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*Exploring the Potential of Vertical Farming: A Case Study  
on Industry Practices and Future Prospects.*

by

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## Abstract

The agriculture industry faces numerous challenges, including growing population, climate change, farmland shortage, soil degradation, and water scarcity. These issues drive the search for alternative methods of food production. Vertical farming (VF), which involves cultivating crops in vertically stacked layers under controlled conditions, presents significant advantages such as reduced water usage, elimination of soil degradation, and closer proximity to consumers, thus reducing transportation emissions. Despite these benefits, VF encounters substantial hurdles, including high initial capital investments, technological dependence, and market acceptance challenges due to higher product costs. This thesis explores how the vertical farming industry can achieve scalability and profitability while maintaining its sustainable benefits.

To address that, an exploratory single-case study method is employed, incorporating semi-structured interviews with stakeholders from across the VF industry. The research framework is built on theories of business models, industry analysis, strategic partnerships, and sustainability, refined through empirical data gathered from these interviews.

The findings identify two main business models, referred to as Model 1 and Model 2. These models differ in factors such as profit formula design and channels for communicating and delivering customer value propositions. Model 1 focuses on producing high-quality, premium products for affluent consumers, requiring strong brand awareness and superior product quality. Model 2 targets the average consumer market, competing directly with traditional agriculture on price point and shelf-life.

Key recommendations include adopting a customer-centric approach, fostering collective innovation through co-competition, and meeting energy needs through renewable sources to enhance sustainability. The choice of location is critical, with hyper-localization benefiting premium models and proximity to distribution centres benefiting cost-competitive models. VF's unique selling point of providing locally produced, fresh food regardless of the season should be leveraged to distinguish it from traditional agricultural methods.

Key words: Vertical Farming, Horticulture, Business Models, Industry Analysis, Strategic Partnerships, Sustainable Agriculture

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# 1 Introduction and problem description

Recent decades have presented new challenges in food provision worldwide. These challenges stem from issues with conventional farming practices and the demands of a growing population for more efficient food production methods. Conventional farming, characterized by the use of open fields, traditional tools, and reliance on natural resources, such as soil, sunlight, and rainfall may also include the use of organic or chemical fertilizers, pesticides, and herbicides to promote plant growth and health. However, such methods are associated with soil nutrient depletion, water scarcity from excessive water use, and loss of biodiversity due to deforestation and habitat destruction (Barros-Rodríguez et al., 2021). Additionally, such methods are acutely vulnerable to climate change effects, especially in areas with high negative yield responses to changes in temperature and ones that rely on natural irrigation systems. It is predicted that global welfare losses could amount to approximately 0.26% of world GDP, representing significant economic repercussions for regions particularly susceptible to agricultural productivity declines due to climate change (Costinot et al., 2014).

One potential solution to address these global challenges is Vertical Farming (VF). This method of cultivation, conducted in a fully controlled environment, offers numerous benefits. Firstly, it eliminates the need for soil usage, thus preventing soil degradation. Secondly, it reduces water usage by up to 95% compared to traditional methods. Additionally, VF can be implemented in any environment, making it less susceptible to climate variations, which is crucial in areas prone to extreme weather conditions. Moreover, certain crops grown using this method can yield up to 12 times more produce per square meter compared to traditional agriculture. Furthermore, if produced in close proximity to consumers, VF can significantly shorten the supply chain from hundreds of kilometers and days to mere hours. This reduction in transportation time also contributes to lower CO<sub>2</sub> emissions associated with agriculture (Benke & Tomkins, 2017). Despite these significant advantages, VF currently only accounts for a small fraction, approximately 0.14%, of global agricultural production (Fortune Business Insights, 2024).

One explanation for this limited adoption is the relative youth of the VF industry, with substantial growth only observed since 2017/18 (Van Gerrewey et al., 2022). However, perhaps the business implications of operating a VF are more critical. The high initial costs associated with VF technology, coupled with the expense of land (especially if production is localized),

and the scarcity of experienced professionals in the field, make operating vertical Farms (VFs) extremely challenging. Consequently, there is a heavy reliance on investors to finance VF undertakings. These factors lead VF production to being as much as five to six times more costly to establish and maintain compared to traditional agriculture (Tasgal, 2019). This leads to many of the VF companies labelling their products at a premium price, potentially harming the demand and the market growth for VF products. Moreover, contemporary shifts in the market due to the COVID-19 pandemic, interest rate increase, and technological advancements are argued to have major implications for the practice, and it remains unclear how these shifts have affected the VF industry (Moghimi and Asiabanpour, 2021).

## 1.1 Aim of the thesis and research question

The presented problematization highlights the purpose of this research, which is to discover and understand the underlying factors that affect the business prospects of the VF industry. To achieve this, the authors reviewed and discussed theories, concepts, and tools related to business models, industry analysis, strategic partnerships, and sustainability, creating a preliminary framework that includes these categories. This framework was then assessed against empirical results gathered through interviews. The final goal of the thesis is to answer the research question posed as:

*What are the Future Business Prospects of Vertical Farming: How can Vertical Farms achieve sustained profit while operating in environmentally and socially sustainable ways?*

Through this, this work aims to provide practitioners with practical insights into the VF industry and enrich the academic literature on VF.

## 1.2 Structure of the thesis

Following the introduction, Chapter 2 provides a literature review that discusses key theories, concepts, and tools used to understand and assess the business perspectives of VF. Based on this review, Chapter 3 presents a preliminary framework derived from identified gaps in the literature and the subject of this research. Next, Chapter 4 introduces the justification and

description of the methodological aspects used in gathering empirical results, which are later discussed. Additionally, it addresses methodological limitations, ethical considerations, and the validity of this thesis. Chapter 5 aims to describe the empirical results gathered through interviews with stakeholders, structured according to the guidelines presented in the preliminary framework and methodology. Chapter 6 presents a revised framework based on the empirical results. Chapter 7 discusses the gathered findings, assessing them against academic literature and secondary sources. The final chapter concludes the thesis, addresses its limitations, and suggests future avenues for research.

## 2 Literature Review

### 2.1 Introduction to Vertical Farming Industry

VF is a contemporary agricultural practice and a subset of indoor agriculture, which, as the name suggests, occurs indoors (e.g., in greenhouses). VF involves the cultivation of crops in vertically stacked layers within entirely controlled environments, a critical aspect from a business perspective. Researchers suggest that a significant technological breakthrough for VF was the development of LED lamps, which replaced solar energy in the cultivation process, thereby enabling the emergence of VF (Van Gerrewey et al., 2022).

The concept of vertical farming dates back to ancient times, with examples like the Hanging Gardens of Babylon. However, the contemporary form of VF can be traced back to 1999 when Professor Dickson Despommier and his students at Columbia University conceptualized using high-rise buildings for food production to reduce the carbon footprint and bring food production closer to urban centres (Al-Kodmany, 2018). Since 2018/2019, VF has gained significant momentum, drawing numerous new entrants and substantial investments. This growth was driven by the rising demand for sustainable food production solutions that can operate independently of weather and soil conditions, especially in urban areas (Van Gerrewey et al., 2022).

There are three primary cultivation methods used in VF: hydroponics, aeroponics, and aquaponics. Hydroponics involves the growth of plants in a soil-less environment, where a nutrient-rich water solution is directly delivered to the plant roots. This method necessitates rigorous control and adjustment of the nutrient composition to maintain optimal plant growth conditions within a controlled environment. Aeroponics, by contrast, employs a soil-less cultivation approach wherein plant roots are suspended in the air and intermittently misted with a nutrient solution. This technique facilitates enhanced oxygen exposure to the roots, resulting in more efficient nutrient uptake and rapid plant growth. Aquaponics integrates hydroponics with aquaculture, creating a symbiotic system where fish waste functions as a plant's natural nutrient source. At the same time, the plants purify and recirculate the water (AlShrouf, 2017).

### 2.2 Business Models Theory

Although scholars agree that there is not one common definition of what a business model is, it can intuitively be understood as a description of company structure as well as ways and processes through which it achieves its goals of profitability, impact, growth etc. (Massa, Tucci & Afuash, 2017). Among many definitions, Amit and Zott (2021) described it as a visualization of transaction content, structure and governance used to create value through the exploitation of business opportunities. A similar approach was earlier proposed by Teece (2010) who described a business model as an outline of the business logic and go-to-market strategy used by an enterprise to provide value to customers and transfer it to profit.

Over the years, researchers have explored the concept of business models from various perspectives, including innovation, strategy, and sustainability. This approach has led to the creation of multiple frameworks for structuring and analysing a company's business model. A notable tool is the Business Model Canvas, developed by Alexander Osterwalder & Yves Pigneur (2010). This framework consists of nine building blocks that describe the logic behind a company's operational activities and revenue generation. These blocks are categorized into four essential areas of business operations: offering, customers, infrastructure, and financial viability. The Business Model Canvas is commonly used in entrepreneurial settings as a gateway to deeper analysis of value proposition, strengths, and weaknesses, or to identify areas for improvement (Salwin et. al, 2022).

From the later analysis of business models in VF, it is also important to talk about business model innovation. This is especially relevant for new, growing industries where best practices have not yet been established. Gambardella and McGahan (2010) argue that a company innovates its business model when it adopts a new strategy to commercialize its assets. While history records some radical business model innovations that have brought significant success to various companies, such as the Spotify music streaming model (Vroom, et. al, 2021), these cases are extremely rare. Among the reasons, one explanation highlights two main challenges in business model innovation: the lack of clear definitions and research on business model development and a generally low understanding of the existing business model by internal stakeholders (Johnson et al, 2008). To refine business model developed, Johnson et al. (2008) proposed a three-step process: identifying or creating a customer value proposition (CVP), designing a profit formula, and identifying key resources and processes. The CVP is described by the authors as "the job to be done," which entails understanding how the product satisfies the needs of targeted customers. The profit formula consists of four elements: revenue model,

margin model, cost structure, and resource velocity. It delineates the financial framework that companies use to ensure operations are financially viable and profitable. Key resources and processes include factors such as technology, distribution channels, and marketing strategy, which enable a company to deliver value to the market (Johnson et al, 2008).

Additionally, they recommend that business model innovation should only be undertaken under specific circumstances, such as to meet the needs of large groups of potential customers who are excluded from a market or to capitalize on a brand-new technology by adopting a business model around it (Johnson et al, 2008).

### 2.2.1 Business Models in Vertical Farming Industry

As previously mentioned, VF is a relatively new industry with limited research on its business models. Nevertheless, technological advancements and accessibility of capital before 2023 enabled entrepreneurs to devise various operating models. These models differ in scale, cultivation method, revenue streams, and cost structure. When considering scale, it is crucial to distinguish between modular solutions catering to small B2B clients and individuals interested in home food production—and larger, centralized VFs. The latter typically function as wholesalers to retailers or restaurants (Marius-Catalin, 2022).

The literature on VF identifies several key revenue streams that contribute to the sector's economic viability. Among these, the sale of fresh produce stands out as a main one. This includes direct sales to consumers via farmers' markets, online platforms, and partnerships with retail entities. Such direct-to-consumer channels enable VFs to capture a larger portion of the value chain. Moreover, they offer the potential to command higher prices, attributed to the produce's perceived superior quality and local origin (Moghimi & Asiabanpour, 2021). Additionally, offering proprietary technology and expertise to other entities within the agricultural sector represents another vital revenue stream. VF companies can license their technologies and accumulated expertise, particularly to traditional greenhouse operators or new entrants to the VF market (Butturini & Marcelis, 2020). The literature also identifies the use of data and analytics services as a potential source of revenue. VFs accumulate substantial real-time data on crop growth, which can be utilized to provide insights and decision-support tools

to other entities in the agricultural sector, such as traditional farmers or technology suppliers (Moghimi & Asiabanpour, 2021).

The cost structure of VF is often characterized by significant initial investment and operational costs, which are higher compared to traditional farming or high-tech greenhouses. The initial investment per square meter of cultivation for a VF can be up to 10 times higher than that of a high-tech greenhouse (Butturini & Marcelis, 2020). The high costs are generally associated with infrastructure, advanced technologies, and energy consumption, especially because of the heavy reliance on artificial lighting needed to grow plants indoors. The high use of artificial lighting makes VFs less energy-efficient compared to greenhouses (Butturini & Marcelis, 2020).

## 2.3 Industry Analysis Theory

Understanding the nature of industry competition and firm strategy has been an important point in strategic management research. Industry analysis theory seeks to explain the enduring question of why certain firms consistently outperform their competitors within the same industry. The following literature review covers models and frameworks used to describe competitiveness of the industry, and factors that influence it.

The earliest approaches, based on industrial organization economics, offered models like the Structure-Conduct-Performance paradigm, suggesting that a firm's performance, reflected in its profitability and efficiency, is determined by the industry structure it operates within. This includes elements like the level of competition, the number of competitors, and barriers to entry. The SCP model specifically posits that a highly concentrated market structure, dominated by a few large firms, leads to less rivalry and higher profits, whereas a fragmented market structure leads to fierce competition and lower profitability (Panhans, 2023).

Porter's Five Forces Framework is another cornerstone of the industry analysis theory, providing a systematic approach for evaluating the five main competitive forces within an industry. The threat of new entrants encapsulates the potential challenges posed by new companies entering the market, which can lead to increased competition and pressure on prices and profitability. The bargaining power of suppliers examines how the dominance of suppliers

may impact the costs and availability of materials, thereby influencing production processes and profit margins. Similarly, the bargaining power of buyers highlights the influence that customers wield in an industry, with the power to demand lower prices or higher quality. The threat of substitute products or services takes into account the presence and viability of alternative offerings that could potentially replace the industry's products, often leading to competitive pricing and product differentiation. Lastly, the rivalry among existing competitors shows the intensity of competition within the market, which affects price points, marketing strategies, and overall industry profitability (Porter, 2008).

One of the fundamental models used to assess the influence of external macroeconomic factors on an industry is the PESTEL model, an abbreviation for Political, Economic, Social, Technological, Ecological, and Legal. This model comprises six dimensions, allowing for the assessment of the current business environment and supporting predictions of potential changes. Political factors include aspects such as political stability and political trajectories. Economic factors encompass variables like exchange rates, labor quality, and the country's GDP and its impact on the labor market. Social factors cover elements such as demographic structure and education levels. Technological and Ecological factors, particularly significant in the context of VF, address the region's technological development and ecological considerations, including soil and water pollution levels and societal attitudes toward environmental preservation. Finally, the Legal environment considers factors such as labor regulations, and requirements and guidelines for establishing businesses (Walsh, 2005; Kolios & Read, 2013; Vasileva, 2018).

SWOT analysis (an abbreviation for Strengths, Weaknesses, Opportunities, and Threats), a tool first described by Learned et al. (1969), is one of the key methods used for structuring the external and internal factors crucial to business operations. While it is often employed for developing company strategies, researchers agree that it can also be utilized to assess the complexity of an industry (Helms & Nixon, 2010). The first internal element, Strengths, refers to the capabilities and positive factors that enhance an industry's ability to deliver value and improve its competitive position e.g. highly skilled workforce available on the market. Secondly, Weaknesses are internal factors that may hinder industry performance, such as high initial costs. Opportunities are external elements that can favour or improve a company's position through factors outside the industry, such as social movements that may increase industry visibility. Finally, Threats are negative external factors that may impede industry



development, e.g. a rise in interest rates if the industry is heavily dependent on external financing (Helms & Nixon, 2010; Namugenyi et al., 2019).

Simultaneously, strategic management research evolved from static models of competition to dynamic theories such as competitive dynamics and evolutionary economics. While traditional models focus on equilibrium states, competitive dynamics emphasize the importance of ongoing actions and reactions among firms in shaping industry landscapes. These are tactical and organizational context-based movements that lead to long-term impacts on firm performance and can be described as sustainable competitors' advantage (Huang et al., 2015).

In summary, the literature on industry analysis theory presents a broad range of models, frameworks, and perspectives that have evolved to address the complex realities of business environments. Moving from static, structure-oriented views to dynamic, resource-based, and capabilities-driven approaches, the theory offers a robust toolkit for diagnosing and navigating the strategic landscapes that firms encounter (Saadatmand et al., 2019).

### 2.3.1 Industry Analysis of Vertical Farming

As previously mentioned, the VF industry is relatively new, therefore, there is limited access to research assessing its competitive factors or analysing it through various industry frameworks such as Porter's Five Forces, PESTEL, or SWOT. However, certain academic efforts have been made in this direction, and numerous business articles and analyses by third-party consulting firms have also addressed this topic.

From an economic standpoint, the VF sector witnessed consistent expansion beginning in 2018, with a short market decline in 2022. This downturn was primarily due to a significant pullback by investors, triggered by a loss of confidence in the sector's stock market performance. This shift led to substantial financial challenges for several major companies within the industry. Notably, AeroFarms, one of the leading VF companies was among the firms that encountered severe financial distress, leading to bankruptcy filings. The market correction reflected broader concerns over the economic sustainability and operational models of VF ventures, prompting a re-evaluation of investment priorities and business strategies within the sector (Klein, 2021). However, the industry is expected to achieve sustained market size growth, with a forecasted compound annual growth rate of 27.3% (during the period from 2022 to 2032) supported by

an increasing global population and the rising demand for locally sourced food products (Statista, 2021).

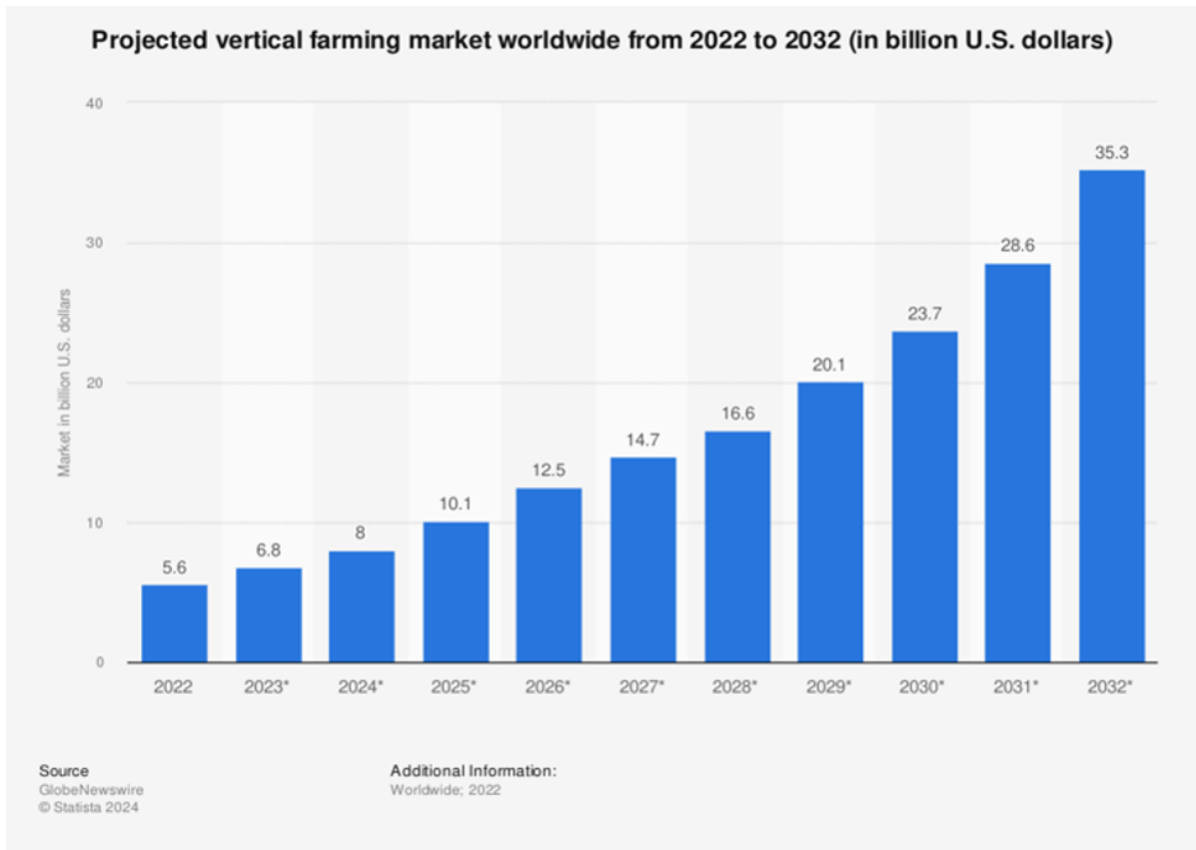


Figure 1. Global market projection for VF 2022 – 2032 (Statista, 2023)

The researchers foresee potential industry growth in advancements in energy-efficient lighting, automation, and climate control systems which have the potential to significantly reduce long-term operating costs. Furthermore, the ability to produce crops year-round, independent of weather conditions, leads to more predictable and potentially higher yields compared to traditional farming (Moghimi & Asiabanpour, 2023). This could result in a competitive edge for VFs, particularly in urban environments where fresh produce typically commands higher market prices. Moreover, policy tailwinds, such as urban agricultural zoning and green city initiatives, coupled with public interest in sustainable production methods, offer additional support to the VF model. However, achieving economic sustainability will likely depend on continuous technological advancements and reducing the cost of inputs. This is particularly important if the sector aims to compete with traditional agriculture, which is often strongly subsidized (Moghimi & Asiabanpour, 2023).

Another analysis of the industry was conducted by Sanne Van Asselt (2018), who used a SWOT framework for the evaluation. The paper describes that the strengths of VFs often lie in their innovative technologies, high-efficiency production systems, and the ability to produce high-quality crops without using pesticides. Additionally, intensive production in limited spaces and proximity to urban populations, which shortens a supply chain significantly, is also an important benefit compared to traditional agriculture. On the opportunities front, VFs are uniquely positioned to contribute to a sustainable, circular economy and can benefit from the growing interest in energy-efficient food production systems. The analysis also outlines significant threats, including technological advancements in greenhouses, such as nanotechnology, which could mitigate the quality advantage of VFs. Social and economic barriers also threaten the industry; public perception issues and reluctance to pay higher prices for vertically farmed produce could affect market viability. Additionally, political factors, such as urban development planning that fails to support or explicitly allow VF developments, could further restrict the industry's growth (Van Asselt, 2018).

The author also developed a PESTEL analysis to assess the macroeconomic factors influencing the VF industry. This analysis highlighted that government policies, including subsidies and incentives for innovation, could significantly impact VF's growth. Furthermore, the analysis indicated that unexplored opportunities for new revenue sources exist within niche markets. An example is specialized restaurants seeking specific tastes from their products, achievable only in the controlled environments of VFs (Van Asselt, 2018).

## 2.4 Partnerships Theory

VF involves a number of different disciplines, including agricultural science, data analysis, engineering, and biology. It requires collaboration among these parties and the facilitation of innovative ideas (Van Delden et al., 2021). Hence, in exploring the business prospects of the practice, the crucial aspect of partnerships is being considered to analyse the value that is created through the relations of these parties, with the purpose of identifying important benefits or challenges that might be encapsulated in the industry.

The term 'partnerships' may be too vague to allow for a deep exploration of the topic, as it does not necessarily encompass the innovative nature, complementarities, substitute relations,

and interactions between involved actors. Therefore, a more accurate term might be “innovation ecosystem” (Adner and Kapoor, 2016). The most widely recognised definition of an innovation ecosystem is that of Granstrand & Holgersson (2020) which explains “*An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors*”. Through this definition, the concept of co-competition is also recognised as an alternative method to collaboration that fosters inter-firm relations within innovation ecosystems (Bacon et.al., 2020). It may also be worth noting that, instead of a business ecosystem which is focused on value capture, an innovation ecosystem is related to value creation (Gomes, et.al., 2018).

Value in an innovation ecosystem can be created through a number of factors. Gomes, et. al., (2018) suggests that knowledge sharing can lead to the co-evolution of innovative capabilities. In line with this research, Wang et.al., (2023) highlights the importance of connectedness among organisations, as well as the crucial role of collaborating with universities and research institutes, which leads to increased knowledge transfer, as well as enterprise-specific talent cultivation. Actors in such ecosystems also benefit from exchange of tangible resources e.g. human capital or technology (Gomes, et.al., 2018). Although this paper is not discussing implications regarding intellectual property, it is worth noting Holgersson’s et.al., (2018) research, which suggests that the complementarity and substitution of appropriability regimes are vital aspects for efficient strategic management in dynamic innovation ecosystems.

Regarding the role of investment attractiveness in innovation ecosystems, Rossi et.al., (2022) suggest that corporate venture capitalists (CVC) contribute significantly to the growth of innovative firms in innovation ecosystems. It is noted that investing in emerging companies enables CVCs to fend off threats to the core business. However, after an initial period, the strategy may change and CVCs may search for opportunities to build ecosystems around existing platforms and products, and act as developers, facilitators and accelerators. (Rossi et.al., 2022). To allow for flexibility and enriched data collection, this paper is not focusing solely on one type of investor.

A study by Oskam et.al., (2021) has looked at tensions that may rise from value disputes (e.g., value capture vs value creation) in ecosystems with sustainable business models. One of the collaboration methods suggested by Oskam et al. (2021) involves a combination of private and

public organizations that formulate clear, common sustainability goals through reciprocity and concurrency. This approach incorporates economic, environmental, and social values, and aims to avoid individual versus collective value disputes (collective orchestration).

It is argued that in cross-sectoral partnerships, the public sector may also choose to be involved, especially when the collaboration implies sustainability purposes (Oskam's et. al., 2021). Carbonara & Pellegrino, (2020) suggest that in order to foster innovation in public-partner partnerships (PPP), retention of ownership from the private sector should be preferred to scheme with low participation of the private sector. However, Brogaard, (2021) indicate that partnerships between the public and private sector involve high risk and high level of uncertainty, as it may include different interests and conflicting motives between the parties.

Looking at the agricultural sector, the EU is strongly emphasizing innovation by financially supporting multi-actor projects across Europe, highlighting the urgency for innovation in the field (EIP AGRI SP, 2017). However, Fieldsend et.al., (2022), and has also discovered a great number of actors (NGOs, academics, businesses etc) that are involved in co-innovation activities without being funded, but driven by the outputs of the project, and enthusiasm regarding advancing innovation, new knowledge and solutions. It is worth noting that, although the shared notions of groups in an agri-food ecosystem can shape the accumulated values of individuals actors into one shared value, similar actors in identical conditions can still make conflicting decisions (Gutiérrez & Macken-Walsh, 2022).

#### 2.4.1 Partnerships in Vertical Farming

The formation and maintenance of a sustainable innovation ecosystem in VF is a crucial component that directly affects the business prospects of the practice. Sharma et.al., (2023) argues that one of the challenges in VF is that specialised technical knowledge is vital for to setting up and operating the farms in the initial stages. Specifying optimum locations, regulatory trajectories and commonly agreed standards and practices require the establishment of multi-sectoral innovation ecosystems that unify stakeholders, such as entrepreneurs, urban planners, real estate sector, agricultural-technology companies and NGOs (Van Delden et.al., 2021). Hence, the importance of inter-firm relations in the industry is highlighted.

Lubna et.al, (2022) highlights that the VF industry suffers from a lack of collaboration and data sharing, and high innovative activities are not being shared due to the secretive nature of the practice. Lubna et.al., (2022) also argues that companies could have saved a lot of effort if more openness and collaboration existed in their resource consumption and growth strategies. The lack of efficient collaboration was also examined by Ryymin et.al., (2020), who has looked at multidisciplinary collaboration in VF, and has recognised the difficulty for researchers in the field to decide on a common research idea.

In recent years, evidence suggest that the public sector has increased interest in facilitating the innovation ecosystem of VF. More specifically, Asia is seeing major investments and subsidies urban agriculture, including VF (Van Delden, 2021). In China, governmental policies and subsidies are directly looking at the prospects of VF, with a similar landscape being present in Japan, Taiwan, and South Korea (Oh & Lu, 2023; Teo & Go, 2121). Evidence suggest that the US has not introduced any specific policies or initiatives directly to VF, apart from general loans and grant programs directed to the wider agricultural sector (Teo & Go, 2021), which reflects the inflexibility of the policy design in the US to adapt in the changing shape of agriculture and address challenges, in comparison to the EU (Blandford and Matthews, 2019).

According to Van Delden (2021), European policies and initiatives that are directed to agriculture in Europe are mostly limited to R&D instead of practical uses, and a few popular agricultural schemes have not been modified to include practices such as VF. Contrary to this, Butturini's and Marcelis' (2020) research contains numerous examples of successful collaboration in the European landscape regarding VF. This research also highlights an interest of major supermarket chains in partnering with VF companies (e.g., Ocado, Amazon Fresh, Coop). In line with the aforementioned evidence about CVCs, Petrovics & Giezen, (2021) agree that venture capitalists are the most common type of investor in VF, especially in the context of North America.

Research on VF practices and private-public collaboration in Singapore stands out compared to other cities (Diehl et al., 2020; Wood et al., 2020; Song et al., 2022; Tablada et al., 2020; Mok et al., 2020). Therefore, increased focus on this area is appropriate. Diehl et.al., (2020) suggests the planning agencies of Singapore have increased inter-agency collaboration, transforming commercial agriculture through land use multiplicity, and providing businesses of multi-functional urban farming flexibility and overlapping use of land. In line with this, the

collaboration in Singapore between the government, commercial firms and research institute may have increased because of the “30 by 30” goal, seeking to fulfil 30% of the city-state's food security needs by 2030. Same study also illustrates the successful collaboration between Sky Greens, a leading firm in the VF industry and the government, regarding the implementation of urban farming ventures in the city-state (Song et.al., 2022). Finally, Van Delden et.al., (2021) suggests that VF products can be labelled as organic in Singapore, whereas in Europe, Canada and US most VF products do not meet the policy criteria for being labelled organic.

## 2.5 Sustainability Theory

In the process of exploring what enables, or hinders the business prospects of VF, this study should also be concerned with the sustainability aspects of the practice, as the correlation with sustainability and business prospects has been widely accepted in the field (Chandler, 2021; Hart, 1995; Hart & Milstein, 1999; Geissdoerfer et. al., 2018; Elkington, 1998). This calls for establishment of a mutually agreed academic definition of sustainability.

Formal literature does not seem to mutually agree on a common definition of sustainability (Moore et al., 2017). Some scholars suggest that sustainability involves a comfortable way of life, within the means of nature (Milne et al., 2006). Others argue that sustainability is the wide concept of balance between economic development, environmental stewardship and social equity (David Lee et al. 2016). These three areas are also referred to as “triple bottom-line”, a term that was coined by Elkington, (1998), which suggests that it is imperative to consider the aforementioned three dimensions in order to achieve sustainable outcomes. The most widely cited definition of sustainability is that of Brundtland et al. (1987), which defines sustainability as *“the need for development that meets present needs without compromising the ability of future generations to meet their own needs”*.

Sustainability has been closely linked with both the development and survivability of firms. In contemporary business literature, the concept of sustainability is often used as a synonym for sustainable development (Elkington, 1998; Dyllick & Hockerts, 2002). The notion of corporate sustainability is also frequently linked with the strategic management and profitability of the company, and the increasing attention in this area is evident in modern literature (Chandler,

2020; Dyllick & Hockerts, 2002; Steurer et.al., 2005). Sustainability in a corporate context suggests that if companies operate in a way that benefits the environment and society, as well as communicate their sustainable actions to stakeholders, they can simultaneously increase their own value (Kraft & Zheng, 2021; Porter & Kramer, 2011). In line with this argument is the fundamental theory about stakeholders, which suggests that companies should aim to create value for all stakeholders, not just shareholders. This approach can promote long-term survivability, ethical responsibility, risk management, innovation, and social approval (Freeman, 2010).

The growing recognition and significance of sustainable transformation could also lead to a general shift from traditional business models to “sustainable business models”. These models integrate sustainability principles into their value propositions, processes, and delivery activities (Geissdoerfer et al., 2018). Furthermore, a sustainable business model emphasizes multi-stakeholder management, generating financial and non-financial value for various stakeholders and prioritizing long-term corporate viability over short-term financial profits (Moss Kanter, 2011).

Recent studies have aimed to unify and synthesize sustainable business model strategies, identifying nine so-called "archetypes." These fall into three different domains: Environmental Archetypes, which focus on ecological sustainability, resource efficiency, and the use of renewable energy; Social Archetypes, which are centred around social responsibility and limiting excessive consumption; and Economic Archetypes, which emphasize inclusive value creation, value distribution and the development of scalable solutions. (Ritala et al., 2018).

Companies also may operate in this way as a response to external pressure. The action that companies take is widely defined as Corporate Social Responsibility (CSR) (Porter & Kramer, 2011). The notion of CSR has been analysed thoroughly, and should not be repeated here (Dahlsrud, 2008). Arguably, a successful CSR strategy can not only secure the legitimacy / image of the brand from erosion and reputational threats, but it can also provide a widely positive impression of the firm to stakeholders, maximising profit and preparing the firm for future legislation (Werther & Chandler, 2005). Hart (1995) also adopts a similar stance, investigating how competitive advantages can be gained through more sustainable use of natural resources. However, it is worth noting that, although CSR practices have been correlated with improved business prospects, actual impact on society and the environment has been



frequently debated, as the effort of companies is related with the “brand image” derived of CSR, instead of actual value (Matten & Moon, 2008).

Companies that include CSR strategies are also favoured by investors. In a study that analysed events in the Dow Jones Sustainability World Index (DJSI), publicly listed companies with sustainability “events” attracted increased attention from financial analysts, and investors that were focusing on long-term investments (Durand et.al., 2019). In line with this, companies with CSR initiatives also seem to attract private investors that aimed for long-term returns (Jansson & Biel, 2011).

Porter and Kramer (2011) offer another perspective by introducing Creating Shared Value. They define it as generating economic and social benefits in relation to costs, emphasizing social value creation and sustainability as essential to profitability and competition, and integrating it throughout the company's operations and budget. However, the literature disagrees on how sustainable practices should be approached. Recognising the increased cost that may occur from pursuing sustainable practices, Bertini et. al., (2021) suggest that sustainable companies should rethink their pricing strategies and create new ways of pricing their products, in order to accommodate the higher cost of products.

Contrary to Porter & Kramer’s (2011) suggestions, Chandler (2021) indicates that profit is the best measurement of value companies currently have, as he does not frame it as an independent measurement from other types of value (social, ethical moral etc). However, he argues the concept of profit maximization is misleading and not helpful for firms. Instead, he puts forth *profit optimisation* as a better depiction of the value decisions that firms make to balance competing stakeholder interests (e.g., shareholder interests and socio-environmental issues).

### 2.5.1 Sustainability in Vertical Farming

A major part of literature regarding VF has been thoroughly discussing the many correlations of the industry with sustainability practices. Research that thoroughly discusses sustainability in the target practice argues that this method yields high crop without use of soil and minimal use of land, enabling continuous crop production regardless of weather conditions, while minimizing the need for chemical pesticides (Oh & Lu, 2022). In line with this argument, another study highlights the benefits of VF regarding the significantly shorter supply chain, eliminating threats of pests, reducing food waste by minimizing transport spoilage, while also

extending the shelf-life of products (Van Delden et al., 2021). Moreover, the reduction of greenhouse gas (GHG) emissions by elimination of feed transportation is also noted, as VFs have been placed in urban areas, close to the consumer (Van Gerrewey, et. al.,2022). However, there is lack of data regarding the accurate numbers of GHG emissions reduced by the practice, which might be due to the early phase of the industry.

Van Gerrewey's (2022) study, which focused on hydroponics suggests water usage is also reduced by around 90% compared to traditional farming. However, Van Delden et al., (2021) suggests that VF is not unique in its water reduction efficiency, as enclosed greenhouses with ongoing cooling could produce similar outcomes. Furthermore, Sharma's (2023) study suggests that aeroponic systems use 90% less water than hydroponic systems, while plants grow faster through this method. Contrary to insights on usage of soil and water, it is highlighted that electricity in VF is considerably higher than in greenhouses and field farms due to the high demand for artificial light through LED light (Jin et.al., 2022). However, this is argued to depend on the type of energy source that powers the farm (Van Gerrewey, et. al.,2022). On that note, a study indicates that the combination of VF with renewable sources is optimal, while optimising energy usage through demand response control could reduce power consumption by 5% to 30% (Arabzadeh et.al., (2023).

The literature is less agreeing regarding the social impact of VF. On one hand, the increased transparency from placing production in urban areas may benefit the trust and awareness of customers through transparency on their sustainability practices (Kraft & Zheng, 2021; Van Delden et al., 2021). On the other hand, it is noted that food produced through VF may be accessible only to elite groups of customers (Van Delden et al., 2021). Additionally, the public may perceive this food as “monster food” due to the factory-like image of the farming technique (Benke & Tomkins, 2017). However, it is worth noting that realising the customer's perspective of the industry is not within the main goals of this research.

Looking at VF with the available data through Geissdoerfert's et al (2018) archetypes, the practice is correlated with almost all the categories of a possible sustainable business model, excluding delivering functionality rather than ownership, as the consumer would still own the end product. It may be conditionally correlated to “Maximising material and energy efficiency”, if the aforementioned issue of increased energy is deducted. Being a bottom of the

pyramid solutions could also be debated, as currently, products of VF are being sold at a premium price (Butturini & Marcelis, 2020).

Looking at the topic through Freeman's (2010) perspective, the VF industry is directly addressing the needs of the environment, society, the shareholders, the governments, the partners and companies themselves (Van Delden et. al., 2021). Both Porter & Kramer's (2011), as well as Chandler's (2021) perspective align with VF as a practice, as its essence aligns profit and shareholder value with socio-environmental interests, by addressing food security issues, resource scarcity issues as well as high GHG emissions, making the need for profit optimisation evident (Van Gerrewey et. al.,2022; Sharma, 2023). Additionally, Van Gerrewey et.al., (2022) argues that food security can be enhanced by increasing the self-sufficiency of food in places with limited resources or urban settings. However, contrary to Porter & Kramer's perspective, VF would still produce socio-environmental value if suppliers were chosen solely based on increasing profit, as the products and operations of the industry have inherited socio-environmental value (Van Delden et.al., 2021).

It is also argued that sustainability in VF makes the industry a relevant solution for sustainable cities. Among other factors, a sustainable city must possess the means to accommodate the growth of its population, to preserve and protect the earth's resources for future generations, to use buildings efficiently, to improve water security and to reduce food waste (Sodiq et al., 2019). Considering these factors, in combination with the sustainability aspects that have been explored so far, VF could be considered an ideal food solution for such an environment, and further exploration regarding the implementation and implications of this could be of use to the field.

### 3 Preliminary Framework

From the literature review, it is possible to recognize that three main areas are directly involved with the fundamental questions of this research: the areas of business models, the area of industry (and investment), and the area of partnerships. Because the area of sustainability is evidently heavily intertwined with the business models of the practice, but also contains the outcomes that the industry could offer by scaling up, it is deemed appropriate to look at it as an "umbrella" that overlays the areas of focus. Moreover, a number of categories that directly relate to the core of each area have been recognized (Figure 2). These areas and categories that

provide the foundation for the preliminary framework are the product of combining previous literature, primarily from the research fields of business, strategic management, innovation, agriculture, and sustainability. By following this method of specifying areas and categories, this paper aims to maintain the frequently mentioned balance between narrowness and broadness in the definitions of different elements of a preliminary framework or template (King, 2004).

Nevertheless, although the establishment of these areas allows for the identification of categories that serve to specify the aspects that influence the business prospects of VF, it is vital to recognize the preliminary character of these areas and categories, as well as the exploratory nature of this paper (King, 2004). The broad views of “business prospects” or the attractiveness of investment in the VF industry make this notion all the more important. Although the approach that the literature review followed allowed for a field of view in potential areas and categories, many of the articles reviewed had a specific focus and were created in various circumstances. Proof of this may be that much of the literature and articles that were reviewed focused on sustainability and food security, cost structure, technological viability of the practice, or viability in specified geographic areas (e.g., Dahlberg & Linden, 2019).

For instance, research indicates that VF could take a leading role in the future of food security and food production that positively influences the triple bottom line (Benke & Tomkins, 2017), which directly relates to the sustainability aspects of the practice. Another instance may be the paper from Van Delden (2021), which discusses how various compartment areas, ranging from technology to socio-economic aspects, could work in harmony in order to lead to the upscaling of VF. This context is fundamentally different from this research, which is assessing the business prospects of VF and all that defines it as an attractive or unattractive industry. Moreover, many of these studies were conducted prior to major events, such as COVID-19 and AI advancement leaps, which are argued to be major factors of influence in the industry (Shahda & Megahed, 2024; Chowdhury et al., 2023). There is no doubt that utilizing this literature is still considered legitimate, as the direct connection between business prospects and business models, industry circumstances, partnerships, and sustainability is evident, and it is particularly useful to shed light on the premature literature of VF compared to other forms of

farming. However, the varying circumstances and exploratory nature of the research need to be recognized, and modifications to the preliminary framework may be required.

Therefore, the literature review indicates the research gap in the viability of contemporary VF as a business practice with no restrictions on geographical location. This indicates that, although previous research may enhance the depth of the specified aforementioned areas individually, this view may have been at the expense of failing to notice critical factors that could have been visible if the areas and categories were viewed from the perspective of future business prospects. Hence, while the literature review and the areas or categories serve as a sense of direction for further exploration and analysis of underlying factors, they should by no means be considered final.

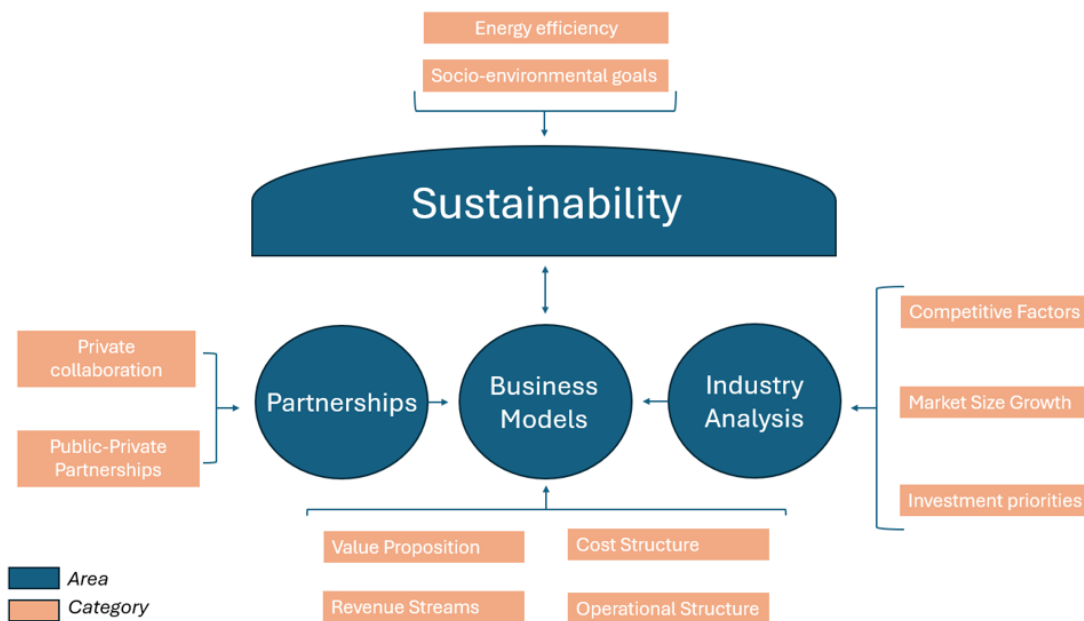


Figure 2. Preliminary framework of possible areas and categories influencing the business prospects of VF based on the literature review

## 4 Methodology

### 4.1 Research design

Maxwell (2012) argues about the great importance of understanding the goals of a research through the framing of the research question. The author highlights that distinguishing between practical (*accomplishing something*) and intellectual goals (*understanding something*) is crucial to forming a coherent argument in qualitative research. Although practical objectives are argued to be crucial in justifying the research, these should be achieved through the study, and consecutively, through the framing of the question, which prevents practical goals interfering with the rationality and feasibility of the research design. Hence, intellectual goals are prioritized. In line with Thabane et al. (2009), it is crucial to reflect on the research question and aim to understand the factors that affect the future business prospects of VF.

The research of Creswell & Creswell (2023) suggests that concepts observed as “immature” due to the lack of relevant literature require an exploratory approach, as they may recognise unexpected factors and phenomena. This leads to the belief that structuring this research with a qualitative method may be the optimal approach. Relating back to the goals of this study, this argument is furtherly enhanced by Glaser & Strauss, (2017), who support that through a qualitative study, it is possible to recognise unexpected factors and phenomena, and construct new “grounded” theories about explaining these factors. Regarding the topic of this paper, it is important to identify the factors that hinder or enable the business prospects of VF. The underlying purpose is to enrich the literature on this aspect of the industry and examine potential practices from a business perspective.

In the context of searching for a *cause*, it is argued that field research is superior to quantified approaches at explanations of specific events and processes that lead to particular outcomes, otherwise known as *local causality* (Maxwell, 2012). Hence, it seems natural to elaborate on why a quantitative approach could hinder the objectives of this research.

According to Creswell & Creswell (2023), a quantitative study builds upon existing theories and tests the correlation between variables, tests causal relationships, observes patterns and generalizes results. He also suggests that quantitative data need to be measurable in numerical values. As it has been observed from the literature review, there is extremely limited evidence

and concrete data that can be quantified and generalised regarding the correlations between the business prospects of VF and its factors. Although Maxwell (2012) points to the argument that both quantitative and qualitative approaches attempt to test causality, he suggests that the question regarding causality is different in each approach. A quantitative approach would assess the extent that variance in x causes change in y, while a qualitative approach would ask *how* x contributes to causing y. Hence, it could be argued that when the factors are not known, and have only been superficially speculated, a quantitative approach would be unsuitable.

As a qualitative approach has been decided upon, further attention on the nature of this method is needed, in regard to how inductive, or deductive the research design should be (Armat et. al., 2018; Creswell & Creswell, 2023; Maxwell, 2012). An inductive approach is appropriate when there is absence of, or limited prior research findings (Mayring, 2014). Although this approach suggests that initial direction is provided by being conscious of the research question, the aims of the study and relevant assumptions, the researcher's mind should be open to new categories and new insights that emerge through the study "*inductively*", and those should be included in forming the research conclusions (Bernard, 2011). It is worth noting Strauss & Corbin's (1990) perspective, that an inductive approach is one without any preconditions. On the other hand, a deductive approach is when previous research has adequately enriched the topic of interest, and the research structure follows pre-existing categories and previous findings (Mayring, 2014). In this study, there are no pre-established categories regarding the factors affecting the business prospects of VF (that are not geographically restricted). Judging by this phenomenon, one could argue that this study is closer to an inductive approach. To allow flexibility in this research, as well as enrich the conclusions of this study, without disregarding previous research, an abductive approach was considered. An abductive approach suggests that the empirical data is systematically compared with the existing literature, utilizing evidence that may be valuable, while allowing for flexibility to discover new possible factors. However, this approach is still within the realm of an inductive reasoning, in the sense of the goals of the research being to discover new variables and relationships. (Dubois and Gadde 2002).

The choice of research design is an exploratory single-case study method focusing on VF as an industry. According to Yin (2023), a single-case study approach should be adopted when; the research question implies exploration of factors rather than defining the extend of the impact those factors might have on business prospects and the study explores a modern phenomenon which the researchers are not able to manipulate. According to these criteria alone, the research

question of this research is suitable for a single-case study approach. Additionally, a case study focuses on “a bounded situation, or an entity with purpose and functioning parts” (Bell et.al., 2022). Following this logic, the case study is conducted within the boundaries of the industry of VF (bounded situation), it is concerned with the business prospects, profitability, and investment attractiveness of the industry (purpose), and involves stakeholders in VF industry (functioning parts). Therefore, this approach could result in complex factors that could be flexibly illustrated (Bell et.al., 2022).

Nevertheless, choosing a single-case study comes with limitations. Instead of a single-case study regarding the whole industry, another potential approach could be a multi-case study and cross-case analysis regarding major companies within the VF industry. Such an approach could allow the researchers to compare the data found in each case, potentially recognizing pattern and spotting vital differences (Bell et.al., 2022). However, considering the time limitations and scope of this study, as well as possibilities of non-participations (Bell et.al., 2022) of many of the targeted stakeholders, a single-case approach was chosen. Being aware of this limitation, the possibilities of rich data that can be obtained in this untapped area of the practice could still contribute to the lacking literature and provide ground for future quantitative studies, while the results could also provide practical implications for companies in the industry.

## 4.2 Data Collection

The data collection strategy involved conducting 9 semi-structured interviews with a range of stakeholders, including companies operating within the VF space, subject matter experts who can provide technical and industry insights, and investors who are crucial in understanding the investment viability of the VF industry. The semi-structured format is particularly beneficial as it allows for the interview to be guided by a set of core questions that address the central research themes, while also providing the flexibility to delve deeper into specific areas based on the stakeholder’s perspective and expertise (Baškarada, 2013).

Interviews are recorded and transcribed to ensure accuracy and provide an accessible dataset for analysis, an essential procedure in qualitative research to preserve the authenticity and depth of the collected material (Maxwell & Chmiel, 2015).



If some of the interviewees were unable to attend in-person meetings due to time constraints, they would receive questionnaires featuring the same set of core questions. They would then fill out these questionnaires at their convenience and return them to authors. This method of data collection can serve as a valuable supplement to in-person interviews, especially when participants face scheduling conflicts or are geographically dispersed (Boynton & Greenhalgh, 2004). Additionally, it offers a degree of objectivity and can complement findings from interviews, as the self-administered nature of questionnaires reduces interviewer bias. However, it is important to note that the questionnaire approach may not capture the depth of responses typically achieved through face-to-face interaction, and the absence of an interviewer eliminates the opportunity for clarifying ambiguous answers. Therefore, it is critical in designing the questionnaire to be as clear and comprehensive as possible to mitigate these limitations (Boynton & Greenhalgh, 2004).

Additionally, data collection also includes the review of existing literature, journal articles, industry reports, and market analysis documents. Such approach follows qualitative research strategy of using multiple sources of information to strengthen the reliability and accuracy of the study findings (Baškarada, 2014).

### 4.3 Interviewee Selection Process

The interviewee selection process in this single-case study on VF is guided by both the study's specific objectives and established qualitative research methodologies. Key stakeholders—companies, subject matter experts, and investors—were chosen to provide a multifaceted perspective on the VF industry.

The rationale for selecting these particular stakeholders is motivated by a desire to understand diverse aspects of VF — from operational to investment perspectives. This approach is consistent with the views of researchers who ascertain that successful recruitment to qualitative research should be based on enrolling participants whose experiences and insights can address the research questions thoroughly (Negrin et al., 2022). Therefore, the selection should include not only stakeholders involved in day-to-day operations but also those who influence and understand the sector from a developmental and economic standpoint.

## 4.4 Interview Guide

Initially, participants were provided with a summary of the study's objectives, the confidential nature of their responses, and the expected length of the interview. Formal consent to participate was obtained before the interview.

The first round of questions aimed to assess the background of the interviewee and their area of expertise within the industry.

The interviewing process was then focused on core questions, which were designed to be applicable to all stakeholders. They investigated key thematic areas of the paper with an emphasis on finding insights that are meaningful for an analysis of the industry. A list of all questions can be found in the Appendix.

## 4.5 Data Analysis

The data analysis phase began with a within-case examination using the open coding method, followed by further analysis employing axial and selective coding. The initial case examination proceeded according to established qualitative research methods, starting with the review of interview transcripts, summaries of meetings, and provided documentation.

Next, data was organized, and preliminary codes were generated in an inductive attempt to reflect key themes and concepts derived from the raw data (Pope et al., 2000). These initial codes served as a foundation for identifying patterns and significant themes within individual cases, which is the basis for within-case analysis. Such approach can be described as “open coding” which involves developing coding categories after the information is acquired during the data collection phase (Corbin & Strauss, 2007). Researchers indicate that “Open coding” is more appropriate than creating pre-set categories, in situations when the researched topic lacks a well-established theory (Maxwell & Chmiel, 2015) which in the case of the VF industry comes from being the relatively new field of business. Although this approach allows for more flexibility, it comes with certain limitations. Since this method of data analysis doesn't rely on a predefined framework, researchers may end up with codes that are too loosely structured or

connected, which could lead to vague and inconsistent results in the paper, thereby diminishing its value to the state of theory (Coffey & Atkinson, 1996).

The “open coding” process was followed by axial coding, which involved connecting categories and identifying relationships, organizing the preliminary themes into a more coherent framework. This facilitates an understanding of how the various themes interrelate within the context of individual case studies and aids in developing a more structured narrative around the emergent findings (Strauss and Corbin, 1998). This final phase of the analysis, selective coding, aimed to further refine the analysis by focusing on the central phenomenon, as identified by the emergent theory, to understand the principal findings of the data. The goal of selective coding is to integrate and refine the theory by outlining the main thematic concept that all other categories support (Blair, 2015).

The further analysis used the method triangulation to validate and enrich the interview findings. Triangulation is a research technique that involves assessing the results of data analysis obtained through one method by using another method to validate the emerging conclusions and balance the strengths and limitations of different approaches (Fielding & Fielding, 1986). This has also a complementarity effect, broadening the range of aspects and characteristics one can investigate (Greene, 2007). The process involved comparing the codes that emerged during the open coding phase with the predefined codes identified in preliminary research (e.g., business models, investments, partnerships). This comparison assisted on determining whether the initial hypothesized themes were relevant within the data or if they required revision or expansion based on the implications of the obtained data. This approach aligns with the ideas presented by Gibbs (2018) who emphasized the necessity of adapting codes due to the dynamic and context-dependent nature of social and business phenomena. Through continuous comparison and refinement of codes and themes, the researchers can ensure that the final result is both evidence-based and theoretically sound (Gibbs, 2012).

Simultaneously, the data analysis process involved cross-referencing interview data with relevant documentation, observational data, and secondary sources, such as industry reports, podcasts, financial statements, annual statements and business articles. This approach, referred to as "triangulation of data", resembles triangulation of methods but focuses on comparing different kinds of data rather than research methods (Flick, 2004).

## 4.6 Validity and Reliability

As is the case with any research design, a vital focus needs to be placed on validity and reliability aspects (Creswell & Creswell, 2023). Even though authors agree on the significance of those concepts, many academics are highlighting distinctions regarding validity and reliability, while those distinctions and definitions are suggested to be subject to the respective research design (Bell et al., 2022). Yin (2009) highlights four criteria essential to the validity and reliability of case studies: construct validity, external validity, and reliability. These should be included in the paper, excluding internal validity, as this is only relevant to explanatory case studies.

Construct of validity is concerned with the introduction of key definitions of concepts and terms in the research. It is argued that those definitions are vital, as the most important terms are being made comprehensive for the reader, who can then judge whether the measurements that are being used are functioning towards their intended purposes (Yin, 2009). In this research, validity is concerned with the key concepts of VF. The extended review of these concepts in the literature review should enable the reader to comprehend these key concepts and decide whether the adopted research design is an appropriate method to explore the research question.

External validity could be argued as the most conventional way to estimate the quality of a case study, while many critics use it as a basis to question a case study's capability to generate generalizable findings (Yin, 2009). It is not worth noting, however, that external validity is not the primary concern in a single case study, which focuses on gaining in-depth insight instead of generalizing the findings (Bell et al., 2022). Regardless, in this case study, authors employ multiple strategies to ensure a certain level of external validity, in line with Creswell's & Creswell's (2023) suggestions, such as method and data triangulation described in previous paragraphs.

Reliability of the findings, which is the final criterion of case studies, ensures that similar results will occur if a similar case study is done again. More specifically, it is argued that the many steps of the research process should be documented (Yin, 2009). This process aims to assist other academics in reconstructing the case study, which should encompass similar results. This research adopts this suggestion, as the various stages of the case study are

documented within this chapter. The research question implies that the case study is conducted in the whole industry internationally. Although such views may be provided from the participants as expert opinions or personal experience, it is imperative to note that the results of this study may be limited from the country-specific, or continent specific perspective of a limited number of participants and generalizing the findings of this study internationally is discouraged. Finally, to endorse reliability and clarity, the readers have the freedom to contact the authors, and seek any details regarding the integrity of the data and interview transcripts that have been used in this research.

## 4.7 Ethical Considerations

Ethical considerations are remarked as vital for research and should also be taken into consideration (Bell et al., 2022). Hence, this section is concerned with ethical considerations and addresses the measures that are taken to address them. A vital ethical consideration involves avoiding harm to participants. Such harm may take various forms, such as inducing stress or causing damage to the career of a participant. In order to avoid it, the participants have been anonymized by providing them with aliases and a slightly amended job description. Moreover, the utilized insights that the interviewees have provided were offered to be sent to the participants in order for them to review their statements and change any quotation that may cause them harm. In order to ensure the confidentiality of companies, the participants are also given the option to anonymize their company. To avoid any other possible stress for the participants, they were given the option to choose the time and place for the conduct of the interview. One more ethical concern relates to the lack of informed consent. To avoid this occurrence, the participants were informed about the setting and the goals of this research from the first contact with the authors. Furthermore, the details regarding this research have also been provided to the participants at the start of each interview. Effort was also taken to avoid the ethical consideration of deception, which involves projecting the research in a manner that strays from its real purpose. Finally, to prevent invasion of privacy, the participants retained the ability to refuse to answer certain questions. Nevertheless, no participant was reluctant to answer any of the questions.

## 5 Empirical Results

This section contains an overview of the empirical findings that were collected from 9 semi-structured interviews. The result of this data has been analyzed using the literature review and preliminary framework that were introduced earlier. However, as expected, the findings endorse modifications to the current framework to include aspects of the VF industry that were not foreseen from reviewing current literature. Therefore, the preliminary framework has been revised and refined in order to encompass the information that was provided by the interviewees. Relevant aspects from the areas of sustainability, business models, partnerships, and industry analysis have been highlighted by the individuals interviewed, leading to the preservation of the main areas of the framework. However, many subcategories have been modified, added to, or subtracted from the preliminary framework. The modified framework, which includes previously undiscovered factors as well as changes in the gravity of certain factors, is shown in the next section (Figure 3). It should also be noted that this chapter focuses solely on analysing the results from the empirical studies. These results are being discussed through the lens of the literature review in the following chapter. It is also worth noting that some of the findings may contain aspects of another topic in the section. However, they were categorized according to what was deemed the primary aspect of the insight, to avoid the confusion of over-complicating the results.

### 5.1 Interviewees Background

1. **The Agtech Specialist** - Agtech thought leader and food & agriculture consultant with expertise in financial markets.
2. **The Technology Specialist** - nutrient solution, and plant expert/consultant with expertise in agriculture technology and cultivation methods.
3. **The Podcast Host** - Podcast host for the #1 podcast dedicated to the VF market, focused on highlighting founders and visionaries in VF and indoor Agtech.
4. **The Construction Specialists** - Two specialists with a background in a global construction company, having worked on numerous projects in the VF industry, with expertise in construction and sustainability.

5. **The News Platform Founder** - Founder and CEO of a global news platform on VF.
6. **The Independent Consultant** - Independent consultant for VF companies, with a track record in business development at one of the largest VF consultancies.
7. **The Scandinavian CFO** - Chief Financial Officer at one of the leading Scandinavian VFs, with expertise in financials and business operations.
8. **The Dutch Manager** - Manager at one of the largest Dutch VFs, with experience in managing VF projects across the Netherlands, Singapore, and UAE.
9. **The Investment Director** - Investment director managing a portfolio of investments at a leading private equity firm engaged in the agriculture sector.

## 5.2 Empirical results on business models and operations

The subsequent section of the paper delves into the perspectives of interviewees regarding the operations of VF companies, their business model structures, and customer perceptions. It also presents their insights on potential upcoming changes in companies' offerings and highlights the most significant mistakes these companies make.

### 5.2.1 Profit formula

A recurring theme among the interviewed stakeholders was the influence of companies' profit strategies on their funding and business models. A major discussion point was how cost structures impact profitability. The Agtech Specialist emphasized the need to consider the customer's perspective and the demand for VFs produce. He suggested that companies should develop financial models that focus on expected sales volumes at specific price points, rather than solely basing prices and margins on company's costs. He noted a common mistake: VFs often operate like tech companies, overlooking critical agricultural market factors such as high costs of goods sold and relatively low margins. The Independent Consultant expressed a similar view, attributing it to one of the reasons for the failures of some major VF companies:

*Major companies that have failed recently didn't truly understand their own business models. If you were to ask them directly, 'Are you a grower or a technology provider?' they wouldn't have a clear answer. That's never a good sign.*

The Independent Consultant also identified another prevalent mistake in VF: investments in energy-intensive production processes that yield products with low caloric value. She highlighted pea production as a prime example, noting that up to 98% of the produced biomass could end up as waste. Although this percentage might be overstated, research supports that a significant amount of biomass is routinely discarded in pea production. Specifically, waste from peas peels can make up about 30-40% of the total weight of harvested peas (Verna, et al., 2011). The Independent Consultant stressed the necessity for companies to explore ways to utilize waste or by-products from their production processes to achieve scalability.

In that discussion, The Scandinavian CFO illustrated how VFs can leverage byproducts to diversify their revenue streams using his company as an example. He explained that in the production of certain plants, the roots were initially considered waste. However, research revealed that these roots could contain up to 10% protein by mass. To enhance company efficiency and profitability, they partnered with a vegan meal subscription service. This partnership involved selling the roots, which were then cut and included in meal orders, adding value to the company's waste products.

Continuing the discussion on business models and operations, The Independent Consultant emphasized that VF companies should place more emphasis on their sales and business development teams. She argued that since VFs are primarily in the food business, not the technology business, their ultimate goal should be to provide high-quality food to as many customers as possible. To do so, establishing robust sales operations was critical, a point that might seem obvious but was often overlooked by VFs in her opinion. She described the essential business processes as follows:

*So first, can I grow crops? Do I know my market? It's really business 101 if you think about it. Is there a demand? Who am I selling to, and at what price? That determines how much I need to produce. What is my sales price? What's my cost price?*

The Podcast Host and The Dutch Manager both discussed the problem of premature scaling, which they believe has affected some companies in the industry. They explained that some



companies, after receiving high initial investments, focused too much on employing the most advanced technology, product development, or expanding to different locations. The Podcast Host argued that before expanding, it is more important to understand market demand and set up operations structures. The Scandinavian CFO shared that not receiving a high investment at the beginning turned out to be a "blessing" for her company. It forced them to create a resilient and efficient cost structure on a small scale first, allowing them to avoid certain mistakes when they eventually scaled up.

### 5.2.3 Companies' Localization and Supply Chain

A key topic discussed was the setup of the supply chain and the strategic location of the company. The Agtech Specialist argued that while being close to consumers is a major advantage of VFs, hyper-localization—being situated just a few kilometres from supermarkets, typically near city centres—can often introduce more challenges than benefits. These include high land costs, expensive utilities, and costly staffing. He suggested that operating from a larger site further from urban centres offers several benefits of relative locality, such as reduced transportation costs and a shorter product-to-consumer cycle, without the operational challenges of city locations. The Dutch Manager shared similar views, noting that urban operations can complicate logistics, particularly in scaling up and transporting products out of the city. She proposed that a viable solution would be to establish VFs near supermarkets' distribution centres to leverage economies of scale with integrated supply chains. Like The Agtech Specialist, she emphasized the advantages of being outside the city but still in proximity to key markets, suggesting that a few strategically placed hubs could efficiently serve most regions in Europe, due to the continent's relatively compact geography.

In contrast, The Podcast Host presented a different situation, describing scenarios where small VFs are located extremely close to their direct consumers, which he referred to as "hyper-local":

*The new phrase I'm hearing more people use is "hyper-local." It's a concept where a container farm is situated next to a hospital, grocery store, or restaurant. For example, a chef can get mushrooms directly from a container farm located right next door.*

#### 5.2.4 Customers Perspective

As stated in the literature review, the primary goals of this research are not concerned with customer perspective. However, during questioning regarding the future prospects of the industry, it has become apparent that a certain level of gravity was given from the interviewees on this aspect in relation to the research question. Hence, it is deemed appropriate that relevant findings on customer perspective are included, to enhance problematization and to endorse further exploration and discussion for future research.

Interviewed stakeholders have been discussing consumer attitudes towards products grown in VFs, focusing primarily on two aspects: whether customers are willing to pay a premium for these crops, and their overall perception of food produced by this method.

Addressing the first question, the interviewees highlighted differences based on the type of crop. For instance, The Agtech Specialist noted that for commonly vertically farmed vegetables like lettuce, consumers are unlikely to pay a premium because they do not invest much thought into this purchasing decision. He also argued that the sustainability elements of the product are not going to influence the decision of the average consumer if the premium price is much higher than the one of other products. However, for high-quality, locally produced strawberries available in winter, consumers, particularly those from higher income brackets, are more inclined to pay a premium due to the perceived quality and nutritional benefits. The Investment Director argued that the herb market could be a profitable area for the same reasons, as the value of this products is higher, which can justify the higher price-tag for the products. However, the relatively small size of such market could raise concerns regarding supply and demand. The Dutch Manager made a similar point, noting that while their company produces leafy greens, they must align with market prices to have a significant impact and capture market share. Additionally, she emphasized the need for companies to have a customer-centric approach, advising them to focus less on the technological system as an end in itself and more on producing affordable and sustainable food. She argued:

*Customers won't pay a premium price for your crops just because you've used a fancy system to produce them.*

Subsequently, her company chose not to advertise the complexity of their VF production. Instead, they focused on highlighting on their packaging that the products are pesticide-free and locally produced.

This approach was supported by The Agtech Specialist, The News Platform Founder and The Independent Consultant stance, who noted that from the customer's perspective, the most important factors in purchasing decisions are price, shelf-life and nutritional value. Additionally, they recognized that the quality and taste of the product are crucial factors in determining the potential for recurring purchases. The Podcast Host also added the location of production as an important factor. From his perspective, customers are increasingly interested in food that is produced locally. He discussed the growth of the “farm-to-table” movement, a social trend promoting the serving of locally produced food in restaurants and shops, with an emphasis on shortening the supply chain and supporting the local economy.

The Independent Consultant discussed strategies that companies employ to educate their customers about food produced in VFs. These efforts aim to enhance awareness, underscore benefits such as delicate flavour, and dispel misconceptions about its quality. She highlighted an approach by Farm.One, a U.S.-based company that organizes cooking workshops and gourmet dinners. These events are led by renowned chefs who use ingredients sourced directly from their VF.

#### 5.2.4 Cost of Labor

The Scandinavian CFO and The Independent Consultant agreed that the two primary recurring costs for companies in VF are labor and energy. The Scandinavian CFO shared his experience with a Taiwanese VF system used by his company, which required intensive manual labor. He highlighted the challenges of implementing such a system in the European market, where labor costs are on average significantly higher than in Asia, identifying this as a major barrier in scaling the company. As a potential solution, he suggested investing in system automation, though he noted that this approach is costly and would require investors support. The Technology Specialist provided a contrasting example from India, arguing that the local labor market can determine what system will be effective:

*The effectiveness of the system really depends on the country. For example, there's a large strawberry farm in India that has almost completely skipped automation because labor is so cheap there. They just employ around 200 people at 50 cents per hour, and for them, that works.*

### 5.2.5 Companies' Production and Offering

In discussions about product differentiation, interviewees agreed that while it is technically feasible to grow almost all types of plants in VFs, the main limiting factor is cost. Leafy greens are commonly chosen because they are in year-round demand, have a short vegetation cycle, and are less prone to diseases than in traditional farming environments. This view was supported by The Independent Consultant, who while discussing VF business cases pointed out:

*“That's why a lot of companies are growing microgreens and baby leaves - it's because you want to have the plants in these really high-energy intensive farms for as short as possible.”*

The Dutch Manager noted that with technological optimization, their company could diversify into more protein and nutrient-rich products, such as water lentils, legumes, or soy. This diversification would allow them to serve a broader segment of the population and enhance their financial performance. Additionally, The Technology Specialist highlighted examples of companies that have chosen to grow peas in VFs. Peas were selected due to their relatively short vegetation cycle, minimal space requirements, and high nutritional value. He emphasized that these factors are particularly crucial in regions affected by hunger, where providing an affordable source of protein could significantly improve the quality of life for the local population. In the discussion on product segmentation and cultivation of protein-rich vegetables, The Scandinavian CFO also pointed out that the cost of energy is the main limiting factor. He described it this way:

*I think when you see electricity prices drop to zero, you will see much more food production moving into VFs. We already know how to make protein-rich products today. It's not nutrition that sets us back; it's the electricity.*

In regard to company's offerings, The Scandinavian CFO highlighted that investments are needed in R&D departments. Unlike traditional agriculture, where cultivation methods are well known, VF still requires extensive research on possible products and their variations. In that example, due to space and cost constraints, his company needed to specialize in specific products to achieve the right scale to meet the demands of their customers. The Scandinavian CFO described the company's position by saying:

*We have around 50 different recipes or products we can make, but we are only supplying 4 to supermarkets because we can't manage to supply all 50. If we did, each supermarket would get about 100 clamshells of each product, which isn't enough for 120 supermarkets.*

The Podcast Host discussed success stories of companies that decided to specialize their production, highlighting the benefits of becoming industry expert in specific fields. He mentioned Ekonoke, a Spain-based farm focused on cultivating hops, which are traditionally difficult to produce in that region due to their susceptibility to weather conditions. He also discussed Vese Farming, which operates the largest VF for saffron cultivation, producing one of the most expensive spices in the world. The Podcast Host argued that by specializing in certain products, companies can leverage their production capabilities and unique position as experts in the systems and cultivation methods for those specific crops.

The Independent Consultant argued that focusing on cultivating plants through all stages of growth is not necessarily the only right approach. She highlighted the benefits of partnering with outdoor farmers and greenhouses, where the initial stage of growth would be conducted in a VF, and then the seedlings could be shipped and continue to grow outside. The main benefits she mentioned include significantly faster growth rates and stronger seedlings with a better rate of survival.

### 5.3 Empirical results on Industry Analysis and Investments

As outlined in the literature review, both academic researchers and industry experts highlighted that VF companies heavily depend on external financing. This section of the paper explores the barriers that deter investment in this sector, as well as the factors that make it attractive to investors.

### 5.3.1 Investment barriers

The Agtech Specialist identified three main barriers that deter investment potential in VF. The first barrier was the significant rise in interest rates, which impacts the overall funding market by increasing the cost of investment.

The second barrier was the high cost of capital, stemming from low profit margins within the industry. In the current market, traditional venture capital organizations expect investment returns within approximately five years. However, in VF, the return on investment is spread over a much longer period, making it a less attractive investment opportunity. The Independent Consultant took a similar stance, discussing the previously unrealistic expectations of CVC and how the current investment landscape has adjusted. She noted that investments have decreased to ticket sizes ranging from \$500K to \$10 million, provided by investors who clearly understand the return patterns in the industry. She said:

*A venture capitalist should never invest in a vertical farm. I think one of the failing partnerships established in the past was due to excitement about this field, but farming has a much longer payback period than venture capitalists want to see. They want fast returns, and you can't provide that in farming.*

The third significant obstacle according to The Agtech Specialist was the high entry barriers to the industry, primarily due to the costly high-tech agricultural systems and the construction structure of the farms. The Agtech Specialist noted that companies closely guard their intellectual property, which is a key differentiator among VF enterprises. This protection leads to inflated prices for technological systems. However, he suggested that as the industry matures, VF systems are likely to become more commoditised, which would lower these entry barriers. The Dutch Manager agreed with this view, noting that for their company, the cost of purchasing agricultural technology was considerably higher—up to 50% more in some cases—than producing it in-house.

The Dutch Manager also argued that a significant issue in the investment landscape derived from a loss of trust, which occurred when companies that had received substantial funding went bankrupt following the burst of the VF market bubble (Peters, 2023). Even now, despite the

presence of many new players in the market, investors are much more inclined to fund VFs that demonstrate positive cash flow. However, there are very few companies able to present such financial stability.

The Scandinavian CFO expressed a very similar viewpoint. He believed that most investors are hesitant to invest in VF companies until they can demonstrate "proof of profit". However, he noted that this approach can vary greatly across different regions, depending on the local food industry and the risk appetite of the investors.

### 5.3.2 Attractiveness of the sector

According to several interviewees, including The Agtech Specialist and The Dutch Manager, a major advantage of VF for investors is its reduced dependency on factors that significantly impact traditional agriculture. These factors include the availability of water and soil, weather conditions that affect crop quality and quantity, and the availability of arable land, as seen in countries like Singapore, Saudi Arabia, and the UAE. Similarly, The Scandinavian CFO highlighted the growing interest among investors in the VF market in southwestern European countries such as Spain, Portugal, and Italy. He noted that these countries face challenges such as rising temperatures and severe water scarcity, which make VF an attractive investment.

An additional benefit of VF that all the interviewees agreed on was the precise predictability of production capabilities. The Scandinavian CFO pointed out that since production occurs in a controlled environment, where all factors are meticulously measured and adjusted, companies can accurately forecast how much they will produce within a specific timeframe. They can also consistently determine the quality and taste of the crops and have significant control over these attributes. The Scandinavian CFO described this level of predictability as particularly valuable as it opens up opportunities in specific markets such as high-profile restaurants, pharmaceutical companies, and fragrance manufacturers.

This point was also highlighted by The Independent Consultant, who provided the example of Interstellar Lab, a company that develops advanced agricultural technology incorporating AI systems, hardware, and plant-based ingredients. The Independent Consultant detailed how they achieved significant market success by collaborating with fragrance companies. Their success

stemmed from the ability to engineer specific molecules into crops, producing the exact scent desired by these companies, which became extremely valuable in the process of creating fragrances.

The Dutch Manager pointed out that investors from the Middle East have a particular interest in VF due to their substantial financial resources, high urban population density, and a climate that is unsuitable for growing most crops, which forces them to rely heavily on food imports. Subsequently, this creates a huge consumer demand for locally produced crops. The Dutch Manager's company itself secured such investment in Singapore and received considerable support from the country's officials, a topic that is elaborated upon in a subsequent section on public-private partnerships.

## 5.4 Empirical Analysis on Partnerships

Following section is focused on partnerships, which is a predetermined area of interest when looking at the business prospects of the VF industry. The section first looks at inter-company collaboration, ecosystems and governmental collaboration.

### 5.4.1 Inter-company collaboration and ecosystems

When asked about strategic partnerships within the industry, The Agtech Specialist expressed his confusion on why companies in the VF industry do not share information between each other. He provided the example of technological companies, and how it is more frequent for these types of firms to share information. The increased knowledge sharing in the tech industry is no secret, and has been highlighted for the benefits it offers, such as new developments, innovation or simply “sharing the load” (Forbes, 2024). It is possible that the following line of thoughts could unwrap a wider issue within the industry:

*In this business (VF), companies tend not to share information. They think they have some special technology that others don't have. I believe this is because very few companies are actually making money. From a cynical perspective, when they do share, very few people will tell you, 'I did X amount of sales and made X amount of money.' I think people want to make*



*it seem bigger than it really is and claim they are profitable, even when they might not be. From my analysis, and I've tried it on many of these companies, very few VFs are profitable today.*

According to The Agtech Specialist, one reason for the lack of collaboration between companies may be that some firms remain secretive to create an image that “hypes the market” and highlight their profitability (even if it is only a “mirage”), which may present the company as more attractive to investors. Although this is the personal opinion of The Agtech Specialist, these expressions are also shared from The Technology Specialist, who suggests that these companies would need to create a “perfect story” and pass a message such as “we are successful and innovative” in order to secure funding and survive longer. As these views highlight an apparent lack of communication, the opinions of The Independent Consultant may also add value to the argument, as she suggests that many companies that failed to collaborate had difficulties relaying a comprehensive view of their business model. The Independent Consultant suggests that the non-established partnerships derive from the fact that major companies that had failed in recent years were not aware of the type of their business model.

On the other hand, The Technology Specialist shared an example of a specific company that would have several reasons to remain secretive. He argued that in the process of trying to improve their system, it is all about grow more with less...less water, less fertilizer and especially with less electricity for the lights. To the authors understanding, these views may be attributed to how the companies are individually chasing development of their processes, which may provide them with a competitive advantage in the industry, and therefore do not wish to share it with competitors.

In line with this reasoning, The Scandinavian CFO suggests that in the near future most of the companies will not be willing to share their business information. According to him, the reason hides behind the immense efforts and fundings that companies have put into creating technological capabilities. While this is a mere speculation shared by the authors, the following aspiration is one that has the potential to be a common consideration of companies within the industry, considering the difficulties in securing funding. In the words of The Scandinavian CFO:

*When companies have more solid ground under their feet... they might be more prepared to talk with others about this, as everyone wants to find their place in all this.*

The Investment Director has provided two examples of a successful partnership in the industry. The first one is between Jones Food (2024) and Ocado Group (2024), to which he argued it has enabled Jones Food to produce higher value leafy greens, such as herbs. The second example is that between the Ontario-based Goodleaf farms (2024) and McCain (2024), which also focuses on herbs-related products. The reasons behind the potential profitability of herbs have already been remarked in the customer's perspective section. However, these collaborations take the form of an investment relationship, and not inter-company collaboration between VF firms.

The Dutch Manager highlighted that the collaboration with traditional agriculture parties and the greenhouse sector had been more successful than with other VF firms. The company would also collaborate with local retailers and food group communities. For example, The Dutch Manager mentions how they collaborate with a group against food waste, as their sustainability goals align.

Although The Dutch Manager suggested that their company had been open to partnering with other firms in the industry, she suggested that there have been major barriers. She expressed the lack of connections the company has had with larger VF firms. It is suggested that this occurrence may be due to the different structure of the company in question, which follows a flatter leadership approach. This means that in the event of discussions with other firms, one side would be represented from a senior level manager, while the other from “just a farmer”, which may put barriers between communication of the two parties. Moreover, it might also be required to sign multiple NDAs for initiating discussions, which could hinder collaboration. To avoid any generalisation of these findings, these suggestions derive from The Dutch Manager’s personal experience.

The perspective of The Podcast Host, who had been communicating with many CEOs of the biggest VF companies introduced a more holistic perspective into the topic. According to him, when the CEOs are probed to talk to their peers and colleagues through broadcastings of VF interviews (Spotify Vertical Farming, 2024), almost all of them share the same opinion on the matter:

*We need to collaborate more, we need to stop operating as a silo and thinking about these proprietary systems, these secrets that we have that we don't share.*

In Expert's 3 opinion, it is true that there is much information that could hardly be shared with partners in the industry. However, when the information is in regard to interoperability, or understanding how people are managing expenses, such as electricity or managing operations, discussions between the different companies and CEOs are believed to be helpful. The Podcast Host also mentioned how Covid, and the Russo-Ukrainian war caused major disruptions to supply chain, and that companies need to prepare for events such as this by building strong collaboration and relationships.

#### 5.4.2 Relationships to Universities

In contrast to collaborations with other companies, The Scandinavian CFO spoke about their close collaboration with local universities, as it involves new students who are also looking in the direction of VF. These close partnerships with the universities allow them to acquire knowledge about a research subject in which they would not have the resources or capacity to search internally.

The Dutch Manager also dwelled into the successful collaborations with local universities. In-line with The Scandinavian CFO's company, their collaboration with universities has enhanced the quality of their research, as well as attract talent for the firm. Moreover, through their involvement with partner universities, they also benefited from subsidised projects that focused on research within the field of the company. These findings are considered a valuable input, as it opens more areas for discussion regarding the matter in the later chapter.

#### 5.4.3 Relationships to retailers

As two interviewees mentioned their experience regarding their collaboration with retailers, these findings are included to enrich any possible argumentation regarding collaborations in the later chapter. The Scandinavian CFO and The Dutch Manager have expressed the importance of their collaboration with supermarkets and restaurants. The Scandinavian CFO

highlighted the efficient communication with large supermarket chains in Denmark covering a wide portion of the market, which enables the company to sell their products efficiently in this current stage of production. However, he also argued that future production could also involve selling their products directly to customers. He also mentions that their products are also distributed to restaurants, hotels and other retailers.

The Dutch Manager also highlighted how their products are distributed through supermarkets. In contrast to The Scandinavian CFO, The Dutch Manager did not support selling their products directly, as supermarkets are more efficient in this manner, at least in western countries.

## 5.5 Private-public partnerships and governmental influence

While questioning the participants, it was realised that governmental influence was a topic particularly dependent on geographic location, with some regions more prone to public-private interaction than others. While this may also be the case for most, if not all the areas and categories in this topic, it is deemed appropriate to firmly set boundaries between the context of governmental influence via geographic categorization (North America, Europe and Singapore), as the circumstances of the topic are heavily influenced by their location.

### 5.5.1 North American Governmental Influence

The Agtech Specialist, who is mostly active in a North American context, described the governmental involvement in VF as a “chicken and egg” situation. The interviewee continued to explain his opinion that the VF market in North America is relatively small, and hence, does not attract the attention of the government. On the other hand, he argued that the market may not be able to get bigger without governmental support. He highlighted the lack of incentives for farmers in the US compared to EU. Despite these views, he suggested that the governmental incentives should be an extra benefit for the companies and should not be integrated into their own strategy. Summarizing his opinion:

*...If incentives can come in, it would be great benefit. But I don't like to set up a model with assuming incentives are there.*

While answering the same question, The Podcast Host suggested that it is important to not view the policies in North America holistically, as the gravity that states put to the policies on the area may vary significantly. He presented the example of the state of Virginia, and how they have put a lot of emphasis on VF. In his views:

*“I can only imagine that more and more states are going to be looking at what Virginia is doing and say “hey, we want to follow that example, or hey, can we learn more”.*

Regarding the matter, the perspective of the US-based The Investment Director is that he does not put too much gravity on governmental policies in the context of Aerofarms, which he has been involved with in the past, as he does not believe that those are part of what drives the firm growth. He remarked that through a North American and UK lens, in his opinion, the industry is “well-served” by existing growers, and requesting subsidies is not going to necessarily provide better results.

### 5.5.2 European Governmental Influence

Despite the increased funding for agriculture in Europe, two of the interviewees stressed the lack of public funding in the industry of VF, particularly in the context of Scandinavia and the Netherlands. While The Construction Specialists shared this opinion, he suggested that part of the reason is the viewing of VF mostly as technological companies instead of food companies. In his views, if these companies' core was viewed as food provision, they would have higher chances to secure funding. The current initiatives are too small to secure big funds, and the VF industry usually falls “off the radar” for government and different institutions to provide major funding.

The Scandinavian CFO also expressed the lack of governmental support for VF companies in Scandinavia. However, he highlighted the vast difference in incentives and beneficial governmental policies between Scandinavia and Germany, where public interest in VF seems to be significant.

*We're going to Germany directly after the expansion in Scandinavia and build a factory which will be four times the size as the one in here. And that is because of the German subsidies. We were looking at Sweden, Norway, Finland and Denmark, but when people from*

*Germany suggested “okay, we want you to come to Germany and we will give you a 30% of subsidies for your expenses of building here, then of course we were looking to expand there.*

The Dutch Manager provided another view of governmental approach in regard to VF practices. Deriving from her experience, the government has been reluctant in providing subsidies, which could have significantly sped up the processes of the company. Because of the lack of support, the company struggled to get funding in its initial stages and delayed expanding their team as they had planned. From the viewpoint of The Dutch Manager, the governmental structures do not believe in the concept. She mentioned how greenhouses are being built by companies in China while the Netherlands, who has been a front runner in food production so far, is slowly losing that role.

As The Independent Consultant suggested, through her experience, individuals from the European Commission were greatly uninformed regarding the industry, forming “naive ideas and expectations”. However, her opinion was that the industry will continue with or without politicians.

### 5.5.3 Singaporean Public-Private Partnership

According to The Investment Director, the lack of arable land in Singapore is a factor that could make VF an attractive option for favourable subsidies and governmental policies. The company represented by The Dutch Manager also operates VFs in Singapore. Through her experience, public-private partnership in Singapore is sharply in contrast with the one in the Netherlands. In here experience:

*They welcomed us with open arms. They give us permits. They help us get an extra building. And we have just finished a farm last month, and they are already asking us to build another one. They are willing to help us get funding.*

The Dutch Manager suggested that Singapore’s approach to VF derives from their need for local food production, which is more absent in the Netherlands. She argued that Singapore has their plan (30-30 goal) set up. Hence, they provide the funding and the effort to make that happen. The Dutch Manager’s views on the attractiveness of the governmental landscape in Singapore was as follows:

*It is working. It is actually working. And we even thought about closing everything in Amsterdam and moving to Singapore, because it is just the help there is so much better, but also the market. Food is more expensive, so that makes it easier for us to match the market price. Even though that is not what this is about, that was still a great option for us.*

## 5.6 Empirical Analysis on Sustainability

This section is concerned with presenting the results in relation to the predetermined area of sustainability, as it was deemed a key area of interests when looking at the business prospects of the VF industry. However, due to differences between the authors' initial speculation and the findings regarding the topic, gravity has been put in different areas than initially expected. The reasons for this occurrence are being explained in the following chapter.

### 5.6.1 Energy Sustainability Concerns

A few concerns regarding energy sustainability were shared through the interviews. The Podcast Host called for caution when companies highlight their sustainability statements and minimal footprint, as those may not provide the full story. He also referred to the possibility of greenwashing. To his opinion, merely suggesting that VF is sustainable and the best choice over greenhouse or even open field may be misleading. To highlight his opinion "*When you talk about free energy, you are not going to beat the sun,*" as he argued that there is a lot that can be learned from greenhouse technology.

In line with high energy needs, another interesting remark came from The Construction Specialists. In his experienced from being involved in VF projects, the intense materials required for the processes (e.g., plastics, lighting fixtures, chains, irrigation systems etc) are assumed to need significant energy to be produced, which puts VF in contrast to other types of urban farming. Considering the background of the expert with the construction industry, these aspects of his experience are welcomed in this research and may open a new type of problematisation regarding energy usage in the industry, one that does not involve sustainability of products directly. The Dutch Manager provided authors with a more holistic perspective of her views:

*There is a lot of VFs that call themselves sustainable, but I know (they) have an energy use that is almost shameful to say out loud. I do not know if you can still call yourself sustainable at that point.*

Through the remarks of The Independent Consultant, an example of a firm that counters these views is Potager Farm (2024), which was able to supply their farm with “clean” energy through their collaboration with Greenman Energy (2024), who specialised in the generation of renewable energy via utilization of solar PV panels. As another example of a successful farm with renewable energy, The Independent Consultant also mentioned Growup in the UK (2024), which was suggested to be receiving its energy supplies from bioreactors. According to this, The Investment Director has also argued about the “smart” way that Growup is handling its energy needs. Although these examples cannot be generalised in the industry, the authors interpret these findings as an indication that some VF companies are actively seeking ways to make their energy use more sustainable.

### 5.6.2 Food Security

The Podcast Host suggested that as different geographical locations, particularly the ones with extreme climate (such as Dubai) with high dependency on imported food have higher needs for “*food sovereignty*” (food security via local production). Hence, these places would look for many solutions that provides them the ability to grow their own food. However, his opinion was that there are different ways to do that, and they do not necessarily need to involve VF solutions.

For The Dutch Manager, sustainability should be at the core of the company from the start. In her view, considering people and planet is paramount, while the produce they grow should reflect the circumstances of the specific market. She mentioned that in Singapore, they do not eat the same salads that they eat in Europe. Hence, they are trying to look at the climate conditions as an indicator of what to grow and where. For example, the company would not want to compete with growing tomatoes in the Netherlands, as there are already acres of greenhouses that are doing that very efficiently and sustainably. When it comes to lettuce, The Dutch Manager stated:



*The Netherlands does not grow almost any of its lettuce. So that is why we decided in the Netherlands, for now, we are only going to grow lettuces and herbs.*

She mentioned that in Singapore, they barely have any food production, and they eat other types of leafy greens. Therefore, the company would look at leafy greens that can be used in hot dishes as well. They would try to look at the local market, and see what people eat.

The Independent Consultant shared her opinion regarding the inclusion of VFs as part of sustainable cities. In her opinion, it is possible for city planners to include VFs in the plans. However, she argued that this would serve more as a motive to attracting investment, as the idea of VF sounds unique, or “*fancy*” in her words. She explained that the output of these farms is fairly insignificant when put into the context of population size. This opinion is included, as it is speculated to be a more pragmatic view of the current capabilities and future prospects of VF as part of a sustainable city, based on the views of caloric output that were aforementioned.

### 5.6.3 Organic, or “beyond-organic” certification?

A portion of the interviewees have commonly highlighted the inability to label VF products organic, which could potentially drive away more conscious consumers, and hinder the sales of products. The authors found the topic vital, as many of these views were not encountered during the initial research on the subject. The interviewees expressed concerns about the lack of an appropriate labelling, which derives from the lack of appropriate institutional measurements, as well as the need for education that could focus on the sustainability of the products (The Agtech Specialist, The Technology Specialist, The Podcast Host, The Scandinavian CFO, The Dutch Manager).

The Dutch Manager expressed interest in finding another label, or creating a new one, as it seems unlikely that VF products will be labelled as organic anytime soon, while the need for that is still in question. As The Podcast Host stated: “People, think that organic is the best, but it may not be the best if it is organic and it is flying 3000 miles to get to your plate.” Regarding the matter, The Scandinavian CFO suggested that false perception is less likely to be formed in countries with more educated population, excluding perhaps older age groups, such as 70 +.

The authors believe that The Agtech Specialist's problematization could be part of a wider issue regarding the image that is formulated via the labels on VF product:

*What does it mean growing in a vertical farm? Why is this pesticide free? Why is this not organic but yet maybe better for you? And then are (the companies) going to start teaching them about whether it is sustainable on top of that? It is a lot of teaching for a product....*

*And it may not be that important for people.*

In these views, The Technology Specialist suggested that not labelling the product organic, or using a label specifically tailored for VF products may divide customers. On one hand, concerns may be expressed, such as "it is not natural" or "cannot be healthy", while other customers may prefer the fact that is zero pesticide usage, or that it is from nearby. He stated that there is no organic certification possible for this kind of products, referring to the following problematisations, which were not considered during the initial structuring of the research:

*So, you know...where is the field located? It may be next to a power plant or highway ramp. What if there is a lot of heavy metals in the soil and stuff like this? Organic the label does not prove anything in the first place.*

The Technology Specialist argued that if companies "do it right", VF products can be beyond organic, which could directly affect the perception of customers regarding sustainability. Hence, the need for appropriate labels could be considered a possible area of further exploration.

## 6 Revised Framework

Taking into consideration the empirical data, the authors present the revised framework with factors that affect the future business prospect of VF, expressed in categories and areas. The new framework builds on the preliminary overview, which was based on the review of literature, and has been modified to include the empirical results of this research. The reasons behind the modification of the framework are being discussed in the chapter that follows.

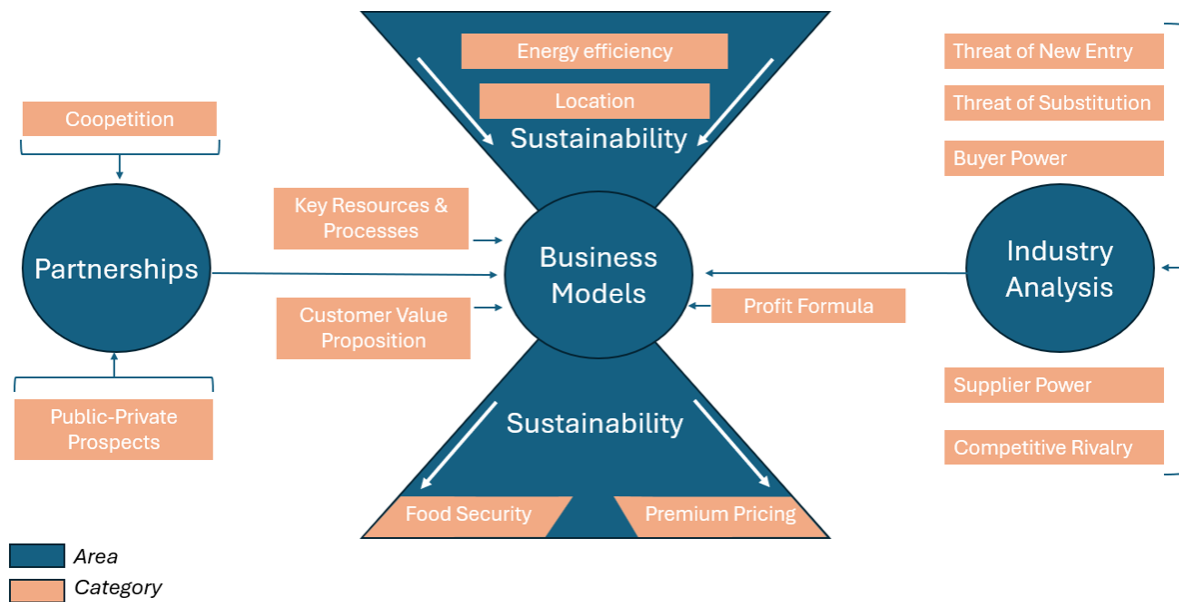


Figure 3. Revised framework on the future business prospects of VF

## 7 Discussion

### 7.1 Business Models Present in Vertical Farming Industry

The following chapter aims to utilize insights from interviews, discuss them, and evaluate them against academic literature and secondary data sources. The focus was put on business models and operations within the industry, as well as potential recommendations or new business avenues for practitioners. The discussion on business models is structured using a framework from the literature review—specifically, an adapted business model from Johnson et al. (2008). This framework was selected because it categorizes essential factors of business operations similarly to the Business Model Canvas while also accommodating business model innovation theory, which appears necessary to include when proposing operational changes.

### 7.2 Profit Formula

#### 7.2.1 Revenue and Margin Model

When it comes to business models, the findings identified two distinct approaches adopted by different companies. Based on the empirical results and secondary sources, they can be categorized as follows:

Model 1 involves selling high-quality products at a high price point, thereby positioning themselves as premium brands. An example of this is Oishii, a company known for its premium, unique varieties of strawberries and tomatoes. With a current price point of approximately \$5 per strawberry, Oishii targets the high-end gourmet market, specifically high-income consumers (Orlean, 2023). It can be assumed that Oishii relies on high margins per unit to achieve profitability. This approach supports the hypothesis proposed by Moghimi and Asiabanpour (2021), which suggests that VFs can potentially command higher prices by emphasizing the local origin and superior quality of their products.

Model 2 is based on selling commodity products targeted at the average consumer and meeting market price points. Its profit formula relies on large-scale production and a high inventory turnover ratio, which allows it to compete on price against traditional farms and greenhouses.

An example of this approach is Aerofarms, which currently operates one of the largest VFs in the world. By leveraging economies of scale and focusing on mass production, they achieve a price point comparable to salad greens sold in the US from different types of production, approximately \$4 per 5-ounce package (Peeva, 2023). This aligns with The Dutch Manager's perspective, who mentioned that her company chose mass production of leafy greens to have a broader impact and compete in the general food market rather than in a specific niche. To do so, they also had to match local prices of leafy greens.

Dahlberg and Lindén (2019) addressed the risk for VFs operating within Model 2, suggesting that traditional agricultural production might reduce profit margins below the levels attainable by VFs. This risk arises because traditional agriculture, benefiting from economies of scale and established practices, often incurs lower production costs (Tell et al., 2016). However, as advancements in technology enhance automation and energy efficiency in these sectors, VFs may substantially lower their costs. This potential is further supported by the S-curve pattern for innovation (Harvard Business Review Press, 2009), which illustrates the pace of innovation relative to industry maturity. Given that VF is a comparatively nascent industry, substantial opportunities likely exist for process optimization, which could lead to considerable reductions in production and operational costs, improving the margins. However, this remains speculative and warrants further investigation.

### 7.2.2 Cost Structure

Literature review and empirical results lead to the conclusion that, VF has relatively cost intensive operations. Experts have noted that one of the highest recurring costs in VF is energy, which varies greatly depending on geographical location, technological advancement, and the type of crops grown. Industry benchmarks seem to support these stances, assessing that energy consumption per kilogram of crops in VF is approximately ten times higher than in traditional agriculture (Galinato and Miles, 2013; Kozai et al., 2020).

Secondly, another important recurring cost is labor. Interviews consistently indicated that labor is one of the highest recurring expenses in their experience. This high cost seems to be strongly associated with the complex technical labor required for growing crops in a closed environment. This method demands delicacy and precision in actions, a higher frequency of

crop cycles, and stricter pest and disease management, making it more labor-intensive.

Previous research has shown that, when calculating man-hours needed to produce one kilogram of product, VF requires 4.75 times more labor compared to traditional agriculture (Galinato and Miles, 2013; Kozai et al., 2020). Additionally, authors speculate that VF, on average, requires more specialized knowledge than traditional agriculture. Interviewees have highlighted a visible talent shortage in the market, as few individuals possess the necessary skills, resulting in a tight labor market and high costs for hiring and retaining specialists.

Despite this, there is disagreement in popular discourse, with some sources suggesting that VF is less labor-intensive than traditional agriculture. For example, IFarm, a VF company from the UAE, claimed on their blog that VF is approximately 30% less expensive in terms of labor costs compared to traditional farming (IFarm, 2022). Their argument is based on the high level of technological development, which allows for the automation of most parts of the process. However, empirical results of this study indicate that, although automation does reduce labor costs, at present moment, VF remains significantly more labor-intensive than traditional farming.

There are certain aspects of VFs where the cost structure is or has the potential to be more efficient than in other forms of agriculture. Researchers and experts agree that the greatest potential for efficiency lies in the volume of water usage and land requirements. As previously mentioned, Benke & Tomkins (2017) suggested that VF can use up to 95% less water than traditional agriculture. Similarly, Moghimi (2021) stated that VF requires only one-tenth of the water compared to traditional agriculture.

Although interviewed executives acknowledged this technical advantage, they mentioned that it currently does not result in significant savings for their companies because water is relatively inexpensive in their regions of operation. Further research is needed with companies operating in regions with limited water access, such as Sub-Saharan Africa or South Asia.

However, the authors speculate that, given the global issue of water scarcity and the fact that agriculture accounts for 70% of freshwater usage (Zhang et al., 2020; Khokhar, 2017), future increases in water prices will make cost savings from VF more significant. This potential for reduced water usage could become an important differentiator between VF and traditional agriculture.

When it comes to land requirements, it is unclear whether VF can currently be treated as cost-saving or cost-intensive. Many researchers argue that as arable land becomes more expensive and regulations concerning deforestation have become stricter in recent years, access to land will be increasingly limited (Olsson et al., 2023). From this perspective, VF presents a significant opportunity due to its land usage efficiency. Academic research supports this view, indicating that VFs require significantly less land—about 37.5 times less per kilogram of crop produced annually—compared to traditional farming methods (Galinato and Miles, 2013; Kozai et al., 2020).

Most interviewees highlighted the importance of producing food locally as a key selling point for VFs. To capitalize on this, farms need to operate close to cities, which typically entails higher land costs. This is especially true for companies that choose to be hyper localized, operating within city boundaries. Examples include Upward Farms in New York and Harvest London in London. In cities with some of the highest land costs per square meter in the world, land can't be treated as a cost-saving factor. A potential solution to that factor could come from partnerships with municipalities, which is being discussed further in the paper. The author suggests that while land may become a generally cost-efficient element of VF in the future, it currently heavily depends on a company's localization strategy.

### 7.2.3 Resource Velocity

Resource velocity is one of the key advantages of VF. Research and empirical results highlight the precise resource planning in VF. Due to the controlled environment, the input of energy, fertilizers, and water is exactly known, as well as the output of crops produced in a given time. Additionally, VF has shorter crop cycles. Therefore, it is fair to assume that VFs have high resource velocity and can operate according to practices like Just-in-Time (JiT), optimizing the production and supply cycle.

## 7.3 Key Resources and Processes

### 7.3.1 Technology

In terms of technologies used by VF companies, the data in research is limited. This is likely due to the secretive nature of the industry, where intellectual property related to the system is often a key differentiator. This topic is further discussed in the chapter on partnerships. However, it is worth examining the market for high-agriculture technology and how companies approach this expense.

As previously mentioned, the high initial costs associated with purchasing advanced agricultural technologies represent a significant entry barrier for new players. Additionally, empirical results suggest that prices can be further inflated due to the limited number of alternatives and strongly guarded intellectual property. Therefore, some companies, like the one represented by The Dutch Manager, choose to develop their own proprietary systems, which can lead to long-term cost savings and scalability benefits.

Another point raised in the empirical results was the risk associated with purchasing technology systems. For example, The Scandinavian CFO highlighted that a system produced in Taiwan required intense manual labor, making it more suitable for countries where labor is both more accessible and affordable.

Therefore, while developing proprietary systems can offer significant advantages, companies must carefully evaluate their technology strategies and consider the unique challenges and opportunities of their operational environment.

### 7.3.2 Location and Channels

One of the critical discourses within the field of VF concerns the appropriate location for these farms. Previous literature often identifies VF as "urban farming," operating within city boundaries (Al-Chalabi, 2015; Despommier, 2019; Yeung, 2023). However, it is generally agreed that locating VFs on the outskirts of cities offers more benefits, such as cheaper land. There are examples of companies operating in city centres, such as AgriPlay Ventures in Calgary, Canada (O'Brien, 2023). However, in authors' opinion, the choice of a city centre location is more common among companies that fit Model 1 description. This is because, with relatively small-scale production, the cost of land is not a significant issue, whereas being near target customers, such as high-end restaurants or specialty grocers, provides a strategic



advantage. This view seems to be supported by Specht et al. (2014) who highlighted that VFs can effectively cater to high-end markets by offering premium, fresh produce directly to discerning consumers and upscale restaurants.

All interviewees concurred that being hyper-localized, or operating in the city centre, is not necessary for success in the industry. Some experts (The Agtech Specialist, The Dutch Manager) argued that operating within city boundaries, especially in the city centre, presents several disadvantages, particularly in terms of scaling the farm and transporting the produce. Both mentioned that an ideal location for large-scale VFs is near supermarket distribution centres. Voss (2013) supports this view, arguing that the optimal location for VFs is near major retailers, as this would minimize transportation requirements by allowing crops to be sold immediately after harvest.

## 7.4 Customer Value Proposition

Based on the literature review and empirical results, the authors assert that there is no single, unique Customer Value Proposition (CVP) that is universally applicable across the entire VF industry. Similar to traditional agriculture, the end value for customers varies. However, specific patterns or strategies for positioning a company's unique selling point can be identified, depending on the customer segment.

### 7.4.1 High-End Consumer

As previously discussed in the Model 1 description, some VF companies specialize in high-end gourmet products such as strawberries, saffron, herbs, or edible flowers. The primary value comes from the superior flavor and quality of the products, which can be achieved in VFs. This target market is not limited to specialized companies, as there are instances of large-scale VFs becoming significant suppliers for Michelin-starred restaurants, such as Bowery or Farm.One (Pointing, 2018; Katrien, 2023; Gowen, 2024). Additionally, some restaurants use their own small-scale, on-site VFs to enhance their cuisine, for example, in Windermere, UK (Gowen, 2024). The Technology Specialist, with a background in production, argued that VF products

can offer better taste compared to traditional agriculture, supporting the value proposition for high-end consumers. An additional value is the ability to deliver fresh, locally produced goods year-round, regardless of seasonal changes, which is a significant advantage for premium retailers and restaurants.

#### 7.4.2 Average Consumer

Both interviewed executives and subject matter experts strongly argued that to serve the general food market, companies need to target average consumers by matching market price points. According to them, the most important qualities that a VF product must offer are shelf-life, price, nutritional value, and taste. Regarding shelf-life, VF has an advantage due to relatively short transport routes, which improve shelf-life. Additionally, some researchers argue that the production method of VF naturally extends the shelf-life of products compared to other methods (Zhuang et al., 2022). In terms of nutrition and taste, as mentioned previously, VF products are often similar or superior to those from traditional agriculture. Finally, the price point is a highly debated issue. Some researchers and interviewees, particularly The Dutch Manager, argued that only by matching market price points can VFs compete in the market for the average consumer. While certain companies manage to match market prices, the authors cannot assess the feasibility of this strategy without analysing the companies' financials. Therefore, further research is needed in this area.

#### 7.4.3 Other sectors

Given the highly saturated market and the challenges in achieving substantial margins within the food industry, it is pertinent to explore what other avenues are available for VFs. The interviewees discussed successful cases of VFs operating within the beauty and life sciences industries. This perspective aligns with Butturini and Marcellis (2020), who suggested in their industry outlook report that VFs are well-suited to produce specific plants with qualities necessary for pharmaceuticals, nutraceuticals, and skincare products. Due to the quality and precision required in these markets, this presents an important opportunity for VFs to diversify their revenue streams. Moreover, it is crucial to note that profit margins per unit are

significantly higher in the beauty and pharmaceutical industries (Ledley et al., 2020; McKinsey, 2023) compared to the food industry. This potential for higher profitability makes these sectors particularly appealing for VFs, which struggle to compete on margins with traditional agriculture.

## 7.5 Industry Analysis of Vertical Farming Industry

The subsequent discussion focuses on assessing the VF industry from an investor's perspective. This analysis employs the Porter Five Forces framework (2008), as the author believes it offers the best structure to present and discuss empirical findings. This section avoids repeating factors such as cost structure, customer perspectives, and technology providers that were covered in the previous analysis of business models. Instead, this chapter concentrates on aspects not extensively discussed earlier, with particular emphasis on elements of the industry investment landscape.

### 7.5.1 Threat of new entrants

When discussing the threat of new entrants, it is crucial to focus not only on the barriers to entry within the industry but also on how the entry of new players can affect incumbents. Among the seven major sources of entry barriers, two appear to be most prevalent based on empirical results. The first is the supply-side economy of scale, which relates to the importance of achieving economies of scale to operate successfully in a sector. In VF, particularly in Model 2 companies, the high capital intensity required for operations and the relatively low margin per unit necessitate spreading fixed costs over many units to achieve profitability. This stance is supported by Dahlberg and Lindén (2019), who identified the required economy of scale as a significant entry barrier. However, they noted that this barrier could be mitigated by larger capital investments, allowing new companies to catch up to incumbents.

The second major entry barrier is capital requirements. As previously mentioned, VF is a capital-intensive undertaking, involving substantial initial costs for purchasing or developing technology, acquiring or renting land, and fixed costs related to energy and labor. Dahlberg

and Lindén (2019) argued that although VF is capital intensive, efficient capital markets make capital intensity a non-significant issue for VF companies. However, it is important to note that their research was conducted in 2019, a period characterized by banks cutting interest rates to support economic growth. In 2024, the focus has shifted to controlling high inflation, leading to significant interest rate hikes by central banks and resulting in more risk-averse capital markets. Additionally, interviewees highlighted a loss of investor trust in VFs due to undelivered promises of high returns. Following the burst of the VF bubble in 2023 and a series of bankruptcies, the authors suggest that capital requirements are currently a significant barrier to entry.

Regarding the effect of new entrants on incumbents, the authors argue that it is not significant. Empirical results indicate that, especially for Model 2 companies, the direct competitor is traditional agriculture, which holds a much larger market share. The competitive forces between VF and traditional agriculture are already so strong that the entry of new VFs will likely not strongly affect other incumbents within the sector. The situation might be different for Model 2 companies, where client awareness plays a more important role, and the market size is significantly smaller. In this scenario, the authors suggest that the entry of new players might have a more significant impact.

### 7.5.2 Suppliers Power

When examining supplier power in the VF industry, authors decided to categorize suppliers into three main groups: utilities, labor, and technology.

Regarding utility suppliers, particularly energy providers, their influence on companies' operations is significant due to the highly energy-intensive nature of the cultivation process. Additionally, the choice of energy providers is often limited. One strategy to mitigate this dependence is to establish strategic partnerships with energy companies, which is being discussed in detail in subsequent sections of this chapter.

In terms of labor, as already mentioned, VF is a relatively young industry with a tight labor market. This situation positions employees in a strong bargaining position, thereby increasing their supplier power.

Lastly, technology providers hold substantial supplier power in the VF industry. According to Porter (2008), one critical factor influencing supplier power is the cost of switching technology. In VF, the systems are both complex and expensive, making the costs of switching considerable due to the need for new investments in technology and training on new equipment.

Therefore, the authors suggest that suppliers currently hold a strong position and significant bargaining power, which is expected to diminish as the industry matures and the market becomes more saturated.

### 7.5.3 Buyers Power

The buyer power of VF products appears to be comparable to that observed in the traditional food market, although this may vary depending on the specific product. Interviewees indicated that customers exert minimal effort in purchasing decisions concerning leafy greens. This perspective is supported by Dahlberg and Lindén (2019), who argue that consumers typically do not have a preferred brand for greens, resulting in low brand loyalty and, consequently, low switching costs. Additionally, since end customers dictate the overall demand for the product, they possess significant bargaining power, making them crucial to consider in business operations.

Regarding retailers, the research indicates that they generally wield substantial bargaining power, particularly supermarkets that hold significant market shares in their regions (Mondliwa et al., 2023). However, interviewees strongly emphasized the ability of VFs to consistently deliver products of uniform quality throughout the year. Based on this, it is suggested that VFs may have increased bargaining power in their relationships with retailers during months when traditional agriculture cannot supply products due to weather conditions.

### 7.5.4 Threat of substitution

The threat of substitution for VF production remains uncertain, with research divided on its significance. Dahlberg and Lindén (2019) argued that because VF products are substitutes for traditional agricultural products and represent a relatively small industry, it is challenging to

identify new technologies attempting to replace VF. One of the main threats of substitution they identified is the possibility that consumers may not adopt VF products and continue to rely on traditional farming. However, over time, this seems less of a threat as academic research indicates that consumers are willing to purchase products from VFs if these products meet or exceed purchasing factors such as quality and shelf life (Jaeger, 2023).

In contrast, Areias (2020) suggested that a potential threat could arise from traditional farmers increasing their production volumes to reduce costs and undercut VF margins to an unsustainable level for VFs. Additionally, she identified a barrier in consolidating customer loyalty by VFs. The empirical data from this research partially supports both positions, indicating that further research is required to properly assess the actual threat of substitution.

### 7.5.5 Competitive Rivalry

The competitive forces shaping this industry can be divided into two categories: the competition among VF companies and the broader market for agricultural products. These two categories are inherently different in their dynamics. The former is being further discussed in the chapter on partnerships and “coopetition,” while the latter is the focus of this chapter.

Porter (2008) describes intense competitive rivalry as arising from a large number of similarly sized competitors, similar products, or perishable products. Applying these criteria, it is evident that the agricultural industry experiences strong competitive rivalry, particularly in commodity products, which are often similar, highly perishable, and significantly influenced by price points. In the author's opinion, this scenario can lead to price competition, which Porter (2008) identifies as particularly destructive for the industry since it often shifts profits from the industry to its customers. However, the authors speculate that, in this case, profits are more likely to be transferred to supermarkets and retailers who possess direct bargaining power, rather than end customers who's indirect bargaining power make them less capable of influencing the price.

This perspective aligns with existing research, which identifies high fixed costs, high exit barriers, similar products, and a large number of market players as factors contributing to the high competitiveness of the agricultural sector (Hudori, 2013; Kurmanalina et al., 2020).

However, the author suggests that in terms of product differentiation and unique value, the competition between VFs and the rest of the agricultural sector is less intense. This might be due to the unique values that VF products offer, which was discussed in the chapter on customer value proposition. Porter (2008) argues that competition based on these dimensions (e.g. product quality or market perception) is less likely to erode industry profitability and can support higher prices. Nevertheless, authors suggest that the extent of this competition largely depends on the type of crops and the customers' perspective, such as whether the product is a commodity or a luxury item and its price elasticity.

## 7.6 Innovation ecosystem prospects

In agreement with the initial research conducted by the authors, the data suggest that the VF industry is not comprised from an environment that encourages collaboration and knowledge sharing. This derives from the remarks of The Agtech Specialist regarding the secretive nature of VF companies, as well as The Dutch Manager's remarks regarding the occasional need for multiple NDAs to initiate discussion, which are in line with Lubna et.al., (2022). The Independent Consultant's remarks regarding the uncertainty of companies to define their business model (technological or food provider), as well as The Dutch Manager's remarks regarding the differences in structure could also relate to the difficulty of scholars to decide on a common research idea in multidisciplinary collaboration of VF (Ryymin et.al., 2020). Although this is a mere speculation by the authors, it could be argued that the complexity of highly varied structures of VF companies may increase the overall complexity of collaborations in the industry. Hence, this reasoning could make it one factor that hinders collaborations.

On the other hand, the insights of The Scandinavian CFO and The Dutch Manager regarding their successful collaboration with universities and the benefits that all parties derive from those (e.g., knowledge transfer, talent attraction) justify Wang's et.al., (2023) suggestions regarding the importance of partnering with universities and research institutes. The Scandinavian CFO and The Dutch Manager's remarks are also in line with Fieldsend et.al., (2022), as both were involved in co-innovation activities without being funded but driven by common goals (referring to university projects and food communities).

What was not foreseen and has been revealed by the empirical data is the reasons that could potentially explain why VF firms remain secretive, such as the views of The Agtech Specialist, The Technology Specialist, The Independent Consultant and The Dutch Manager. Their remarks reveal the willingness of VF companies to create a favourable image, in order to remain competitive and secure funding, which appears to hinder collaborative relationships. Although the empirical data suggest that this image may often be exaggerated by companies, it also reveals that they may have a good reason to stay secretive, which the authors interpret as their strong belief in their own innovations. Indeed, according to the concept of a business ecosystem, such an environment does not encourage trade of tangible resources, human capital and technology (Gomes, et.al., 2018). However, according to the definition of an “innovation ecosystem”, the lack of collaborative relationships, or “partnerships” does not necessarily disregard the benefits of innovation enhancement, as competing/substitute relations are argued to be equally important to collaborating relations in fostering innovation (Granstrand & Holgersson, 2020). And yet, Expert’s 3 input suggests that there is willingness from company executives to collaborate, and selective exchange of information, in his opinion, could strengthen the resilience of the industry in unforeseeable events, such as the pandemic and the Russo-Ukrainian war.

Considering the above, the authors argue that the concept of cooptation should be considered as the ideal basis for inter-firm relations within the VF industry (Bacon et.al., 2020). Through the introduction of content-specific measures, this concept could endorse the exchange of explicit information (e.g., information regarding managing electricity or operations) strengthen ties and should be fostered in the basis of learning intent. As transparency is increased while remaining within these boundaries, the firms can attempt to unravel any personalized or investigative components. By doing so, the authors argue that the exchange of information remains explicit, while the knowledge transfer between competing parties is increased, and value is created, in line with Bacon et.al., (2020).

## 7.8 Private-public collaboration prospects



The data revealed major differences between continents regarding the engagement of government in the VF industry, particularly in the context of North America, Europe, and Singapore, where the participants had experience or informed opinions to share.

In the context of North America, the remarks of The Agtech Specialist suggest the weakness of governmental support to farmers in comparison to the EU. Although agricultural policy comparison between the US and the EU is beyond the scope of this research, his opinions may reflect Blandford's and Matthew's (2019) suggestions, regarding the hindered flexibility of the agricultural policies in the US in comparison to the EU. In line with this, although Teo & Go's (2021) suggestion involving the lack of industry-specific policies could be related to The Agtech Specialist's remarks regarding the unattractiveness of the sector to policy makers due to its size, there is currently no concrete evidence supporting those views.

On the other hand, The Podcast Host's remarks in viewing the North American policy landscape through the lens of states, and not holistically, could be argued to bear some value. Supporting these views, it is indicated that Governor Glenn Youngkin has proclaimed March as Virginia Controlled Environment Agriculture Month, endorsing practices such as VF among others ([vdacs.virginia.gov](http://vdacs.virginia.gov), 2024). Hence, to the authors opinion, future research may be more fruitful if the study is conducted on a state level, rather than in a country-wide level.

Nevertheless, the views of The Agtech Specialist and The Investment Director highlighted how subsidies are not needed to drive VF industry growth. Although this is speculated, this might reflect the corporate governance stage in the US, which has been more independent from the government historically, according to the varieties of capitalism framework (Hall & Soskice, 2001). Considering that there is no available study regarding private-public collaboration of VF in the US, the authors are led to believe that private-public collaboration in the country is still in its infancy. While these views are heavily restricted by the current data, perhaps initial steps for collaboration with state officials, such as the ones in Virginia, could be positive first steps towards a future private-public partnership.

Although the initial research regarding policy in the EU showed a more favourable environment compared to the US (Blandford and Matthews, 2019), the empirical data painted a different picture. Specifically in the context of the Netherlands and Scandinavia, the participants stressed that governmental support was lacking. Moreover, The Independent

Consultant's remarks regarding the lack of information by European Commission Representatives. As the report from EIP AGRI SP (2017) highlights how the EU emphasized the need for agriculture innovation in Europe, it comes as a surprise that VF, which could be argued to be one of the most innovative types of agriculture, is not included in this category. However, the results are in line with Van Delden's (2021) research, which argues that agricultural policy in the EU has not been modified to include VFs. Here, Gutierrez's and Macken-Walsh's (2022) argument about the different decisions between similar actors may have some gravity.

The findings also revealed the unequal character of policies amongst countries in Europe, as The Scandinavian CFO remarked the superior governmental support on VF from the German government, and how this influenced their decision about his company expanding to Germany. As no other previous research has been involved with Germany's policy regarding VF, these remarks may be a be worth investigating. In line with The Dutch Manager's suggestions about the need for policies in the field, these findings suggest that policy in the EU may bear more gravity in the future prospects of the industry than in the US and the need for change from government officials may be more urgent.

As speculated in the beginning of the research, the governmental policies in Singapore are in contrast to the ones in EU and in North America, which is in line with many studies VF in Singapore (Diehl et.al., 2020; Wood et.al., 2020; Song et.al., 2022; Tablada et.al., 2020; Mok et.al., 2020). Although the data comes mainly from The Dutch Manager, it bears gravity, as the company she is affiliated with owns farms in Singapore, and she provides first-hand information through the company's experience. The willingness and flexibility of the Singaporean officials to support the company could stem from Diehl's et.al., (2020), regarding multi-functional urban farming flexibility and overlapping use of land. As Oskam et.al., (2021) suggests, by formulating clear, common sustainability goals through social, economic and environmental values through the 30-30 goal (Song et.al., 2022), collaboration is more possible and beneficial. Moreover, as the company would be able to match the higher market price, individual versus collective gain disputes is less likely. Hence, collective orchestration in Singapore is highly possible. The interpretation of the authors regarding ownership in Singapore is that the company affiliated with The Dutch Manager would retain ownership in these farms.

Hence, the suggestions of Carbonara & Pellegrino (2020) regarding the benefits of increased private ownership in PPP agree with this case. What is highlighted through these results are the consideration of a company to relocate in another market, located far from the headquarters of the firm, mainly because of the favourable governmental support. Although these findings cannot be generalised, they highlight the importance of governmental influence in the business prospects of VF, and how they could boost the companies to achieve better results in the future.

Overall, even though it seems that companies in the VF industry are not reliant in governmental support, the results suggest that subsidies and favourable collaboration with the government could bear many benefits to the industry. Although these may be argued to not be the core driver of VF firms, their influence in the future prospect of the industry may be vital, as they could significantly reduce the time it takes to achieve sustainable scalability and profitability.

## 7.9 Sustainability considerations

### 7.9.1 Energy Sustainability Prospects

The initial research conducted by the authors involved much literature that confirms the sustainability benefits of VF, such as soilless farming and significant reduction of water consumption (Oh & Lu, 2022; Van Gerrewey, et. al.,2022; Van Delden et al., 2021; Sharma, 2023). While it was also highlighted that there are energy concerns within the industry (Jin et.al., 2022), the authors did not foresee the extend of those concerns, and the empirical data provided an unexpected outcome. Even though Van Delden et al., (2021) highlighted the similarity in water reduction between the two practices, The Podcast Host, The Construction Specialists and The Dutch Manager dwelled on the energy concerns in VF. In The Podcast Host's remarks, it is unclear if VF is more sustainable than greenhouses. The Dutch Manager's opinion stressed how many VFs, while identifying as sustainable, their energy usage is significant. In a more indirect sense, The Construction Specialists commented on the significant energy that is required to create VF equipment, an aspect which the authors did not encounter in the available literature.

The Podcast Host's suggestions regarding the sustainability statements of companies agrees with (Kraft and Zheng, 2021), as by doing so, companies can appeal to stakeholders and

increase value. These statements can also be related to a CSR strategy, to secure the legitimacy of the brand or even secure investment (Werther & Chandler, 2005; Hart, 1995). However, reflecting on the data provided from the participants, Matten's & Moon's (2008) suggestions regarding the misplaced value of CSR should be considered, and more critical view of these statements may be appropriate.

Despite the concerns regarding energy efficiency, the data has also revealed a few examples of sustainable practices, including energy efficiency practices, which should be noted to form a more holistic picture. When asked about successful companies, The Independent Consultant introduced an example of a company that utilised renewable energy in their farms, referring to Potager Farm (2024). Additionally, the "smart" way that GrowUp is handling its energy need, highlighted by The Investment Director, is assumed to be in relation with the strategic location of the company, as its farm is placed within Discovery Park, a science park that includes a low-carbon renewable energy plant, as well as a condensed community of innovative and scientific businesses (Kennedy, 2022; UK Bioindustry Association, 2022). These findings suggest that the type of energy is a crucial factor in the sustainability of VF, and that renewable energy is an efficient way to achieve sustainability, which is justified by the arguments of Van Gerrewey, et.al., (2022) and Arabzadeh et.al., (2023).

Therefore, the authors are led to believe that despite the possible misinterpretation of the energy consumption of VF firms, solutions that confront energy problems exist within the industry, and companies that are seeking to secure more sustainable prospects should seek those over traditional energy supply.

### 7.9.2 Food Security Prospects

As Van Gerrewey et.al., (2022) mentioned, by increasing the self-sufficiency of food in places with limited resources or urban settings, food security can be increased. However, the data in this research suggest that VF is not the only practice that can achieve such results, nor they suggest that it is the best option (referring to the inputs of The Podcast Host and The Dutch Manager). For example, if it is more efficient to grow tomatoes in greenhouses in the Netherlands, then VFs would not need to focus on this product. Following the same reasoning, in the context of Singapore, where most of the products are imported, VF, or greenhouses could

focus on more products, depending on what is more efficient to grow and with what method. Judging exclusively by the data, although VF may not be the sole solution for food security, it still remains part of the solution, which suggests that Porter and Krammer's (2011), as well as Chandler's (2021) perspective is still applicable in the industry, as profit and shareholder value is in alignment with socio-environmental interests.

As, through The Dutch Manager's suggestions, VF is far from "fixing world hunger" with leafy greens, the data has also shown that products of high caloric value require higher costs, which, as aforementioned in the profit formula section, leads the firms to sell their product at a premium price. As Van Delden (2021) has stated, these products are mostly targeted to higher-income consumers, instead of the average consumer. The Agtech Specialist's remarks about the reluctance of buyers with budget constraints to pay a premium based on sustainability is also supported by Aschemann-Witzel & Zielke (2017). Food security cannot be currently achieved through high caloric products, as those stray away from the provision of basic needs, in line with (Butturini & Marcelis, 2020). Therefore, according to their circumstances, companies will either choose a direction towards food security or premium pricing, as shown in Figure 3. Nevertheless, it is also important to recall Bertini's et.al., (2021) argument, as VF companies may benefit from rethinking their own pricing strategies and create new ways for pricing the products that do not fall under the same category as the aforementioned "winter strawberries".

Finally, it may be difficult to consider VF as a currently viable option for sustainable cities. Although VF abides to most of the factors of Sodiq et al., (2019), The Independent Consultant's suggestions, as well as the findings that were discussed above show that VF may have difficulties in accommodating the growth of its population. However, if the industry is able to solve the aforementioned problems regarding food security, then the authors argue that VF could be an excellent option for providing food security in sustainable cities.

### 7.9.3 Labelling

As Van Delden et.al., (2021) mentioned, VF products are not widely being labelled organic in the Europe and the US. In line with this, the data in this research also expressed the inability of companies to label the VF products as organic. As The Agtech Specialist stated, not being able to label the product organic may hurt the sales of VF products. In literature, although there are

some uncertainties regarding the effect of organic labelling, organic labelling seems to directly affect the product evaluation from consumers (Kun & Kiss, 2021, Drexler et.al., 2017). What was not foreseen by the authors was how many of the participants expressed views against organic labelling by characterizing it inadequate, as in most cases “it is not representative of the benefits of VF products”. Many of the interviewees questioned whether an organic label was needed for VF products, while others remarked that even products that have one organic label does not make the product sustainable. Indeed, research has questioned the sustainability of organic soil in the past (Leifeld, 2012), while another research suggests that just by being organic does not make a farm sustainable (Reganold & Wachter, 2016). Although it is not one of the goals of this research to debate the topic, considering these findings, there may be value in exploring the claims of participants regarding how appropriate organic labels are for VF products.

As seen in the literature review, it is possible for VF products to be seen as “monster-food” because of the factory-like production (Benke & Tomkins, 2017). According to the authors interpretation, The Dutch Manager argued that in countries of higher educational level, these kinds of perceptions would not pose a problem in purchasing decisions. Indeed, a study conducted in Sweden revealed that consumer attitude was positive to sustainably perceived organic products. However, consumers found it difficult to understand the judge whether organic or conventional farming is more sustainable (Bosona & Gebresenbet, 2018). Therefore, in the context of VF, it is difficult to deny or accept The Scandinavian CFO’s suggestion regarding the correlation between educational level and buying decisions of sustainable food products, as most of the available literature seems to be intertwining sustainable food products with organic products, and studies regarding VF products are not available. This may explain The Dutch Manager’s positive attitude towards creating their own label. Considering the above, we argue that an organic certification not only is not needed, but it is also not appropriate for VF products, as it does not educate the consumer accurately on the benefits of choosing a VF product.

## 8 Conclusions

### 8.1 Conclusions and implications of the study

The thesis aimed to enhance the understanding of the VF industry from a business perspective, exploring business models, examining industry practices and perspectives, and analysing empirical data gathered from interviews with industry experts and executives. The goal was to create a business analysis of the sector from four perspectives: business model, industry analysis, strategic partnerships and sustainability, and through that analysis to answer the research question formulated as:

*What are the Future Business Prospects of Vertical Farming: How can vertical farms achieve sustained profit while operating in environmentally and socially sustainable ways?*

The empirical data, authors' discussion, and review of academic literature and secondary sources have yielded findings that can prove valuable for both future researchers and practitioners, including entrepreneurs and investors. The authors have identified two primary business avenues that VFs can adopt:

Model 1 focuses on producing high-quality, premium products for affluent consumers. Companies pursuing this model need to build strong brand awareness and ensure that the quality of their produce surpasses that of traditional agriculture.

Model 2 targets the average consumer market, competing directly with traditional agriculture on factors such as price, shelf-life, and quality.

A key recommendation from experts is for VFs to adopt a "customer-centric" approach. This paper highlights how previous strategies may have overly prioritized technological advancements at the expense of understanding and meeting customer needs. Without delivering the desired value to consumers, VFs will struggle to generate the profits necessary for sustained operations. Another recommendation is aimed at enhancing collective innovation through encouraging co-competition in the industry. Considering the secretive nature of companies, co-competition may be the ideal means to enhancing the innovation ecosystem in VF, which is a factor that could directly affect the scalability of the industry. This study also strengthens the

argument that VF operations should meet their energy needs through renewable energy to enhance the overall sustainability aspects of the practice.

Another critical factor identified is the choice of location, which significantly impacts the scalability of the business. For Model 1, hyper-localization near end consumers is advantageous, enhancing the perceived freshness and premium quality of the products. Conversely, Model 2 benefits from being situated outside of urban areas, preferably near distribution centres, to optimize logistics and cost efficiencies. Research suggest that successful VFs are those that can clearly define their value proposition, whether through offering premium quality and unique products or by achieving cost competitiveness through economies of scale. To optimize cost structures, the authors see significant potential in investing in energy optimization and automation technologies to reduce labor costs. Additionally, VFs should leverage their unique selling point of providing locally produced, fresh food to consumers regardless of the season, distinguishing themselves from traditional agricultural methods.

## 8.2 Limitations and future research

The main limitations of this thesis stem from the chosen methodology and the sample size. Utilizing a qualitative case study approach with empirical results gathered through semi-structured interviews introduces potential subjectivity and biases from both the authors and the interviewees. Additionally, the sample size of nine interviews is insufficient to draw conclusions that are broadly generalizable to the entire industry, especially in an international context. The sample predominantly consisted of industry experts, with only a small set of executives and just one investor. This imbalance suggests that certain topics, such as the investment landscape, require further validation through additional research.

For future research, the authors suggest assessing the viability and market size for VFs in industries beyond agriculture, such as fragrances and pharmaceuticals. Existing research indicates that VF could have significant applications in these markets, but the actual size of these opportunities warrants further investigation. Additionally, the potential of small-scale or container VFs to substitute Model 1 farms, especially in the context of high-end gourmet stores and restaurants, should be explored. The option to choose between providing food or



technology for these customers presents an interesting theory that could be further assessed and analysed.

Additionally, the results of the study imply that the highly diverse structure of VF companies may pose a barrier to collaborations, with further research on that subject being appropriate. Moreover, the energy intensity of producing VF equipment may be another area in need of exploration, as the literature projects a clear gap in this topic. Finally, further research should be concerned with the labelling of VF products, as labelling the products of VF as organic is not supported in this study and requires further exploration.

## 9 References

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## 10 APPENDIX

### Background Question:

1. Could you describe your role and experience in the vertical farming sector?

### Core Questions:

1. From your perspective, what are the defining characteristics of a successful business model in vertical farming?
2. Can you discuss the role of strategic partnerships in vertical farming? What types of collaborations have you seen or been a part of within the industry?
3. Considering the triple bottom line (people, planet, profit), how are sustainability considerations integrated into decision-making and operations in vertical farming?
4. What are the key factors that make the vertical farming industry attractive for investment today? What are the main barriers that deter the investments?
5. Can you point to a successful case study of a vertical farming company that effectively designed and employed its operational model?
6. How do market demands and consumer preferences influence the operational and strategic decisions of vertical farming companies?
7. How does vertical farming contribute to food security and urban sustainability, particularly in the context of growing urban populations and climate change?
8. How can vertical farming companies achieve scalability and profitability, given the high initial costs associated with advanced agricultural technologies? Can you identify any other high cost necessities that may hinder the project?
9. What role do governmental policies and regulations play in shaping the vertical farming industry, and what policy changes would you recommend to foster industry growth?
10. To what extent is the current vertical farming industry is dependent on government subsidies and government collaboration?



11. Based on your expertise, what are the most significant mistakes that vertical farming companies make?