors.

The research approach contains a desk research and case-study method. Where the actor analysis provides context and input for the case-study. Also, a technological maps helps the reader and researcher to better understand the vertical farming concepts underlying technologies and required infrastructure. The data collection methods for the case-study are observation by the researcher and interviews with experts a newly started business ecosystem.

Before the start of this research, the researcher started a student job in software engineering at Glowfarms. This provided the opportunity to follow the start-up and collect data on the business ecosystem next to the researcher's job. During eight months, the weekly meetings, site visits and important presentations enabled this study to get insight in the opacity of a vertical farming start-up and its business ecosystem forming.

To combine the data points into one coherent and holistic analysis, this research requires an empirical framework. The 6C framework is one of the few framework that complements the business ecosystem perspective as analysis tool. It does so by reviewing six dimensions in more detail. These are the context, construct, configuration, cooperation, capabilities, and change dimension.

Next, the researcher lists all the data per dimension and assigns an impact factor per sub category of the dimensions. This process accentuates the most important factors that form the basis of the conclusions. An explanation building process links the most impact factors with other relevant data points to provide tentative statements that fit in the context of the research question and function as business ecosystem analysis of the start-up of the case-study.

8.1. Explanation Building for the Main Conclusion

Explanation building is all about formulating a logical order of events that cause a phenomenon to appear. This logical order of events must be built around multiple data points to be accepted. It is therefore a process of multiple revisions. With the help of the results, there are four main factors that influence the commercial success of a Dutch vertical farming start-up. These four factors can be further subdivided into two enabling and two constraining factors.

8.1.1. The new value capture of vertical farming

The vertical farming industry is in a birth stage, which makes it understandable the environment is sub-optimal and profits are low. In spite of the starting limitations, even if the technology matures there is a high energy requirement and manual labor is a large expense as well. A business model must be able to sufficiently support these costs that are relatively high compared to current standards.

The current food system in place is firmly centered around a small number of food distributors, which causes lengthy food chains. Since the current vertical farming sector is in a niche state and without much bargaining power, it must adapt to the current food system en regulations. This setting blocks its circular potential from being usable and ignites the solid competition from the Dutch greenhouses, which are renowned for implementing the latest advancements.

Yet, vertical farming imposes potential upgrades on the cultivation of plants. Due to the clean facilities and tight regulation, circularity can be improved. As plants are growing soil-less, water gets recirculated in the system and the growing medium is able to be recycled into bricks, the only waste-stream left is clean organic material without pesticides. In addition, there is a steady production rate during all seasons as the vertical farm is a closed facility.

This year-round production and no impact from external seasonal factors creates food security, which is a hot topic after the Covid-19 measures emphasized the severity of dependence on food from import. The Covid-19 measures fostered the food securing cultivation techniques even more than the ongoing climate change impacts.

These positive and negative aspects on vertical farming are the reason for a new type of value creation. With the vision of a fully automated vertical farm, the manual labor costs are minimized. To cover the high investments required at the start of operation, marketing and branding around the products and services must highlight its upside potential relative to the status quo. These improved products are then sold at a minor price premium.

Since governmental and private funding protects the vertical farming niche at the moment, time will tell if this new value creation survives. What can be observed is that it is a different business model compared to the earlier Dutch vertical farming start-ups and with a similar value creation in other sectors, this study expects that it enables the commercial success and growth.

8.1.2. The synergy within the business ecosystem

The actors are unanimous in describing a vision towards a sustainable and circular food system that enables food security for the 10 billion inhabitants of the world by 2050. One of the actors goes even further by expressing the need of food sovereignty in the world. Food sovereignty establishes food security by a fair profit distribution among members of the food system and by managing the environmental footprint of the processes. Thus, the visions of the actors in the business ecosystem share a common goal and higher aim.

Having a similar vision helps the integration and connection with firms, however, the products and services must fit the vision and beliefs of the actors as well. The results conclude that the actors within the business ecosystem belief in the product and services of Glowfarms. Vertical farming is an improvement for the food system and it is likely that the design of Glowfarms becomes the dominant design of the future. There is one actor that stated the new value creation of Glowfarms which focuses on branding. The actor expressed ambivalence about this American model in the Netherlands.

The future is uncertain, as this actor affirms, and organizations must act in an ambidextrous way. This alignment in today's business and anticipating on future changes is what most actors in the business ecosystem manage by nurturing their way in and forecast anticipated pattern shifts. The members of the business ecosystem belief in the design of Glowfarms, however, their organizations cannot run on the profits from this start-up firm and sector. Therefore, the actors nurture the relationship with Glowfarms by sufficiently helping the organization without growing dependency.

Another unanimous finding is the quality of the relationship between the actors of the business ecosystem. There is regular contact between Glowfarms and the actors by phone, mail, or other online communication tools. This study concludes that the common goal, belief in vertical farming, and the quality of the relationships bring commitment to the business ecosystem. Observations strengthen this statement as site visits of the actors show the enthusiasm there is among them.

This study further expects that this commitment opens up the shared benefits of the business ecosystem. One of the most obvious shared benefits for Glowfarms is the introduction to new actors. This form of actor recruitment adds important tacit and implicit knowledge to the business ecosystem as a wider range of actors joins them. In this way heterogeneity establishes in the business ecosystem with more knowledge infrastructure that improves products and services. Simultaneously, the business ecosystem matures as more industrial and professional solutions are in place.

8.1.3. The lack of successful co-creation

From the actor search it is evident that the Dutch vertical farming sector did not establish a dominant design. There are many different interpretations on how a vertical farming system must look like. This shows that vertical farming is in the birth stage, where actors try to become the dominant design in place. The technology is of a sufficient level to support these different business models in the sector. However, due to the variance in designs not all vertical farms use similar technologies, which in the end block more rapid development.

A lack of dominant design in combination with the early stage of the sector results in less volume for inter business ecosystem projects and services. From the interviews with the actors it becomes clear that with less volume there are less possibilities for activity integration and co-creation. In addition, services and products become relatively expensive for smaller batches. With limited resources in place, vertical farming start-ups have less bargaining power and possibilities.

Since the batch size of services and products by third party suppliers in the vertical farming start-ups is small, actors are not dependent on the performance of the start-up. The third party suppliers either see Glowfarms as personally interesting or as a firm with the right intentions that is able to afford larger quotations at a later stage. Yet, this lack of dependence does imply that less services or products are co-created for Glowfarms.

A last factor that hampers co-creation is the amount of available resources. The Dutch government assists in generating new knowledge as well as supporting the not yet working business models of early start ups in the vertical farming industry by tax reductions and subsidies. Still, private investors supply most financial resources, but interviewees observe a shift to a later stage when private funding becomes easier available. This limited amount of resources make it impossible to procure adapted products and services in the start-up phase.

This issue affects circularity in a similar manner as most service and products in place are not automatically designed for circularity. Thus, circularity needs volume as most circular processes are more costly compared to waste processes. The founders of Glowfarms explain that circularity is not possible at the current stage of VF, yet smaller experiments show positive results. The observant establishes a similar finding as the water recycling process hampers due to problems with filtration and irrigation.

Although there are joint goals and strategies, the co-creation is far from optimal due to volume boundaries and expensive quotation set by niche players. These boundaries are in place since the

established horticulture sector provides efficient and larger projects for the niche player, which earns them more money at the moment. However, due to the vision, prospects and co-evolution of the ecosystem, many niche actors do join as supplier to anticipate when the sector grows.

8.1.4. The secrecy about tacit and implicit knowledge

Since there are many different methods trying to become the standard vertical farming technique. The fear of passing tacit or implicit knowledge to a competitor is high in the Dutch vertical farming sector. This causes some constraining elements to exist, such as the absence of cooperation among focal firms. The NDAs that Glowfarms signs with the niche players and the quiet LinkedIn groups confirm this secrecy in the sector. There are plenty of niche players available in the Netherlands that are interested in helping out the VF sector. However, when secrecy surrounds the project, the cooperation is less efficient and result in fewer exchange of tacit and implicit knowledge.

Moreover, without cooperation between the different vertical farming business ecosystems, establishing a forefront in vertical farming becomes impossible. This constrains the commercial success as there is less bargaining power for the individual firms, there is less or splintered education towards the consumers and there is less knowledge exchange. The sector needs these factors in place as there is a strong network of incumbent firms in the horticulture sector that does cooperate, which makes a tough competitor.

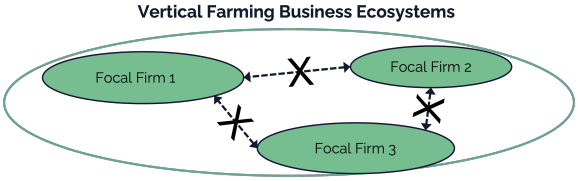


Figure 8.2: The autonomous vertical farming system by (Glowfarms, 2021)

These incumbent firms and their business ecosystems form a regime that is firmly present in the Dutch food system. To gain commercial success, vertical farms want a spot in this regime. Nevertheless without a forefront or cooperation it becomes a difficult task as vertical farming is all very new. Thus, this secrecy among focal firms constraints commercial success in the Netherlands. Figure 8.2 portrays this effect in a conceptual manner.

8.2. Answers to the sub research questions

In addition to the main research question, three sub questions provided scope and a direction to this study. The questions follow a chronological order with respect to the research timeline and aim to find information on the expected results, an optimal analysis method, and generalization of the results. This section elaborates on the answers and the process on finding answers of these sub questions.

How is vertical farming envisioned and embraced by experts in the business field?

Sub question 1 assists in generating expected results for the study. Although forming expected results by interviews and literature research may look like inductive research, it assists in scoping the research and gives grip on the framework and case-study. Because the answer originates from different data point and layers in the complex business environment, the inductiveness is kept small.

There is a split in proponents and opponents to vertical farming implementation. Whereas the proponents make the link to a vision of circular food chain and food security, the opponents make a comparisons with the current cultivation methods in place. Both directions express the uncertainty about the progress of vertical farming, however, different beliefs in outcomes are leading to the various parties.

By reading and listening the researcher constructs five expected results that are most often found in literature and the interviews. The top two are expected to be constraining factors, whereas the bottom three are expected to be enabling factors. Moreover, it is expected that these five topics are important in the commercial success of vertical farming and return in the conclusion. For that reason the research is including these topics in more interest, without limiting itself to these topics. The expected results:

- The business model lacks improvement
- The business network is closed

- The underlying tech is sufficient
- There is support from government
- The synergy is high

What is a preferable framework and its corresponding dimensions for analysis?

Sub question 2 facilitates the search for an optimal perspective and empirical framework to analyze a vertical farming start-up. Literature covers multiple possibilities with each their positive and negative aspects. The main aspects of start-ups in vertical farming regarding the perspective and framework is the early stage of this sector, the large dependence on third party suppliers and the network formation starting outside of the current incumbent firms.

By considering these aspects, a business ecosystem perspective presents itself as an optimal fit. It is the perspective which identifies a constellation of actors that work towards a single goal by means of a focal firm that orchestrates those loosely coupled actors. The vertical farming start-ups are the focal firms and the third party suppliers, retailers and waste collectors are niche players that work together to serve the vertical farming goal.

An empirical framework is required in order to analyze the business ecosystem perspective. Since the framework is not matured and its literature is scattered, this study identify only one empirical framework. The 6C framework analyzes a business ecosystem by elaborating on six dimensions: context, construct, configuration, cooperation, capabilities and change. With adapting the framework to the vertical farming sector a suitable analysis method is established.

In what degree are similar factors present across the Dutch vertical farming sector?

Sub question 3 is about the generalizability of the main research question. The vertical farming concepts is far from new, only the high-tech and latest technical advances make it innovative. Yet, there is no successful firm in the Netherlands that operates this new cultivation concept. Therefore, studying a start-up and clarifying the opacity in this stage helps the sector if the start-up is comparable to others. Next to the actor search that concluded this similarity, a verifying interview must assure that the results are also in line with other vertical farms.

So, in order to check whether the case-study results are comparable to other start-up vertical farming business ecosystem, this research includes a verification interview with a similar focal firm. In this setting, the same researcher interviews a manager. A focus in questioning and analysis is on the conclusions from this chapter. With data collected from more actors across the business field, the conclusions get more external validity.

The firm of the verification interview also started to create value around a brand. Instead of focusing on the retailers and supermarkets, they sell to restaurants and wholesale. However, the main principle of selling at a price premium because of the circular and sustainable principles in addition to the fine quality is comparable to the results from the case-study.

Also, this other focal firm experiences synergy in the vertical farming sector. Although the Covid-19 measure made their profit drop, the pandemic ensured even a larger focus on food security and food production in every country. The difficulties with the export due to Covid-19 checks at the border, made importing (food) products more complicated as usual. So, the synergy is not only established in the case-study, but it is present in more business ecosystems in the vertical farming sector.

Unfortunately, the interviewee gave little insights on the amount of co-creation. This may confirm that there is a lack of co-creation with other specialized actors. The interviewee mentioned that a merger with a software team took place, so most software and high-tech related products are produced in-house. So, this may confirm a lack of resources and the necessity to try to make most products by yourself, but it lack the arguments to confirm the lack of co-creation due to the limited amount of information.

What this vagueness immediately does confirm is the secrecy there between the vertical farms. There were specific business related questions that the interviewee avoided with answers in different directions. This secrecy is found in all research methods and therefore is expected to be present in the complete sector.

8.3. Recommendations & Implications

Next to the conclusions that follow from the results, the researcher provides recommendations for the vertical farming start-ups and for further research possibilities that create most impact regarding this research topic.

8.3.1. The vertical farming start-up

There are three main recommendations for increasing the commercial success of the business ecosystems that this study proposes. These recommendations focus on the results and conclusions.

A first recommendation centers around the lack of cooperation between focal firms. This indicates that the trust is not established and protection of the tacit and implicit knowledge is important. This latter aspect is logical and perhaps even wanted by a birth stage sector for the individual firms. Yet, the lack of a forefront is considered damaging for the commercial success. In addition, the exchange of essential knowledge might be meaningful for the sector.

So, this study proposes a better cooperation between focal firms. This may solve the volume boundary of circularity and help to improve the strategic marketing of vertical farming products. In order to penetrate and settle in this regime of incumbent firms, vertical farms must work together to create a forefront. By educating the public and retailers, the firms can easier create legitimacy in the food system. Figure 8.3 depicts this recommendation in a conceptual way.

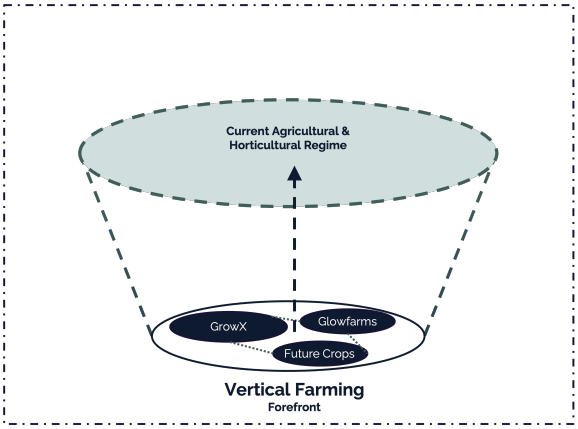


Figure 8.3: The autonomous vertical farming system by (Glowfarms, 2021)

A second recommendation focuses on the lack of co-creating in the business ecosystem. This lack of co-creation is inherent to the lack of a dominant design. New actors or operating firms choose more often for a product with more complementary products and services. Creating the dominant design is therefore a critical element when wanting to sell products and services.

This study opts for more interaction with start-up firms that are less volume bounded and more dependent on vertical farming. When these firms start to develop a new product or service range, it is automatically more dependent and better aligned with the focal firm. This is also perceived when interacting with firms that focus completely on vertical farming and its future. The main goal here is to find and own the dominant design, which is able to develop faster when more actors get involved.

Another possibility for more co-creation is by obtaining more resources. Governmental resources have a boundary, yet private resources often tent to be available for more risky start-ups. However, this may shift to focus from the circular and sustainable character is the wrong investors are included. The vertical farms must not dismantle their the momentum and synergy by renouncing their sustainable prospects.

A third recommendation is on this sustainable character of vertical farming that enables synergy and facilitates a new potential value creation model. Don't forget the circular focus, which granted the new start and momentum in the first place. Much focus on gaining as quickly as much resources to make the dominant design. Yet, this should be in balance with the improved circular benefits.

This study recommends including more circular principles. A service model with third party suppliers is an example of such. The light can be serviced by a third party supplier. In this way, this actors increases the profit by making the light more efficient and modular. This also improve sustainability in a business driven manner. When also performing innovative elements on this perspective, the branding and marketing of the products gets a boost.

8.3.2. Further Research

There are also recommendations made for further research possibilities that seem vital to understand. In the academic world of vertical farming still a lot of gaps exist, but academics conclude that vertical

farming has benefits. This new technique has already a small niche role in the dutch food system, but needs to be given more direction. Therefore, this study proposes to do research on the following topics listed below.

- the optimal context for vertical farming usage from a business perspective (which countries / locations)
- the best fitting plants in existence today for vertical farming
- the dominant vertical farming design for the Netherlands
- the optimal vertical farming crop and indoor climate
- the functionality and rigidness of the new value creation model
- the impact of a horticulture collaboration platform
- the business and transitional aspects towards a circular food system
- Investigate the circular recycling technologies
- the constraining and enabling factors in other circular transitions in the Netherlands

8.3.3. Implications

The research establishes a holistic insight in the networking and intra-business ecosystem activities of a start-up in vertical farming. After reading this dissertation a reader understands what vertical farming is and what potential it has. In a similar way the perspective and framework enlighten the reader with a new conceptualization of the network of actors in the vertical farming sector.

However, due to the limit resources and responses of actors in the Dutch vertical farming business field, it is difficult to take the conclusions as truth for every start-up. The limitations of this study are impact the research quality and therefore the conclusions are better taken as propositions for a next research.

The research provides Glowfarms, the start-up case-study, with valuable feedback on improving its commercial success. It also provides insights for policy makers on the current position and potential of vertical farming. With extra funds available from government or other support systems, there certainly is potential to improve the food security, and circularity of the food system in the Netherlands.

Bibliography

Adner, R. (2006). Match your innovation strategy to your innovation ecosystem.

Adner, R., & Kapoor, R. (2010). Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. *Strategic Management Journal*, *31*(3). https://doi.org/10.1002/smj.821

Aerofarms. (2021). Aerofarms technology. Retrieved April 14, 2021, from https://aerofarms.com/technology/

Agtech Institute. (2021). Retrieved April 22, 2021, from https://www.tudelft.nl/en/agtech-institute

Anggraeni, E., Hartigh, E. D., & Zegveld, M. (2007). Business ecosystem as a perspective for studying the relations between firms and their business networks. *Eccon 2007*, (January 2016).

Avgoustaki, D. D., & Xydis, G. (2020). Indoor vertical farming in the Urban nexus context: Business growth and resource savings. *Sustainability (Switzerland)*, *12*(5). https://doi.org/10.3390/su12051965

Baarsma, B. (Ed.). (2020). *Nederland voedselparadijs*. Pluim.

Benis, K., & Ferrão, P. (2018). Commercial farming within the urban built environment – Taking stock of an evolving field in northern countries. https://doi.org/10.1016/j.gfs.2018.03.005

Benke, K., & Tomkins, B. (2017). Future food-production systems: Vertical farming and controlled-environment agriculture. *Sustainability: Science, Practice and Policy*, *13*(1), 13–26.

Breukers, A., Hietbrink, O., & Ruijs, M. (Eds.). (2008). *The power of dutch greenhouse vegetable horticulture*. LEI Wageningen UR. https://edepot.wur.nl/27928

Bryman, A. (2016). *Social research methods*. Oxford university press.

CBS. (2021). Open data - statline. Retrieved April 21, 2021, from https://opendata.cbs.nl/statline/#/CBS/nl/

CBS and LEI (Ed.). (2012). *Land- en tuinbouwcijfers 2012*. Statistics Netherlands (CBS); Agricultural Economics Research Instititute (LEI).

Chin, Y. S., & Audah, L. (2017). Vertical farming monitoring system using the internet of things (iot). *AIP Conference Proceedings*, *1883*(1), 020021.

Codema. (2021). Retrieved April 21, 2021, from https://codema.nl/nl/

De Bosatlas van het voedsel (Ed.). (2014). *De bosatlas van het voedsel*. Noordhoff Uitgevers bv.

de Zwarte, I., & Candel, J. (Eds.). (2020). *10 miljard monden*. Prometheus.

den Besten, J. (2018). Vertical Farming Development; the Dutch Approach. *Plant factory using artificial light: Adapting to environmental disruption and clues to agricultural innovation*. https://doi.org/10.1016/B978-0-12-813973-8.00027-0

Despommier, D. (Ed.). (2020). *The vertical farm*. Picador.

Eigenbrod, C., & Gruda, N. (2015). Urban vegetable for food security in cities. A review. https://doi.org/10.1007/s13593-014-0273-y

Ergin Birinci and Alexandra Virlan. (2017). Food needs transport, grow it! Retrieved May 30, 2021, from https://www.unstudio.com/en/page/8128

European Commission. (2021). A new way of working for the future of farming. Retrieved April 21, 2021, from https://ec.europa.eu/info/news/new-way-working-future-farming-2020-may-20_en

FAO. (2009). How to Feed the World in 2050. *Insights from an expert meeting at FAO*, *2050*(1).

Farhangi, M. H., Turvani, M. E., van der Valk, A., & Carsjens, G. J. (2020). High-tech urban agriculture in Amsterdam: An actor network analysis. *Sustainability (Switzerland)*, *12*(10). https://doi.org/10.3390/SU12103955

Figge, F., Hahn, T., Schaltegger, S., & Wagner, M. (2002). The sustainability balanced scorecard - Linking sustainability management to business strategy. *Business Strategy and the Environment*, *11*(5). https://doi.org/10.1002/bse.339

Future Crops. (2021). Retrieved April 21, 2021, from https://www.future-crops.com/nl/

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8-9). https://doi.org/10.1016/S0048-7333(02)00062-8

Glowfarms. (2021). Glowfarms: Rooted in innovation. Retrieved July 2, 2021, from https://glowfarms.com

Graamans, L., Baeza, E., van den Dobbelsteen, A., Tsafaras, I., & Stanghellini, C. (2018). Plant factories versus greenhouses: Comparison of resource use efficiency. *Agricultural Systems*, *160*. https://doi.org/10.1016/j.agsy.2017.11.003

Greenport West-Holland. (2021). Retrieved April 21, 2021, from https://greenportwestholland.nl/

Group L. (2019). Vertical farming in tokyo - spm9730. Retrieved March 21, 2021, from https://brightspace.tudelft.nl/d2l/le/content/279958/viewContent/1974035/View

GROWx. (2021). Retrieved April 21, 2021, from https://www.growx.co/

Gupta, R., Mejia, C., & Kajikawa, Y. (2019). Business, innovation and digital ecosystems landscape survey and knowledge cross sharing. *Technological Forecasting and Social Change*, *147*. https://doi.org/10.1016/j.techfore.2019.07.004

Gupta, S., Chen, H., Hazen, B. T., Kaur, S., & Santibañez Gonzalez, E. D. (2019). Circular economy and big data analytics: A stakeholder perspective. *Technological Forecasting and Social Change*, *144*. https://doi.org/10.1016/j.techfore.2018.06.030

Iansiti, M., & Levien, R. (2004). Strategy as Ecology.

Infinite Acres. (2021). Retrieved April 21, 2021, from https://infinite-acres.com

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikäinen, J., Saikku, L., & Schösler, H. (2016). Transition towards circular economy in the food system. *Sustainability (Switzerland)*, *8*(1). https://doi.org/10.3390/su8010069

Kahneman, D. (2011). *Thinking, fast and slow*. Macmillan.

Kamp, L. M., & Vanheule, L. F. (2015). Review of the small wind turbine sector in Kenya: Status and bottlenecks for growth. https://doi.org/10.1016/j.rser.2015.04.082

Klerkx, L., & Rose, D. (2020). Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways? *Global Food Security*, *24*. https://doi.org/10.1016/j.gfs.2019.100347

Koppert Cress. (2021). Retrieved April 21, 2021, from https://www.koppertcress.com/nl

Kozai, T. (2013). Resource use efficiency of closed plant production system with artificial light: Concept, estimation and application to plant factory. https://doi.org/10.2183/pjab.89.447

Kozai, T., Niu, G., & Takagaki, M. (2019). *Plant factory: An indoor vertical farming system for efficient quality food production: Second edition*.

Lacy, P., Long, J., & Spindler, W. (2020). *THE CIRCULAR ECONOMY HANDBOOK Realizing the Circular Advantage*.

Li, L., Li, X., Chong, C., Wang, C. H., & Wang, X. (2020). A decision support framework for the design and operation of sustainable urban farming systems. *Journal of Cleaner Production*, *268*. https://doi.org/10.1016/j.jclepro.2020.121928

Light4Food. (2021). Retrieved April 21, 2021, from http://light4food.com/

Martin, M., Poulikidou, S., & Molin, E. (2019). Exploring the environmental performance of urban symbiosis for vertical hydroponic farming. *Sustainability (Switzerland)*, *11*(23). https://doi.org/10.3390/su11236724

Ministerie van Infrastructuur en Waterstaat (Ed.). (2018). *Transitie-agenda circulaire economie*. Rijksoverheid. https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/documenten/rapporten/2018/01/15/bijlage-5-transitieagenda-biomassa-en-voedsel

Ministry of Agriculture, Nature and Food Quality. (2021). Agriculture and horticulture. Retrieved April 21, 2021, from https://www.government.nl/topics/agriculture/agriculture-and-horticulture

Möller, K., Nenonen, S., & Storbacka, K. (2020). Networks, ecosystems, fields, market systems? Making sense of the business environment. *Industrial Marketing Management*, *90*. https://doi.org/10.1016/j.indmarman.2020.07.013

Moore, J. F. (1993). Predators and prey: a new ecology of competition. *Harvard Business Review*, *71*(3).

OneFarm. (2021). Retrieved April 21, 2021, from https://www.onefarm.io

Orsini, F., Pennisi, G., Zulfiqar, F., & Gianquinto, G. (2020). Sustainable use of resources in plant factories with artificial lighting (PFALs). https://doi.org/10.17660/eJHS.2020/85.5.1

Own Greens. (2021). Retrieved April 21, 2021, from https://www.owngreens.com/

Parida, V., Burström, T., Visnjic, I., & Wincent, J. (2019). Orchestrating industrial ecosystem in circular economy: A two-stage transformation model for large manufacturing companies. *Journal of Business Research*, *101*. https://doi.org/10.1016/j.jbusres.2019.01.006

Phoodkitchen. (2021). Retrieved April 21, 2021, from https://phoodkitchen.com/

Pieterse, B. (Ed.). (2019). *The development of the japanese vertical farming industry and its impact on the food system*. University of Applied Sciences Middelburg.

Planbureau voor de Leefomgeving (Ed.). (2018). *Balans van de leefomgeving 2018 - nederland duurzaam vernieuwen*. https://www.pbl.nl/publicaties/balans-van-de-leefomgeving-2018

PlantLab. (2021). Retrieved April 21, 2021, from https://www.plantlab.com/

Plenty. (2021). The future of modern farming. Retrieved January 19, 2021, from https://www.plenty.ag

R Shamshiri, R., Kalantari, F., Ting, K., Thorp, K. R., Hameed, I. A., Weltzien, C., Ahmad, D., & Shad, Z. M. (2018). Advances in greenhouse automation and controlled environment agriculture: A transition to plant factories and urban agriculture.

Raad voor de Leefomgeving en Infrastructuur (Ed.). (2020). *De bodem bereikt?!* https://www.rli.nl/sites/default/files/advies_de_bodem_bereikt_-_def.pdf

Reijtenbagh, Q. (2020). *A circular business ecosystem approach towards achieving high value use of salvaged building materials in the dutch built environment* (Master's thesis, Ed.). TU Delft. https://repository.tudelft.nl/islandora/search/reijtenbagh?collection=education

Ridder. (2021). Retrieved April 21, 2021, from https://ridder.com/nl/

Rijksoverheid. (2021). Ministerie van landbouw, natuur en voedselkwaliteit. Retrieved April 21, 2021, from https://www.rijksoverheid.nl/ministeries/ministerie-van-landbouw-natuur-en-voedselkwaliteit

Rong, K., Hu, G., Lin, Y., Shi, Y., & Guo, L. (2015). Understanding business ecosystem using a 6C framework in Internet-of-Things-based sectors. *International Journal of Production Economics*, *159*. https://doi.org/10.1016/j.ijpe.2014.09.003

Saldaña, J. (2021). *The coding manual for qualitative researchers*. sage.

Sekaran, U., & Bougie, R. (2016). Research Method for Business Textbook: A Skill Building Approach. *John Wiley & Sons Ltd.*

SMARTKAS. (2021). Retrieved April 21, 2021, from https://smartkas.com/

Smit, M. (2020). De nederlandse landbouw in 2040. *Landschap*, *37*(4), 206–214.

Srai, J. S., & Gregory, M. (2008). A supply network configuration perspective on international supply chain development. *International Journal of Operations and Production Management*, *28*(5). https://doi.org/10.1108/01443570810867178

Statista. (2021). Amsterdam: Total population. Retrieved January 19, 2021, from https://www.statista.com/statistics/753235/total-population-of-amsterdam/

Stein, E. W. (2021). The transformative environmental effects large-scale indoor farming may have on air, water, and soil. *Air, Soil and Water Research*, *14*, 1178622121995819.

Tate, W. L., Bals, L., Bals, C., & Foerstl, K. (2019). Seeing the forest and not the trees: Learning from nature's circular economy. *Resources, Conservation and Recycling*, *149*. https://doi.org/10.1016/j.resconrec.2019.05.023

The Indoor Farming Nederland Community, LinkedIn. (2021). Retrieved April 21, 2021, from https://www.linkedin.com/groups/13917547/

Thomaier, S., Specht, K., Henckel, D., Dierich, A., Siebert, R., Freisinger, U. B., & Sawicka, M. (2015). Farming in and on urban buildings: Present practice and specific novelties of zero-acreage farming (ZFarming). *Renewable Agriculture and Food Systems*, *30*(1). https://doi.org/10.1017/S1742170514000143

United Nations. (2014). *World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352)*. https://doi.org/10.4054/DemRes.2005.12.9

Valkokari, K. (2015). Business, Innovation, and Knowledge Ecosystems: How They Differ and How to Survive and Thrive within Them. *Technology Innovation Management Review*, *5*(8). https://doi.org/10.22215/timreview919

Wageningen University. (2021). Retrieved April 21, 2021, from https://www.wur.nl/

Walrave, B., Talmar, M., Podoynitsyna, K. S., Romme, A. G. L., & Verbong, G. P. (2018). A multi-level perspective on innovation ecosystems for path-breaking innovation. *Technological Forecasting and Social Change*, *136*. https://doi.org/10.1016/j.techfore.2017.04.011

Weidner, T., Yang, A., & Hamm, M. W. (2019). Consolidating the current knowledge on urban agriculture in productive urban food systems: Learnings, gaps and outlook. https://doi.org/10.1016/j.jclepro.2018.11.004

Worland, J. (2021). Aerofarms. Retrieved January 19, 2021, from https://time.com/collection/best-inventions-2019/5733085/aerofarms/

Yin, R. K. (2014). *Case study research: Design and methods (5th ed.)*

Zhang, X., & Cai, X. (2011). Climate change impacts on global agricultural land availability. *Environmental Research Letters*, *6*(1). https://doi.org/10.1088/1748-9326/6/1/014014

Zhang, Y., Gregory, M., & Shi, Y. J. (2007). Global engineering networks: The integrating framework and key patterns. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(8). https://doi.org/10.1243/09544054JEM820

A

Search Description

In order to assess this literature review as trustworthy, there is a demand for both scanning all related literature available as well as investigating their credibility. This chapter elaborates on the search method used for this literature review. The search with predefined terms on Scopus is described, which is followed by an elaboration on the selection procedure. A last section explains two interesting phenomena that occurred during the search.

A.1. Acquainting the Correct Terminology

After listening to various podcasts, news articles and YouTube videos, I became more interested in the topic. Reading and scanning books on the topic helped in becoming acquired with the terminology. Despommier (2020) elaborates on his view of vertical farming and his more-than-20-years of knowledge in the field clarifies what vertical farming entails. Baarsma (2020) and de Zwarte and Candel (2020) go more in depth about the position of the Netherlands and how the Dutch food system should adapt, from which I acquainted a more circular economy vocabulary. These books were found by entering Vertical Farm in the bookshop, so no real search process went upfront. Once I felt confident enough about the terminology, I conducted a Scopus search.

Table A.1: Search Results of Scopus

	Circularity	**Circular Economy**	**Dutch**	**The Netherlands**	**Transitions**
A. Farming (1. Urban, 2. Vertical)	22	135 –>(6, 4)	624 –>(3, 2)	1105 –>(4, 5)	2879 –>(20, 9)
B. Agriculture (1. Urban, 2. Vertical)	54	494 –>(21, 0)	1003 –>(10, 0)	1817 –>(23, 0)	6892 –>(65, 1)
C. Horticulture (1. Urban, 2. Vertical)	5	27	158 –>(1, 0)	183 –>(3, 0)	169 –>(4, 0)
D. ”Food System” (1. Urban, 2. Circular)	13	57	35	114 –>(9, 5)	768 –>(69, 26)
E. ”Food Security” (1. Urban, 2. Overview)	22	79 –>(22, 2)	28	2879 –>(20, 9)	827 –>(119, 12)

The search on Scopus is visualized in table A.1. Scopus searched within Title, Abstract and Keywords, so all relevant documents would show. The table can be read as follows, I started by entering the bold phrases / words in the search bar, separated by ”AND”. When 60+ results matched the input, the search terms were adjusted by the non bold phrases on the left side of the table. If the search would show far too many results after scoping down, the sorting button would be used to go over the most cited and newest. The latter was not required. An example:

TITLE-ABS-KEY (”Vertical Farming” AND ”Circular Economy”)

All titles were read and if the title could by any logical thinking lead to a relevant article the abstract was read. A next step was to limit the results further down. During the process the selection criteria

may have adapted due to the amount of available literature, however, the final selection is composed of studies which contribute to:

- Specific information on vertical farming (VF) in the Netherlands
- Reviewing the transition to a circular economy in the agri-food sector AND including VF
- Reviewing the business opportunity of VF
- Being a reference study for VF

There are some terminologies used in scientific literature that I did not include in the first large search. I became aware of this perspective after reading more from Despommier (2020) and became more informed with the scientific literature found in the first round. These terms included ”Plant Factory”, often used in Asia, and ”Controlled Environment Agriculture”. ”Precision Farming” was yet another term, but did not bring any fruitful results. The itemized search terms below gave 3 more results that were suitable for this literature review.

- TITLE-ABS-KEY (”The Netherlands” AND ”Farming” AND ”Overview”)
- TITLE-ABS-KEY (”Controlled Environment Agriculture” AND ”Overview”)
- TITLE-ABS-KEY (”Plant Factory” AND ”Review”)

A last still missing literature gap on more governmental and institutional reports still existed after the search methods. That’s why these type of documents were ought to find by utilizing the google search machine. This last search included reports in which the Netherlands played a more central role. Such reports seemed quite essential to me for a research focused on the Netherlands. On the other hand, they belong to the ’gray literature’, so should be handled with care.

A.2. Selection Process of the Results

After the pre-selection phase, to see if any literature suited this literature review, the articles and documents were scrutinized for credibility. This was rather difficult as the topic is relatively new. Most sources are from 2017-2021, which makes it more difficult to follow simply the amount of citations.

A short analysis, as good as possible by a student relatively new to the field, I reviewed the first authors and the journals of the documents. Nevertheless, some authors did not publish 5 or more articles, making it more challenging. The governmental and other institutional literature were defined as credible, but were handled with care due to their non-scientific origin.

The last step in the process was to scan the introduction and conclusion of the final list of literature. As the scope is narrow and the topic relatively new, there was not much room to deselect literature. If the paper was found to be suitable, it was added to my final list for this literature review. The end result consists of quite new articles some with a minor amount of citations, however, all literature is published in renowned journals.

A.3. Interesting Findings

As mentioned earlier, during the search for adequate articles and documents to ground this literature review, the results showed mostly relatively new articles. This may indicate missing out on important search terminology, however, this phenomena emerged at all search terms. Of course, I did base my terminology on relatively new materials, so it might be that terminology has changed over time. On the other hand, I could not find older credible articles when looking for them. This makes me conclude that the topic is relatively new and hot.

Another significant finding during the search was that ”the Netherlands” and ”Circular Economy” are search terms that will generate more results as ”Circularity” and ”Dutch”. Nevertheless, not all outputs coincide. This made me aware to include both terminologies, although a lot of similarities in the outcome exists. A last note on the search terms is that ”Transition” in combination with ”Urban” and ”Vertical Farming” gave the best results for the topic of this literature review.

B

Agricultural Data

This appendix contains an elaboration on part of the used data in this literature review. First, table B.1 shows the outcomes of a study researching the food quality of the Netherlands. The focus in this study is agricultural food cultivated on soil in the Netherlands. A depletion of fertile land causes a reduction in minerals and vitamins in our food. Figure B.1 shows the outcome of a study on emissions connected to agriculture in the Netherlands. This data is directly copied from sources that advice the Dutch government on their strategy.

Table B.1: Depletion of land causes decrease in food quality (Raad voor de Leefomgeving en Infrastructuur, 2020, p. 47)

Vitamines & Mineralen		**Resultaten**			**Verschillen**	
		1985	1996	2002	1985- 1996	1985- 2002
Broccoli	Calcium	103	33	28	-68%	-73%
	Foliumzuur	47	23	18	-52%	-62%
	Magnesium	24	18	11	-25%	-55%
Bonen	Calcium	56	34	22	-38%	-51%
	Foliumzuur	39	34	30	-12%	-23%
	Magnesium	26	22	18	-15%	-31%
	Vitamine B6	140	55	32	-61%	-77%
Aardappelen	Calcium	14	4	3	-70%	-78%
	Magnesium	27	18	14	-33%	-48%
Wortelen	Calcium	37	31	28	-17%	-24%
	Magnesium	21	9	6	-57%	-75%
Spinazie	Magnesium	62	19	15	-68%	-76%
	Vitamine C	51	21	18	-58%	-65%
Appel	Vitamine C	5	1	2	-80%	-60%
Banaan	Calcium	8	7	7	-12%	-12%
	Foliumzuur	23	3	5	-84%	-79%
	Magnesium	31	27	24	-13%	-23%
	Vitamine B6	330	22	18	-92%	-95%
Aardbeien	Calcium	21	18	12	-14%	-43%
	Vitamine C	60	13	8	-67%	-87%

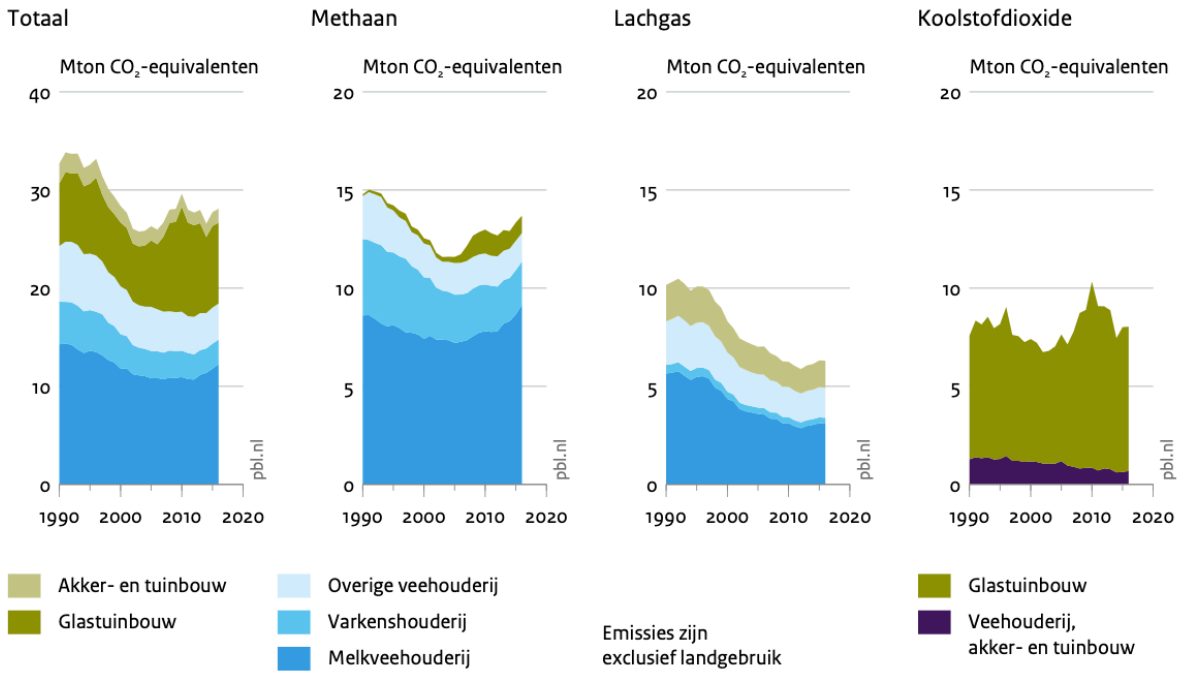


Figure B.1: Emission of greenhouse gasses by agriculture (Planbureau voor de Leefomgeving, 2018, p. 126)

C

Elaboration on the different ecosystems

Table C.1: The three different ecosystems conceptualized (Valkokari, 2015).

	Business Ecosystems	**Innovation Ecosystems**	**Knowledge Ecosystems**
Baseline of Ecosystem	Resource exploitation for customer value	Co-creation of innovation	Knowledge exploration
Relationships and Connectivity	Global business relationships both competitive and co-operative	Geographically clustered actors, different levels of collaboration and openness	Decentralized and disturbed knowledge nodes, synergies through knowledge exchange
Actors and Roles	Suppliers, customers, and focal companies as a core, other actors more loosely involved	Innovation policymakers, local intermediators, innovation brokers, and funding organizations	Research institutes, innovators, and technology entrepreneurs serve as knowledge nodes
Logic of Action	A main actor that operates as a platform sharing resources, assets, and benefits or aggregates other actors together in the networked business operations	Geographically proximate actors interacting around hubs facilitated by intermediating actors	A large number of actors that are grouped around knowledge exchange or a central non-proprietary resource for the benefit of all actors

D

Interview Protocol

This appendix describes the process of interviewing and the corresponding data management. A step that follows this process is the coding of the data as described in chapter 3. It starts by an elaboration on the interview and transcript process. An academic researcher from the TPM faculty provided this research with important interview techniques which are included in this section to outline the interview process in even more detail. Two sections in Dutch follow, as Dutch is the main language for data collection of this study. These two sections contain the introduction mail and interview questions, which can be translated on request. A final section in this appendix contains information on the data management plan.

D.1. Aim and Expected Data

Interviews are the main data collection method for this study, which makes it important to aim for unbiased data. It is, therefore, vital to collect the qualitative interview data by means of a neutral process. Above all, the study designs the interviews in such a way to optimize the collection of data on the details of the business ecosystem case-study. However, this research relies on the honesty and willingness to share information of the interviewees. So, the interview's aim is to gather as neutral and specific information as possible, but its appearance must spark enthusiasm and decency.

The expected data is directly linked to the expected results as described in chapter 1. This study expects to find qualitative data from the interviews that depict a closed business ecosystem, however, with a high synergy inside the business ecosystem. Furthermore, this study expects that the underlying technologies are sufficiently developed for a working business model, yet the business model lacks real financial improvements compared to the more traditional agriculture and horticulture industry. A last expected result focuses on the governmental support, which this study predicts to be supportive as the circular agriculture is a main priority.

D.2. Interview and transcript process

Before the interview introduction mail, initial contact with the interviewees is made. The contact information is either gathered via the desk research in chapter 4 or via a post in the LinkedIn community of "Indoor Farming Nederland". The case study selection criteria as described in chapter 3 still remains leading in finding optimal case studies.

A next procedure is to send the introduction and general information mail with the proposed questions. Since the interview is set up as semi-structured, the list of questions is merely a referencing tool. This entails that whenever the interview touches upon interesting subjects, the interviewer starts to probe. It is the interviewer that defines in the moment if a certain subject or aspect is interesting. Since the interviewer is the main author of this study, the author is sufficiently connected to the topic to justify this action.

At the start of the interview, the interviewer asks again for permission to record this interview. If the interview gets recorded, the interviewer checks the recording mechanism and takes a laptop or notebook for making notes. Key words were written down during the interview, to enhance probing and

unstructured questions. If the interviewee does not give permission for recording, more specific notes are made, which may hamper the probing.

During the interview, the interviewer tries not to express approval or disagreement. Furthermore, if the interviewee shows fatigue, a break is proposed by the interviewer. This study chooses for these procedures enhance reliability of the study, which is often seen as a drawback in case-study research.

The interviewer makes a transcript directly after interview, within 14 days, and sends it to the interviewee for verification. If the recording did not fully work, the keywords are used to fill the gaps. Due to confidentiality issues, the transcript and thesis contains solely psuedo names. A description is given of the firm and role of the interviewee. The anonymous names are linked to the actor in chapter 3. A software assisted with the transcribing part.

D.3. Introduction and general information

Ik ben Tim Koning en ben bezig met het afronden van mijn master Management of Technology aan de TU Delft. Onderwerpen die aan het licht komen tijdens deze master zijn onder andere, innovatie process management, bedrijfskunde, en management processen. Dit alles heeft als doel het leren in de markt brengen en bestuderen van nieuwe technische producten of services. Vandaar dat vertical farming mijn interesse heeft gewekt en ik mijn afstudeer opdracht heb toegewijd aan deze sector.

Voor mijn afstuderen onderzoek ik hoe een business ecosystem van partijen eruitziet die zich samen inzetten om en werkend business model rondom vertical farming te verkrijgen. Aangezien er veel technieken in de vertical farming methode worden gebruikt, verwacht ik dat deze componenten niet allen door dezelfde partij worden aangeleverd of gemaakt. Denk aan componenten zoals, LED-verlichting, een hydroponics systeem, binnen-klimaat, robotica, sensor-modules, etc. Vanwege de complexiteit van zo'n verscheidenheid aan componenten, die zich niet allen alleen voor vertical farming laten gebruiken, is het interessant om deze sector te bestuderen vanuit een business ecosystem perspectief.

Als bijlage vindt u de vragen voor het interview. Tijdens het interview is er genoeg tijd om eventuele onduidelijke vragen verder toe te lichten. Het gehele interview bestaat uit 25 vragen, die in ongeveer 75 minuten kunnen worden beantwoord. Mocht er een interessant antwoord zich voordoen, zal ik de kans aangrijpen om hier op door te vragen. Dit houdt in dat het interview enigszins kan afwijken van de hieronder voorgestelde lijst aan vragen. Uiteraard zal ik het begrijpen wanneer u niet op de hoogte bent van verder informatie of deze liever achterwege houdt.

Naast de 75 minuten aan interview, zou ik graag nog enkele minuten willen gebruiken om te kijken of al mijn vragen beantwoord zijn. Wanneer dit niet het geval is, geeft de extra ingeplande tijd mij dan de mogelijkheid om de onbeantwoorde vragen alsnog te kunnen stellen. Ik zal de uitwerking van het gesprek naar u toe mailen binnen 7 dagen. Alleen als ik uw akkoord heb ontvangen zal ik de data, louter en alleen, gebruiken voor mijn onderzoek. Verder zal ik uw naam, uw bedrijfsnaam en eventuele projecten waarover wij komen te spreken, anonimiseren. Gaat u hierop akkoord? Mag ik dit gesprek ook opnemen?

D.4. Interview questions

(Background) (5 min)

Wat zijn uw functies binnen het bedrijf geweest en wat is uw huidige functie?

Kunt u kort de geschiedenis van uw bedrijf toelichten?
Wat waren en zijn de bedrijfsactiviteiten? (Micro layer)

(Context) (15 min)

Welke diensten en producten m.b.t. vertical farming bent u gaan aanbieden? Sinds wanneer?

Waarom bent uw deze deze diensten of producten gaan aanbieden?
Hoe sluit het aan bij uw bedrijf haar missie? (Drivers, Missions)

Wat zijn de specifieke technieken en innovaties die vertical farming nodig heeft? En welke zou u als minst ontwikkeld beschouwen? (Nested context, Barriers)

Wat bemoeilijkt het aanbieden van diensten en producten m.b.t. vertical farming?
Verschilt dit per project? (Barriers)

Heeft u het idee dat uw bedrijf een competitief en/of strategisch voordeel heeft gekregen verdergaant dan de producten of diensten m.b.t. vertical farming sinds u deze bent gaan aanbieden (Drivers)?

In wat voor stadium zou u de projecten m.b.t. vertical farming beschrijven?
Wat is de gewenste uitkomst en is dit al bereikt? (Mission)

In welke mate is er verandering in het aantal externe partners?
(Stage of the Business Ecosystem)

(Construct) (15 min)

Met wat voor soort en hoeveelheid partijen werkt uw bedrijf samen om een goed product neer te zetten?
Hoe zou u uw rol en uw verantwoordelijkheid beschrijven?
En wat waren de rollen van andere partijen? (Actor Roles)

Is er een specifieke infrastructuur (fysiek, virtueel en/of data) noodzakelijk om de projecten, diensten en producten m.b.t. vertical farming tot een succes te maken? (Infrastructure) Zo ja, wat voor?

In welke mate werden nieuwe partijen actief betrokken bij de projecten m.b.t. vertical farming? Is hier ook gekeken naar circulaire stromingen? Zo ja, wat voor? (Structure, Actor roles)

(Configuration) (10 min)

Welke activiteiten zijn er noodzakelijk om een product of dienst m.b.t. vertical farming mogelijk te maken (Sequence of Activities/Value Chain)? Eigen notitie: het business process in kaart brengen.

Wat was de toegevoegde waarde voor uw bedrijf en de betrokken partijen om projecten m.b.t. vertical farming op te starten (Value Capture)? Eigen notitie: de business modellen achterhalen.

In hoeverre zijn de verbeteringen vanuit een sociaal perspectief en duurzaamheidsperspectief van belang bij de keuzes die uw bedrijf maakt? (Business Process)

(Cooperation) (10 min)

Werkt u samen met regionale, nationale, Europese en internationale bedrijven en waarom is er gekozen voor deze structuur in samenwerking (Complexity)?

Hoe zou u de onderlinge relaties met samenwerkingspartners kort beschrijven? (Relationships)

Hoe zijn de partijen onderling afhankelijk van elkaar bij de projecten m.b.t. vertical farming?
Meer specifiek vanuit uw rol: van wie was u afhankelijk en wie van u? (Interdependency)

Doorgaand op de afhankelijkheid:
Hoe zorgen alle betrokkenen voor een eerlijke winst en risico verdeling (Governance)?

(Capabilities) (15 min)

Welke competenties en houdingen zijn er noodzakelijk om projecten m.b.t. vertical farming tot een succes te brengen (Learning Adaptability, Communication & Accessibility)?

Is er sprake van informatiedeling en kennis en/of kunde deling in de projecten m.b.t. vertical farming? Zo ja, hoe uit deze zich? (Learning adaptability, Communication & Accessibility)

Deelt u een gemeenschappelijke visie of doel met de partijen met wie u samenwerkte in deze projecten? Zo ja, welke? (Integration & Synergy)

Was er sprake van co-creatie of gezamenlijk problemen oplossing? Zo ja, hoe wordt er op deze aspecten samengewerkt? (Integration & Synergy)

In hoeverre spelen investeerders en klanten een rol in het aanpassen van samenwerkingspartners of koers in het algemeen? (Adoption & Mobility)

(Change) (5 min)

Hoe verschilt de rol van uw bedrijf binnen een project m.b.t. vertical farming van een regulier project? En hoe verschilt de samenwerking met de betrokken partijen? (Renewal)

Hoe verandert de rol van uw bedrijf bij een opschaling van de projecten m.b.t. vertical farming waarin uw bedrijf deelneemt?
Hoe verandert de samenwerking dan met de betrokken partijen? (Co-evolution, Renewal)

(Afsluiting)

Is er nog andersoortige informatie over welk van belang zou kunnen zijn voor mijn onderzoek, mag ik deze gebruiken?

Mag ik u eventueel nog benaderen voor mijn onderzoek, indien noodzakelijk?

Bedankt voor het interview!