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How to create value by entrepreneurially using the innovation Vertical Indoor Farming in Smart Sustainable Cities?

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Abstract

This master thesis report investigates the potential of five different innovations for value creation in the context of Smart Sustainable Cities by 2050, applying the research question "How to create value by entrepreneurially using innovations in Smart Sustainable Cities?" The individual part focuses on the innovation of Vertical indoor farming. Interviews, calculations, research, and sustainability assessments have been done. In conclusion, environmental sustainability without sacrificing price, quality or other advantages leads to an increase of value.

Keywords: Digital Business, Technology Strategy, Smart Cities, Sustainability, Technology, Entrepreneurship, Innovation, Value Creation, Digital Transformation, Business Model, Technology Adoption, Technological Innovation, Sustainability Assessment, Sustainable Development Goals, Mobility, New Product Development, Smart Sustainable Mobility, Mobility-as-a-Service, Biophilic Design, Green Buildings, Sustainable Architecture, Renewable Energies, Energy Efficiency, Energy Management, Clean Energy, Energy Market, Peer to Peer Energy Trading, Blockchain, Financial Technology, Fintech

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Table of Figures

Table of Contents

Table of Abbreviations:

Agtech: Agriculture Technology

AI: Artificial Intelligence

AML: Lisbon Metropolitan Area (Área Metropolitana de Lisboa)

App: Appendix

BC: Blockchain

BD: Biophilic Design

CA: Conventional agriculture

CAPEX: Capital Expenditure

CE: Circular Economy

CF: Cash Flow

DIY: Do It Yourself

EGME: Eletric Mobility Network Regulator (Entidade Gestora da Rede de Mobilidade Elétrica)

EM: Energy Market

EV: Electric Vehicle

FF: Freight Farms

Fintech: Financial Technology

GHG: Greenhouse Gas

ICE: Internal Combustion Engine

IoT: Internet of Things

ML: Machine Learning

P2P: Peer-to-Peer

R&D: Research & Development

RE: Renewables or Renewable Energy

RQ: Research Question

SDG: Sustainable Development Goal

SG&A: Selling, General & Administrative

SME: Small- and medium-sized enterprises

SUMP: Sustainable Urban Mobility Plan

TML: Transports Authority for AML (Transportes Metropolitanos de Lisboa)

UN: United Nations

UNECE: United Nations Economic Commission for Europe

VC: Venture Capitalists

VIF: Vertical Indoor Farming

1. General Introduction

"If we could build an economy that would use things rather than use them up, we could build a future. There is a massive economic opportunity out there to be taken without waiting for government legislation. When you start, you're trying to achieve staying alive and getting home."

– Ellen MacArthur

How will we live in 30 years? The answers to this question can be very diverging, but one thing is certain - the world will change dramatically. In the context of digitalization, Smart Cities is a concept that is constantly being discussed. New urban projects offer their inhabitants a vast amount of possibilities, of which many are still undiscovered and there is much to understand still. The state of affairs regarding this topic is constantly shifting and incorporating innovations and concepts that until very recently would have been considered futuristic but now are a reality.

Added to this is the growing importance of sustainability since issues such as the climate change, increasing scarcity of raw materials, and lack of urban space will be decisive not only for the coming years but for the future generations that are yet to come. It is the responsibility of companies and innovators to entrepreneurially tackle problems that now urge to be solved, as the consequences of ignoring them can be disastrous.

Therefore, the question which needs to be answered is: How to create value by entrepreneurially using innovations in Smart Sustainable Cities?

1.1. Previous research

"Smart city concept enjoys different aspects and a variety of definitions" (Mohseni 2021), meaning there is no unambiguous way to describe them in a sizable pool of research.

According to Anand Prakash (2019), the concept of Smart Cities was invented by an information technology firm, the International Business Machines (IBM) Corporation. First, the words “smart” and “cities” were separated, and several definitions analysed. It is then concluded that a Smart City is a city in which many essential business problems – such as “organized power supply, provision of clean water, strong civic infrastructure, sewage, and waste treatment plant, rainwater harvesting and solar energy through advanced connectivity” – are tackled. Often a Smart City is also defined as a city “that monitors and integrates conditions of all of its critical infrastructures, [...] can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens” (Hall, 2008).

Research about Smart Cities has suggested various components and features that also range between many different areas, such as infrastructures, buildings, transportation, energy, health care, financials, governance or education (Mohseni 2021). Other definitions include other “aspects of urban life, such as urban planning, sustainable development, environment, energy grid, economic development, (...), social participation and so on” (Prakash 2019).

While discussing these components that compromise Smart Cities, the concept of sustainability becomes increasingly relevant. According to Virtanen (Virtanen, Siragusa, and Guttorm 2020), “the Brundtland Commission initially provided the notion of ‘sustainable development’ with its three intersecting and ranked hierarchically pillars (social, economic, environmental)”.

To achieve the functioning and building of Smart Cities with sustainable methods, a modern and technology-driven approach (Prakash 2019), meaning technological and digital innovation, needs to be involved. So, the concept of ‘Smart City’ is outlined by its technical core, which, in turn, is inspired by advances in computer science and engineering field (Prakash 2019).

1.2. Research Gap and Aim of the Work Project

This work project considers the existing research and focuses rather on the exploration of innovative methods to make cities smarter and more sustainable through technological or digital innovation. A preliminary analysis of several innovations will be performed, which allows a scoping of five approaches that were selected due to their high potential for value creation and contribution towards sustainability.

The objective is to get insight into different, individual dimensions within Smart Cities, that are backed up by an innovative technology or digital platform. Within these individual dimensions, it will be determined how value is created and its impact on the environment, economy and society. In this way, a better impression can be created of what our lives will look like in 30 years from now. To delimit the analyses, it will be geographically focused on Europe, and the timeframe will be set until 2050.

1.3. Research Question

The above-described gap and research objective lead to the following defined Research Question (RQ) that will be explored throughout this paper: How to create value by entrepreneurially using sustainable innovations in Smart Sustainable Cities?

This question is separated into three main topics: technological innovation, sustainability assessment, and value creation. The first topic, technological innovation, will be tackled by defining five key areas of focus of this research. The work project aims to analyse the value these innovations create in this setting of cities of the future. After analysing the current state of affairs for each specific case, the second and third topic will be tackled by performing a value creation and sustainability assessment must. Theses assessments will be conducted through several formats, resulting in a critical discussion on the connection between these two dimensions.

Therefore, value creation must be defined in a specific way to understand better the question at hand. This can give us insights into the structure and analysis of this work project. Value Creation is achieved when a company generates added benefits for its customers through its work and resources. It can be assessed through different approaches. One way to validate it is to understand if the solution generates benefits of any kind for all the stakeholders involved. At the same time, it is important to assess what is the extent of these benefits. Another methodology is to assess the financial viability of the company business model, thus proving that financial value is created. Throughout this work project, the five different innovations presented will assess value creation using different methods.

This work project aims to answer the RQ on the ground of these dimensions of value creation on each of the subtopics and through a comprehension at the end. As mentioned in Chapter 1.1., sustainability comprises a social, economic, and an environmental dimension and will be explained in the later chapters. Each one of these can be tested and validated in different ways, ranging from gathering of primary data to question how citizens and other stakeholders are impacted to thorough research of available data to validate whether all of the dimensions are met, or even through a quantitative analysis of potential environmentally sustainable impact that an innovation can bring.

To thoroughly answer the RQ, it is additionally essential that a future outlook is provided to give a clear understanding of the state-of-the-art, potential, and associated implications of the innovation at the moment and in the future.

1.4. Supporting Questions

To answer the RQ as precisely and accurately as possible, it is necessary to define supporting questions first, which lead to the overall RQ, to ensure a clear understanding of every individual aspects. These questions will be answered in the General Conclusion, functioning as a final validation framework of the conclusions that were the product of each of the innovations analysed.

For what do sustainable innovations create value?

To analyse and explain how to create value by entrepreneurially using sustainable innovations in smart sustainable cities, the output that the sustainable innovations lead to must be defined. Additionally, the stakeholders or key areas affected must be defined.

Are current Smart Cities already applying/adopting these technologies/digital services?

The willingness to implement and adopt new technologies and digital services is fundamental for possible value creation. If this willingness does not exist, value creation is not even possible from the start. Therefore, the prerequisite for answering the RQ is to consider the readiness of Smart Cities to adopt and implement the technologies and digital services.

What are the key challenges of the innovation?

In addition to the state of affairs, the challenges that may arise are also considered. The extent to which each challenge can be posed as a barrier to entry can depend on micro and macroenvironmental factors. Still, an assessment of each challenge and understanding of the level of risk towards implementation that it poses is key to a critical analysis.

Are these innovations in these Smart Cities truly sustainable?

Another very important point, after analysing the possible value creation, implementation and risks, is to assess whether the listed innovations have a positive environmentally sustainable effect on Smart Cities.

After answering these supporting questions, based on the detailed analysis of the possible value creation of the different sustainable innovations in sustainable Smart Cities, the RQs of this master thesis can be answered successfully.

1.5. Relevance of Research Question

Despite occupying only 2% of the world's surface, cities have a disproportionate climatic impact and energy footprint, according to C40, a network of megacities committed to tackling climate change. Cities consume more than two-thirds of the world's energy and produce over 70% of global emissions (‘Beyond Smart Cities: Why Smart and Sustainable Cities Are the Way Forward’ n.d.). Environmental externalities - primarily resulting from population growth, rapid urbanization, high private motor vehicle dependency, the deregulated market, mass livestock production, and excessive consumerism - have raised serious concerns about the future of natural ecosystems in which we are a part of. Global climate change, one of the most significant problems humanity has ever faced, directly influences people's well-being and, in the long term, on humanity's existence (‘Climate Effects on Health | CDC’ 2021). In the past two decades, the concept of Smart City, especially the sustainable development of Smart Cities, has increasingly become the focus of attention in the fields of technology, science, urban and environmental planning, development and management, as well as for urban decision makers and practitioners. This was caused by digital technologies being a key enabler in stimulating paradigmatic transformations in visions, strategies, execution, and learning connected to urban development.. The combination of technocentric and environmentalist views is a path to the ideal urban form of the 21st century (Ahad et al. 2020).

1.6. Organization of Work Project and Delineation of Field of Study

In the following section, the structure of this paper and the procedure for answering the RQ will be explained. First, the basic building blocks for answering the question are laid in Chapter 2. For this purpose, a precise definition and literature review of Smart Sustainable Cities, along with an historical context and the analysis of existing Smart City business models will be performed. Furthermore, sustainable innovations in the context of Smart Cities will be defined.

The potentials, challenges, trends, and developments of these are examined in more detail. Next, the delimitation strategy is described by breaking down the general overarching theme of Smart Sustainable Cites to the focus of sustainable innovations within Smart Cites. After the basic building blocks have been laid, the methodology used in the further work for the analysis and application of the RQ is discussed in Chapter 3. For this purpose, the used data sources are listed, and the methodology used to define the five key innovations chosen is explained. The analytical methods to assess entrepreneurial and sustainable value are outlined in each individual part. In the following chapters, five different sustainable innovation areas within Smart Sustainable Cities are discussed in detail, ranging from smart sustainable mobility, vertical farming, and biophilic design to Fintech and blockchain in the energy market. Thereby, an analysis will be carried out on how and to what extent these sustainable innovations create value in Smart Cities. In Chapter 3, a general discussion of the research project will be conducted. Finally, the limitations of the RQs are discussed, and a look into the future of sustainable innovations in Smart Cities is ventured.

The RQ will be elaborated in the field lab "Technology Strategy" focusing on sustainability. The question was derived by breaking down this defined topic area into various possible application areas. The choice fell on the application area Smart City since, within a Smart City, multiple stakeholders and dimensions are affected by the implementation of new technologies. To create a link to sustainability, it was decided to limit the topic to innovations , that make cities smarter and more sustainable, as this topic is of significant relevance today, as explained in Chapter 1.2.

2. General Literature review

2.1. Delimitation Strategy of the Literature Review

As previously demonstrated, Sustainable Smart Cities contain a wide range of cross-cutting topics that can be evaluated within an in-depth analysis. Although this type of analysis would enrich the research in terms of content, this work project will limit the focus of the research to sustainable innovations.

The urgency of adapting the traditional business models to preserve the human species and environment to guarantee a future for the new generations has never been higher. In many societies, the government is responsible and leading the innovation policy. These innovation processes are, however, often hindered by extreme bureaucracy. Therefore, innovations are typically tackled and achieved by entrepreneurs, adapting and creating new business models, in a faster and more efficient manner.

2.2. Smart Sustainable Cities

2.2.1. Definition

As previously established, the concept of Smart Sustainable Cities is very innovative and can have several definitions. To establish which new technologies can entrepreneurially create value for smart sustainable cities, a definition of "smart" and "sustainable" needs to be set up first. The UN in 1987 defined sustainability the following way: "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Nations n.d.). United Nations Economic Commission For Europe (UNECE)'s definition distinguishes both parts of the concept of Smart Sustainable City very clearly, defining it as "an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects" ('Sustainable Smart Cities | UNECE' n.d.).

Dr. Rudolf Giffinger and the European Smart Cities research group at the Centre of Regional Science of Vienna University defined six Smart City areas of action (Giffinger 2015), which were later popularized in Dr. Boyd Cohen's "Smart Cities Wheel" (Cohen 2018). Although these areas only refer to the sustainability dimension of Smart Sustainable Cities, they will be applied in the further work project to categorize the innovations assessed and to assess their sustainability according to the parameters defined in UNECE's definition.

The first area of action is "Smart Government", which includes creating synergies between the government and all stakeholders through the creation of policies, fostering transparency, and taking a digitally innovative approach. The second area, "Smart Economy", comprises the use of an entrepreneurial spirit and technology to create economic efficiencies, such as making a city more attractive for new businesses, and leading to local and global interconnectedness. Thirdly, "Smart Environment" relates to urban planning and the management of all key city infrastructures, ranging from waste management to the energy sources that are used. "Smart Living" also focuses on quality of life, but from a social standpoint. It relates to the access to basic services such as healthcare, housing, and the internet, and how access to these key infrastructures is enabled. "Smart Mobility" concerns the maximization of the efficiency of urban transports, making it more economically and environmentally sustainable through innovative and technological solutions. Finally, the sixth dimension – "Smart People" – focuses on the interaction with each other and with the public and private sectors. A Smart City should provide accessible and inclusive measures that foster the participation of all stakeholders in the city's matters through the implementation of intelligent solutions.

2.2.2. Historical Evolution of the Concept

As the definition of Smart Sustainable Cities has been established, taking into consideration the status quo for being "smart", "sustainable" and a "city", it is important to stress that this concept has evolved and changed over time, due to the constant development of society. In fact, Höjer and Wangel stated five key areas that ultimately led to the origin of research of the Smart Sustainable Cities concept (Höjer and Wangel 2014) – globalization of environmental problems and sustainable development, urbanization, and urban growth, sustainable urban development and sustainable cities, information and communication technologies and Smart Cities. By understanding the latest developments within these five key areas, it is possible to trace the historical development of the Smart Sustainable Cities concept.

For a long time, environmental problems were perceived as local issues. In 1972, the Stockholm Conference – the first United Nations conference that focused on international environmental issues – these matters started to be perceived as a global concern, and the foundation for global environmental governance was set (United Nations n.d.). Later, in 1987, the concept of sustainable development appeared through the Brundtland Report (also known as "Our Common Future"), released by the World Commission on Environment and Development. In this report, sustainability was defined, as previously mentioned, as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). Additionally, among other results, the report set the grounds for the 1992 Rio Summit, in Rio de Janeiro, which ultimately led to the creation of the UN Commission on Sustainable Development in the same year. This commission was created with the purpose of tracking and implementing Agenda 21 – the output of the Rio Summit -, which was strongly reaffirmed at the World Summit on Sustainable Development held in 2002 in Johannesburg (United Nations n.d.). Other key events that were essential to international cooperation for environmental sustainability were the Kyoto Protocol in 1997, which consisted in a commitment to reduce GHG emissions through binding individual targets, requiring stronger efforts from developed nations (UNFCCC n.d.), and the Paris Agreement in 2015, which requires effort from all nations and introduces a higher level of flexibility and national ownership, allowing countries to set their own emission targets according to their development level (United Nations 2015). Even though the literal definition of "Smart Sustainable City" words has not been previously applied, the political, environmental, and economic factors that have been evolving over time lead to an update of past policies, adapting them to the current state of affairs. Therefore, it is essential to mention the European Green Deal, which is a "new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use" (European Comission 2019). It was proposed at the end of 2019, amidst a rise of global leaders that are considered to be hostile to the climate action cause, such as the former President of the USA, Donald Trump, and the current President of Brazil, Jair Bolsonaro. As so, it was not only a call for action for environmental purposes but also a political statement from the European Commission, presided by Ursula von der Leyen, as to what the priorities should be for the next decades, until at least 2050. It focuses on key areas of action, defining how to develop Smart City infrastructures and ultimately stating what factors need to be met to be considered as a sustainable city, and which policies and technologies should be developed to have a smarter path towards a more sustainable future.

It is expected that, as technology, policies, and cities evolve, the concept also shifts. To understand potential reasons for a transition and assess the value Smart Sustainable Cities can create, the City Model Canvas framework, introduced in the next chapter, will be used.

2.2.3. Key Concepts Related to Smart Sustainable Cities

The following concepts will be relevant for this work; Sustainable Development Goals (SDGs), the Three Principles of Sustainability, the ESGs, the Circular Economy, the Well-to-Wheel Analysis.

The Global Sustainable Development Goals (SDGs) ('THE 17 GOALS | Sustainable Development' n.d.). will be applied, which were created by the UN in 2016, as these can more distinctly describe the individual contributions of each innovation even though they might not be related. This helps to better frame and assess the innovations with regards to answering the RQ. In addition, the SDGs are very contemporary and are a global standard. Those define sustainability goals in 17 areas, which bound every aspect together in one concept even though they do not seem related at first sight. This is the upside of applying the SDGs in the frame of this thesis as well. In the individual thesis report that tackles specific innovations, sustainability concepts are applied to assess and determine if the discussed innovation can be considered sustainable or not. For that, the definitions of sustainability (UN and SDGs) plus additional frameworks such as Circular Economy will be applied.

In connection to Smart Sustainable Cities, it is crucial to mention that sustainability can also be assessed by differentiating and analysing the technology at hand with the help of the three principles; environmental, social, and economic sustainability. Based on this dating definition, the concept of ESG emerged and became a standard in the financial world. Even though investing, transactions and loans might not be connected to sustainability, the history of sustainability concepts is linked. ESG stands for the pillars of sustainability: Environment, Social (Society), Governance (which stands for the governance of economic bodies). Nowadays, different standards of ESG are used to classify e.g. investment funds. For example, the higher the ESG standard, the more selective the screening process becomes for assets in one fund (eg. MCSI World (1601 Assets); MSCI World ESG Screened (1506 Assets); MSCI World ESG Enhanced Focus (1490 Assets); MSCI World SRI (386 Assets) (Zeiter 2021). Furthermore, banks, insurances, and other financial bodies express their contribution to sustainability in ESG terms.

Another concept that is more strictly bound to the concept of Smart Cities is Circular Economy (CE), which can be used to assess the environmental sustainability of an innovation. The advantage of the concept is that the Ellen MacArthur Foundation cooperates with firms that focus on Smart Cities. Often, it is required that autonomy in the food supply is needed for an urban population in a Smart City, which would mean that a working Circular Economy has to be applied. Looping back to the initial definition, a wasteless city is the goal also of the dating definition from the UN, as waste necessarily harms future generations as even treated waste occupies space. If a working CE is applied, no waste is generated, all materials are resources, regardless of the state. This transformative approach has also the advantage as physical processes can be assessed based on their output of harmful material (e.g. CO_2) or waste created.

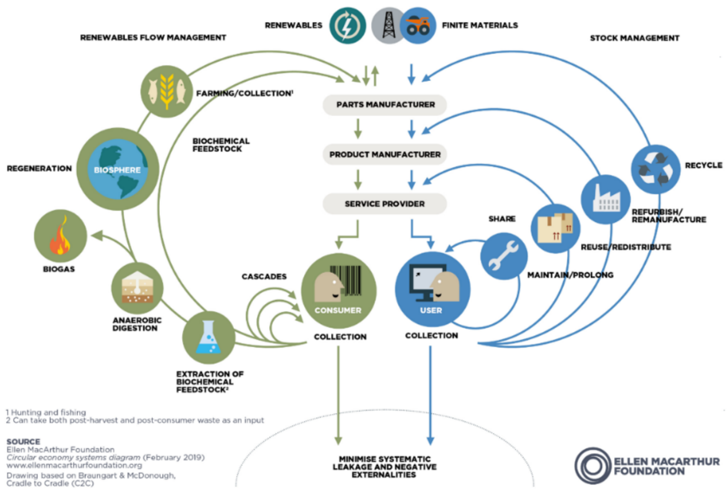

Figure 1: Circular Economy: Ellen MacArthur Foundation, SUN, and McKinsey Center for Business and Environment; Drawing from Braungart & McDonough, Cradle to Cradle (C2C) ('Intelligent Assets: Unlocking the Circular Economy Potential' n.d.)

Finally, a more quantitative concept is the Well-to-Wheel Analysis, which is a policy-neutral methodology that allows for the calculation of GHG emissions, energy efficiency, and industrial costs associated with several types of fuels, as well as respective technological implications. As shown in the figure below, this analysis focuses on the emissions exhausted from well to tank – meaning, from the moment these are produced to the moment these reach the fuel tank – and tank to wheel – meaning, the burning of the fuel. (Nieuweling 2016)

Those concepts are no definite answer to the question of what is and how to get to ultimate sustainability as there is no clear answer to it. Rather, those serve us as possible ways to assess the innovations presented in the context of Smart Cities, even though they seem unrelated. And the concepts show that those innovations are connected through the criteria posed.

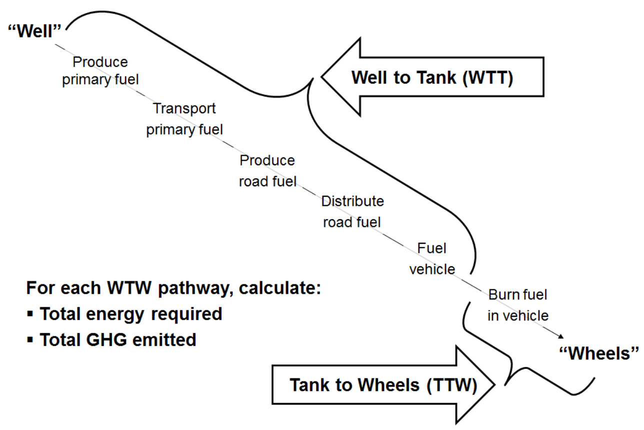

Figure 2: Graphic representation of the Well-to-Wheel Analysis

2.2.4. Smart Cities Business Model Canvas

To analyse sustainable value creation in depth the Business Model Canvas is applied. According to Alexander Osterwalder, creator of the Business Model Canvas "the Business Model describes the logic by which an organization creates, distributes and captures value" (Osterwalder, Pigneur, 2010). Essentially at the corporate level, the company creates value, markets it to the market, satisfying the desires of consumers, and obtains for itself a share of that generated value, i.e. profit. The Business Model is not a strategy, but a concrete and immediate tool, not based on the future but the action in the present (Magretta, 2002).

Humankind, who increasingly moving towards urban centers, representing a wide range of innovations and development to satisfy the daily needs, pushes the city apparatus to provide adequate services that can enhance the living experience within the social context. Thus, in recent years, cities have sought to accelerate the innovation process, using technologies that simplify citizens' lives such as the Internet of Things (IoT), Artificial Intelligence (AI), and Blockchain (BC). Population growth, largely due to the influx of people populating large urban centers for greater economic opportunities, has pushed cities to ensure an improved quality of life by focusing mainly on environmental impact, safety, mobility, and public and private health. Smart Cities are those that use new technologies to solve society's daily urgent tasks such as housing, transport, and energy in urban planning and governance. To realize them, investments in Smart Cities are the result of complex relationships between the public sector and private leaders, who together contribute to the final result. Therefore, all these solutions need to be mapped correctly according to a business model that is fit for purpose. But how can we apply a Business Model to Smart Cities? As previously mentioned, the Business Model Canvas is one of the best tools to synthesize and analyse value creation through a business or technology. The canvas consists of nine building blocks divided into key partners, key activities, key resources, value proposition, customer relationships, channels, customer segmentation, cost structure and revenue streams (Timeus, Vinaixa & Pardo-Bosch, 2020).

It is a very useful tool to graphically represent all the fundamental components of a business model in a single image, while still being clear and useful to understand how the company works and how to create value or find new business opportunities. A more recent and extended version of the Business Model Canvas adapted to Smart Cities, proposed by Díaz-Díaz, Muñoz and Pérez-González called *City Model Canvas* (Timeus, Vinaixa & Pardo-Bosch, 2020). By adding an environmental dimension to the economic assessment of business models, it helps municipalities to deliver value sustainably, which will be used within the research.

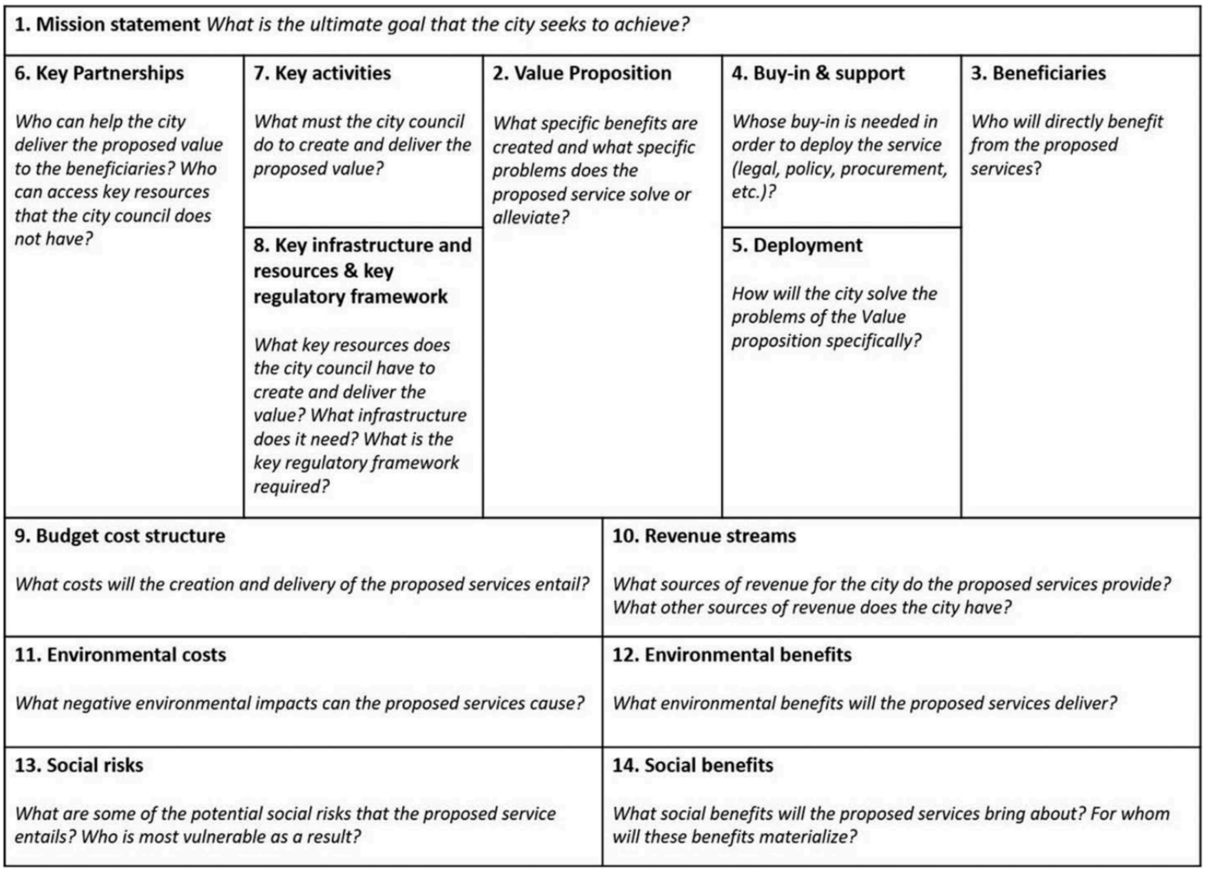

Figure 3: City Model Canvas

It consists of 14 blocks that are divided into four parts. The first part of the model concerns the presentation of the mission, i.e. the objective the city wants to achieve and the value proposition. The second part focuses on stakeholder action and the logistics of service delivery for citizens. The third part focuses on all aspects of value creation, in particular financial resources, infrastructure, and political resources. The fourth and final part consists of an assessment of the economic, social and environmental costs and benefits of the intelligent service to be proposed (Joyce and Paquin (2016). With this tool, not only the economic feasibility of the project is being assessed, but above all the sustainable impact it has on society and the environment.

2.3. Sustainable Innovations

2.3.1. Definition in the Context of Smart Cities

As previously established, sustainability is one of the requirements of Smart Cities, so innovations that benefit that pillar could already be regarded as sustainable innovations in the context of Smart Cities. However, sustainability in Smart Cities might have different definitions compared to e. g. sustainability in the context of Circular Economy or sustainable development. For this purpose, the definition of sustainability that was set in Chapter 2.2.1 - "meeting the needs of the present without compromising the ability of future generations to meet their own needs" – is relevant to define sustainable innovation.

To bring all relevant terms into context and provide consistency through the overall work project, a definition of innovation is necessary. As such, "Innovation is the creation and implementation of new processes, products, services, and methods of delivery which result in significant improvements in outcomes, efficiency, effectiveness or quality" (Eveleens 2010).

Finally, after defining the concepts of "sustainable" and "innovation", it is clear that the concept of sustainable innovation comprises the creation of a new tangible or intangible component that causes significant improvements in any area without harming others. This definition is in accordance with the definition given by Lee, who defines sustainable innovation as the creation of or adaption of existing products or services to achieve sustainable social, environmental, and ecological impact, while at the same time generating profits for the company. Through sustainable innovation, companies can create and deliver products or services that directly can contribute to sustainability (Lee n.d.).

In the context of this thesis, innovation has two major criteria: 1. It has to create value in the sense that it can be entrepreneurially harnessed and ultimately, profits can be achieved. 2. One aspect of sustainability has to be benefitted without harming another one. This is due to the complexity of sustainability (Tainter 2006), which implies potential downsides to every achieved progression. The most prominent example is that a more efficient technology (which could be beneficial e.g. carbon reduction due to more efficient usage) often leads to higher consumption, which on the other hand has a negative influence on the absolute CO_2 emission balance. Therefore, this report aims at considering innovations that are not bound to this effect but are truly benefitting one area of sustainability (e.g. carbon reduction despite increased demand).

2.3.2. Potential for Sustainable Innovation

The biggest potential stems from the value created by sustainable innovations as a multitude of aspects are tackled at the same time. First, Smart Cities benefit from businesses that are successful and this can be the measured by the value generated for the inhabitants. Second, such an innovation would not only create value in terms of a service or product to the customers, but also leverage the sustainability of the service or product. For example, if the innovation creates a product that cuts 50% of the CO_2 emissions compared to its conventional counterpart and represents an integral part of a Smart City, then multiple desired outcomes for Smart Cities are pursued at the same time.

2.3.3. Challenges of Sustainable Innovation

The special context of Smart Cities, in which innovations should be integrated, poses a unique set of difficulties, that need to be overcome to foster value and succeed in such a market. A few findings are outlined:

1. The Articulation of technological innovation and change to the lifestyles of the individuals: Smart cities require a different lifestyle for the inhabitants compared to conventional cities. This inevitability becomes even more dominant when innovations are not only radical by the concept but also by implication. Therefore, if the implication of a disruptive technology offers or forces an adapting behaviour of a user, then resistance might be one of the reactions (Saujot & Erard 2021).
2. The complexity of intersectionality: Like the complexity of sustainability intersectionality can pose challenges to the interactivity of innovations and their users.

This is mainly an issue of infrastructure and data management and applies if the innovations are integrated in such a way that interdependency is the result (Saujot & Erard 2021).

3. The organisation of citizen participation: This point is highly business-model-specific and depends also on the innovation itself. For example, some business models require the users to be administers at the same time, which poses challenges in terms of communication misconduct questions and role issues. Furthermore, the business model identified (Saujot & Erard 2021)
4. The collaboration of public and private partners: What seems like a communication problem also is a funding problem and is, again, a specificity that arises from the applied business model (Saujot & Erard 2021)

3. General Methodology

3.1. Time Horizon and Geographical Delimitation

The time period and geographical area investigated are limited to answer the RQ in a more targeted and detailed manner. This paper examines only sustainable innovations in Smart Cities within Europe. Furthermore, the time horizon limitation is set to the year 2050. This determination was made based on the European Green Deal by the EU and following the EU's Paris Agreement commitment to global climate action. The key objective of the European Green Deal by the EU is to be climate-neutral by 2050, based on the fact that the targeted 1.5ºC to 2ºC increase in global warmth is the maximum that the planet can take without bearing uncontrollable consequences.

Furthermore, by 2050 the EU aims to become an economy with net-zero GHG emissions. To reach this goal, the EU aims to provide 100 climate-neutral and Smart Cities by 2030. Furthermore, according to the EU Commission, cities are a significant factor in achieving this mission of climate neutrality by 2050, as they account for only 4% of the EU's land area. Still, the cities house 75% of EU citizens, using more than 65% of the world's energy, and produce more than 70% of CO_2 emissions (‘EU Mission: Climate-Neutral and Smart Cities | European Commission’ n.d.). Based on the EU's mission and the remarkable role of Smart Cities, the delimitation for this RQ was set.

3.2. Rationale of the Selection of the Innovations

Based on the previous chapter, recent trends were identified, which led to innovations commonly associated with Smart Cities in the context of sustainability. In addition, contemporary sources identify key technologies that were also considered in the frame of this report. For the selection of the five innovations further deepened in the subtopics a pool of 22 suitable and relevant innovations was selected and analysed through an Innovations Scorecard, presented in Appendix 1.1. The innovations are ranked based on the following criteria to assess their usefulness in this thesis and rated with a 3-point system.

The final score for each innovation results on the weighted average of the score attributed to the following variables:

Quality of life (15%). 3 points: An innovation has a significant positive impact on the quality of life throughout different areas of life; 1 point: No or negative effect on the quality of life through the innovation.

Efficiency of urban operation and services (15%). 3 points: A significant increase in efficiency in at least one of the mentioned areas (communication infrastructure, waste, energy and mobility); 1 point: No increase or a decrease in quality in urban operations and services.

Competitiveness (15%). 3 points: The innovation and its business model have a solid and differentiated value proposition compared to competitors; 1 point: Weak or common value proposition.

Economy (15%). 3 points: Long-term economic growth and profitability are expected for the innovations and its business model; 1 point: Long-term economic growth is not expected, or decrease is expected.

Environment (15%). 3 points: The innovation (almost) causes no harm to the environment (e.g. air and material pollution/land usage/resource exploitation/biodiversity loss/biomass loss etc.) or even recovers prevalent environmental damage; 1 point: The innovation does not improve / not significantly improve environmental standards compared with the conventional counter technologies.

Society and Culture (15%). 3 points: A Life-changing positive impact in societal & cultural factors is expected through the implementation of the innovation; 1 point: No or a negative impact in societal & cultural factors is expected.

Own Interest/Experience (10%). This category is based on interest and experience. It is ranked from no (1 point) to strong interest (3 points).

The highest ranks are the innovations discussed in the individual chapters: Fintech (Ø 2,55), Blockchain in the Energy Market (Ø 2,55), Vertical Farming (Ø 2,4), Biophilic Design (Ø 2,4), Cooperation for Sustainable Mobility (Ø 2,7).

3.3. Resources and Data Sources

For the analysis of all sustainable innovations, both primary and secondary data were used for data collection. The primary data was generated using semi-structured interviews with experts and surveys. The secondary data was collected through in-depth analysis of contemporary sources, existing studies and academic papers, with a focus on the quality of these to ensure the highest academic quality of the work project. A detailed description of the resources used and the approach to data collection is provided in the individual sections of each innovation.

4. Motivation

The authors of this paper were driven by different motivations to contribute to the academic community with the analysis of each subtopic. The climate emergency is real. To achieve climate neutrality, a 90% reduction in transport emissions is needed until 2050 (European

Commission 2019). However, innovations and technology are the opportunities the world needs to exploit today to achieve sustainability goals. The cause of “technology for good” allowed to highlight the economic benefits of the sharing economy for cities in the branch of Smart Mobility. The reason for the focus on Biophilic Design, on the other hand, stems from the focus on a state of human well-being, a psycho-physical, mental, almost philosophical condition. The need for the human to live in a positive environment that can generate well-being and increase daily performance, using energy and hydraulic sustainability tools within the four walls. This fusion of art, design, and attention to future investments is the result of passion, academia, and the desire for a better quality of life. Vertical Farming represents an innovation that creates a value potentially recognized by every human being, since everyone has to eat, and this is an important driver for research. Furthermore, conventional agriculture needs to be revolutionized in terms of sustainability and indoor aquaponics represent a technology that leverages sustainability and has the potential to be economically scalable. VIF has the potential to become the new standard for growing leafy greens in urban areas in the next 10-30 years (Diaz, 2021), and can be used in a completely decentralized way, so with little initial capital an entrepreneur can grow the business from city to city, from a small scale to a larger one. Burning fossil fuels creates large amounts of carbon emissions and in addition in today's power grid due to long-distance transmission, there are significant energy losses. The idea of using Blockchain, a very recent technology with a large number of applications, to give the next generation a future with less inequality has motivated research to provide a timely and comprehensive review of possible solutions. Finally, coming back to everyday life, today Fintech has become an integral part of most people's daily lives. It facilitates human life every day, through the integration in various public services and easy usage through mobile devices. However, what needs to be considered about this opportunities are its sustainability and, above all, whether it can create long-term value.

5. Innovations Analysis

5.3. Vertical Farming

1. Introduction

With the climate emergency unfolding, many topics are at the centre of the current sustainability debate. One of those topics is the need of a transition from conventional agriculture. It is associated with threats such as biodiversity loss, soil pollution, groundwater exploitation, overuse of pesticides and the effects such as less pollination, less wild fauna due to lower nutrients, droughts, and the overall acceleration of climate change due to greenhouse gas emissions (Tal 2018). But some solutions might solve these issues by cutting the water usage significantly, making the use of pesticides and transportation obsolete and process nutrients and resources more effectively. One of these solutions is vertical indoor farming (VIF) an agricultural technology (or “agtech”) which also have great potential (Stein 2021) for automation and autonomous food production (Kyaw and Ng 2017). The desired scenario for those facilities to be applied is Sustainable Smart Cities until 2050. Today, there are pilot projects (school or research) of VIFs (Lobillo-Eguíbar et al. 2020) and large-scale investment projects such as Vertivegies (‘Indoor Vertical Farming | VertiVegies | Singapore’ n.d.). But if the benefits for sustainability and the entrepreneurial value are prevalent – why are there not more small-scale investors trying to apply this innovation?

1.1. Research Question and Scope

This master thesis report answers the question: “How to create value by entrepreneurially using sustainable innovations in Smart Cities?” and the specific case Research Question (RQ): “How to fund a business from cash flow?”. As part of the contribution to the academic community, this report focuses on the value creation by small business owners in Smart Cities as they have fewer funding options compared to large-scale investors and enterprises supported by VCs (R. Yang, Xia, and Wen 2016). This is significant because of three points: 1. The technology of

VIF is sustainable as it almost represents a perfect Circular Economy (CE) (App. 4.1 and 4.2), compared to conventional agriculture (CA), and needs fast adoption because of global climate distress caused (in part) by agriculture; 2. VIF has its highest leverage to the saving of CO_2 emissions if the production plants are decentralized (transportation as an issue) (Despommier 2019), therefore individual ownership and spread of the innovation is beneficial 3. VIF is a modern technology with growing disruptive markets in urban areas (Shirvell n.d.) (adoption seems to peak early (2030) in Singapore, which serves as an example of a more saturated market ('3 Ways Singapore Is Creating Food Security with Urban Farms — Quartz' n.d.). Additionally, the innovation matches with the scope and concept of Smart Cities fulfilling the need for self-sufficient food production without causing environmental harm (Chapter 2.2.3 Smart Sustainable Cities).

1.2. Short Explanation of the Innovation

The basic idea is the indoor cultivation of crops based on automation facilities. This way the space can be used efficiently while the yield is not susceptible to weather changes and therefore can be planned. There are multiple types of VIFs: Soil-based vertical farming, aquaponics, aeroponics or hybrid solutions that combine the growing of leafy greens with breeding fish (App. 4.6 and 4.7) (Despommier 2019). This report focuses on vertical aquaponics because it matches the technology the use case of Freight Farms applies (App. 4.6). All the types have in common the fact that they are based on a circular concept and, therefore, represent sustainable farming (fish breeding) options. The potential for automation and the implication for planning and scaling poses the threat of disruption to conventional agriculture in urban areas for leafy greens. Singapore already has high-scaled VIF plants that are competitors on the market, so, assuming this as a benchmark, adoption of other markets is a likely scenario.

2. Literature Review

2.1. Sustainability & Agriculture

It is evident, because of multiple reasons, that conventional agriculture contributes to the current climate emergency by the following activities: nitrate pollution through the overuse of manure; inefficient land use (has multiple reasons e.g. food production for meat production); groundwater consumption; GHG emission release (has multiple reasons e.g. long transportation); biodiversity loss; insect extinction (loss of biomass); negative side effects of pesticides (Tal 2018).

Because of those reasons, alternatives are discussed as part of possible solutions – one being VIF. VIF only has the potential to solve a few of those issues as problems associated with meat production cannot be tackled by VIF (currently) (Guerrero, Sharma, and de Pinho n.d.).

2.2. Circular Economy

The concept of Circular Economy by Ellen MacArthur is based on the concept of Craddle to Craddle by Bungard and Bessler (App. 4.1) and presumes the absence of waste in the sense that every material can be reused in different flows considering the whole lifecycle of one product or material. By that, the framework divides the flows into two main loops: the biodegradable and the technical one. Organic materials become soil eventually through degradation, which closes the loop – while technical resources must be recycled to close the loop. Along with both loops, there are multiple ways that either downgrade the use of one resource or shows ways to extract e.g. methane by processing the resource ('Intelligent Assets: Unlocking the Circular Economy Potential' n.d.). In this report, the framework was applied to VIF and the results can be found in the Circular Economy Results chapter.

2.3. Funding methods

Depending on the source, 5 to 7 common funding methods are identified to fund start-ups:

1. **Bootstrapping: represents own (personal) financial savings and methods.** Need of caution is critical as this financially bounds own credibility with the firm
2. **Friends and Family (love money):** People who want to support the entrepreneur invest;

also requires caution because business failure might cause emotional distress

3. **Crowdfunding:** small investors that are convinced by the entrepreneur's idea can invest. After a critical amount was funded, the idea can be executed (often investments are connected to deals, which can mean that the undeveloped products can be pre-ordered).
4. **Angel Investors:** Typically, Business Angels funded and scaled an enterprise in the past and now benefit the ideas they want to support.
5. **Bank Loan/Venture Capital:** Loans that are connected to certain trust or requirements (contract). VCs typically come with a task force that collaborates with the entrepreneurs and provides resources to scale, while a bank loan typically is associated with collateral that serves as a deposit for the cash (Hall 2012).

In the context of this thesis, the method "fund from cash flow" presumes an initial personal or love money investment and relates to the natural growth of the VIF start-up.

3. Method, Results and Analysis

3.1. Methodological Approach

The procedure focuses on three elements: sustainability assessment, cash flow/funding options and interviews with experts. Additionally, the reasons for the fit of the innovation for Smart Cities will be elaborated as part of answering the RQ. The sustainability assessment should state why the innovation and its business model (App. 4.4) can or cannot be considered sustainable, and therefore is (or is not) a good fit for Sustainable Smart Cities. The framework discussed in Chapter 2.2 of Circular Economy (CE) will be directly applied to a potential VIF solution and contrasted with a generic application with a conventional CE analysis (App. 4.2 and 4.3).

The exploration of cash-flow and funding models should measure the problem of entrepreneurs wanting to scale without much capital. Plus, it should make transparent which opportunities lie in the business case of Freight Farms (if there are any) as this is designed for small business owners that can scale without VCs or large investments which would benefit collective ownership and encourage entrepreneurship within Smart Cities.

Interviews with experts (App. 4.9 - 4.12) are conducted to gather key insights on entrepreneurship and sustainability linked to VIF and the conversation with Freight should further elaborate and discuss the business application. Those five interviews are qualitative as this fits the frame of this report.

3.2. Results of the Circular Economy Analysis

In Appendix 4.2 and 4.3 a flow of the loops of leafy greens was displayed as a demonstration of the loops implicated in VIF and to highlight material flows that do not exist in a conventional cycle.

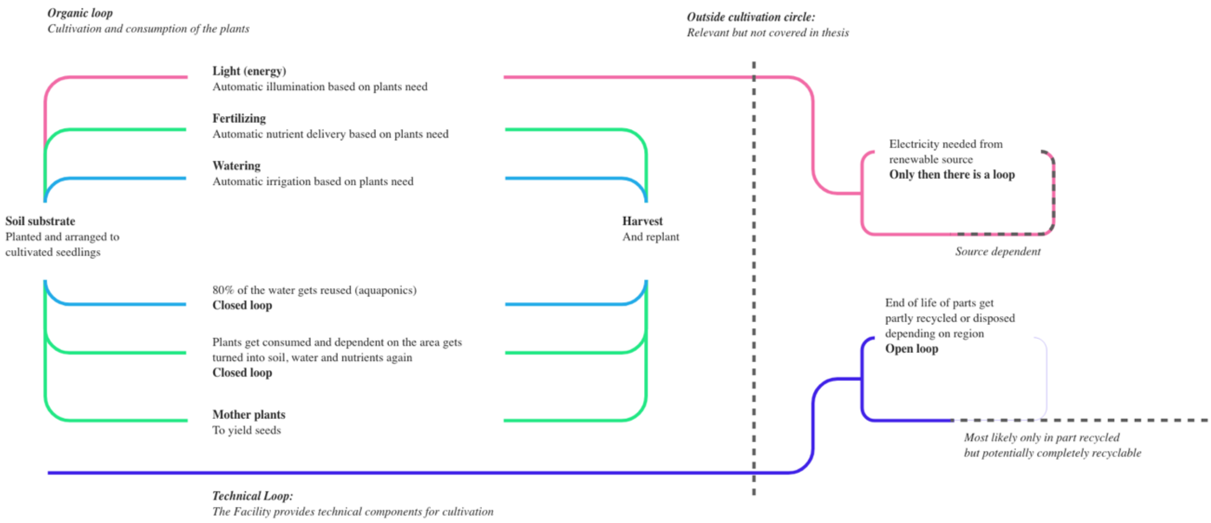

Figure 4: Own interpretation of Circular Economy to the material flows of VIF (generic)

The first major difference worth mentioning is the leakage of material. E.g., Fertilizers are used in conventional agriculture as well as in indoor farming, however, conventional agriculture is known for its poisoning effect on groundwater due to leakage (e.g. nitrate pollution). Indoor farming, on the other hand, only uses the fertilizer the medium can absorb. Furthermore, mediums are controlled, so a leakage would be inappropriate and economically inviable.

Another difference is the use of water. Here, the reason is the same. The facilities allow the farmers to satisfy the exact need of the crops. Over or under usage is also not a concern due to the absence of seasons. In fact, in the case of Freight, up to 80% of the water can be recycled in comparison with conventional agriculture, which is not as controllable due to the usage of soil and land and the inability to control the environment.

Because of the fundamentally different concepts (CA and VF), the occupation of land is also beneficial in terms of CE for VF, as less land is used per kg of protein and half of the habitable land is occupied by agriculture compared to CA (Guerrero, Sharma, and de Pinho n.d.). Consequently, VF has more potential for land preservation. Monoculture is a threat to biodiversity only if it replaces wild natural landscapes, which is only done with CA in this comparison. However, land usage is still an issue for VFs, as the facilities have to be integrated into buildings. But, because those are vertical and can stack on each other, VF is much more efficient compared to CA in this field as well.

CE states that in-between processes should be (at best) the avoidance of GHG emissions. This is highly dependent on the locality of each installation. If CA is local to a store, transportation is not an issue. Far away shipping, which also can be considered conventional, is a disadvantage due to inefficient (often fossil fuel-based) transportation, which has its drawbacks. VIFs are intended to be decentralized, but as the case EFC-Farms, ('ECF Farm Berlin | Urban Farming trifft Aquaponik!' n.d.) proves, (they deliver to the whole area of Berlin and have a centralized production) not every application of the technology uses the benefits it can provide.

An argument that the VF loses is initial GHG emissions due to the production and installation of the facilities since there are several requirements in terms of technological material (automation, computer, metal crops, tubes). The CA, in that regard, is efficient, as tractors are shared among farmers.

Pesticides are commonly used in conventional agriculture, even to a certain degree in the eco quality (Tal 2018), whereas the VF, due to the controlled indoor environment, does not employ the use of pesticides etc.

Not visible in the model but relevant in the sustainability assessment is hyper-regionality (in the context of Smart Cities). The concept of VIF (vertical indoor farming) allows a decentralized production of food, meaning that, per small town/village/district there is a production facility (given that there is a market). This has multiple implications to the way the products are sold and their sustainability: 1. transportation is redundant as the production can be a few meters away from the store (saves emissions and pollution); 2. the regionality can be part of the branding (e.g. a regional positioning with example names: Carcavelos lettuce or Bairro Alto Tomatoes) leading to a sustainability awareness through regionality for the customers and inhabitants of the Smart City; 3. prices and economic flows might vary drastically between places (implication to the unpredictability of some aspects of economic regions and markets); 4. Hyper-regionality agrees with the requirements of Smart Cities as the need for autonomous food production is possible through the capsuled design of VIF facilities.

3.3. Results Funding Models

For VIF multiple business models are possible, but the most fitting model for answering the RQ is to apply the business model for small businesses. Also, economies of scale can be anticipated: large investments are needed for buying high yield facilities. The possible downside might be that those facilities are big and can therefore not be as decentralized. ECF Farm systems Berlin is a real case that shows that the successful farm has a budget of more than 1,5 million € per system to achieve competitiveness and profitability (Staff n.d.).

The desired method of this thesis is cash flow funded: atypical but aspired for entrepreneurs with small funding budget in growing and emerging cities – by 2050 Smart Cities. It is possible to set up a farm that grows (potentially) into profitability but those are not very professional and evolve from single individuals seeking autonomy (called DIY-VIF). So, a gap is identified, as seen below **(The Gap):**

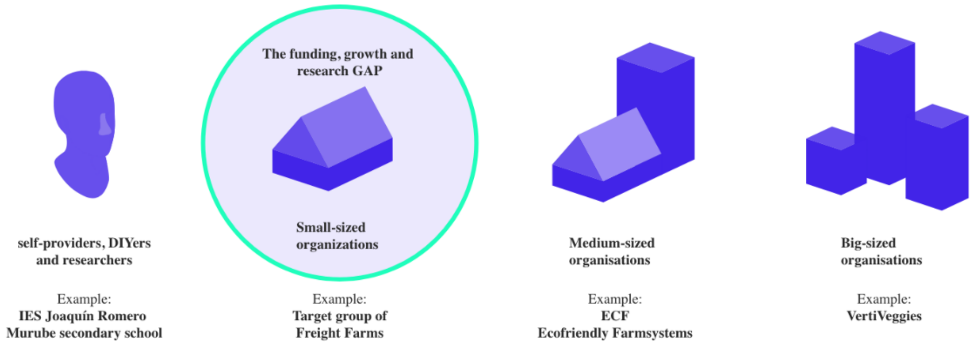

Figure 5:"The Gap"

3.4. Validation with Potential Stakeholders

In total, four interviews have been conducted with five experts in different fields. A short list is provided. Furthermore, the key insights are listed below:

- Yasser Chehade, Entrepreneur, Procurement Lead for renewable energy projects: Has experience with successful digital ventures; Would he be interested in VIF?; Perspective on sustainability (App. 4.9, Chehade, interview)
- Joscha Bröhrmann; Founder of Tahibi a high-quality food vendor platform, Wind and electrical engineer: Owns a platform for groceries; Does he think that an entrepreneur has success on his online platform?; Perspective on sustainability (App. 4.10, Bröhrmann, interview)
- Rick Trenchard: Lead salesman at Freight Farms: Perspective of Freight Farms; What does FF think is relevant for the success of a farm? (App. 4.11, Trenchard & Rademaerkers, inteview & webinar)
- Harrie Rademaekers, Founder of a business based on FF system, Marketing lead: Owns 2 FF facilities; Has first-hand experience on the application of a FF system and can share key insights (App. 4.11, Trenchard & Rademaerkers, inteview & webinar)
- Rachel Wisentaner, Account executive: How does Freight Farms help the clients to succeed? (App. 4.12, Wisentaner, interview)

Y. Chehade, J. Bröhrmann and R. Wisentaner were interviewed face to face while the conversation with R. Trenchard and H. Rademaerkers was part of a webinar which was equally qualitative (for more details see script files). The major insights are the following:

All interviewees believe that VIF is a key technology for overcoming the dangers of conventional agriculture; Consumer perspective and Tahibi: Buy prices can be slightly above market average; FF systems are designed for small business owners, calculation and planning is a service by FF that help to succeed – scaling is desired and can be achieved with the facilities that can be bought; initial minimum investment is 122.472,90 €; VIF-Food should not only be sold in regional stores but also to restaurants, platforms direct customers, firms etc.; All experts see themselves and with their professional roles as positive contributes to a more sustainable world – all experts promote sustainability in some sense; Collaboration with a VIF is potentially interesting for the entrepreneur experts; All experts agree with the value creation of VIF; The success of a venture is extremely dependent on the business model; Shipping of the facilities is a challenge; Freight Farms helps by creating and optimizing the business model.

4. Use Case Analysis: "Freight Farms"

4.1. The Concept

Freight Farms use the international freight shipping container format (therefore Freight Farms) as the basis for their VIF facilities (Greenery S). By that, they provide the smallest unit of a complete system for a potential investor. The facilities can be combined and with the increase in the number of containers the food portfolio grows (e.g. kale + pak choi + basil + 4-week salad) ('Investment Calculator' n.d.).

The technology is based on vertical aquaponics, meaning that constant water and nutrient solution gets constantly pumped circularly. This way, the water gets recycled, and the nutrients can be controlled. Furthermore, environmental parameters such as air humidity, pressure and temperature can be regulated according to the plant's needs – per container.

4.2. Cash Flow & Scalability Calculations

The case of this thesis is based on a cash flow calculation provided by freight farms with estimates of the market of Bargteheide (average German town which could serve as a pilot city). The market identified has limitations but only serves as an example in this thesis report to draw implications on the operation and mathematics of the business model:

The success of an operation depends on the selection and price of vegetables. Slow-growing vegetables such as spinach or kale yield 156kg (312 units of 500g) per month compared to the "4-week-heads" such as romaine with 4044 units per month causing leverage on the fast-growing vegetables. Profitability for slower growing plants can therefore only be reached if above-market prices are asked (spinach market: 1,99€ / Break-even VIF: 10,48€). However, the selling of fast-growing plants can compete on the market (Romain salad head market: 0,90€ / Break-even VIF: 0,86€) (App. 4.5).

One "Greenery S" container by FF costs 139,000$ = EUR 122,472.90€ ('FAQ - Frequent Asked Questions' n.d.) (quote from 1st December 2021) resulting in different payback periods and scalabilities. The following scenarios were calculated: A, yearly cash flow (CF) = 6000€; B, CF = 12000€; C, CF = 24000€; D, CF = 48000€; E, CF = 96000€. The results to the budget for reinvesting and the number of facilities that can be purchased are seen here:

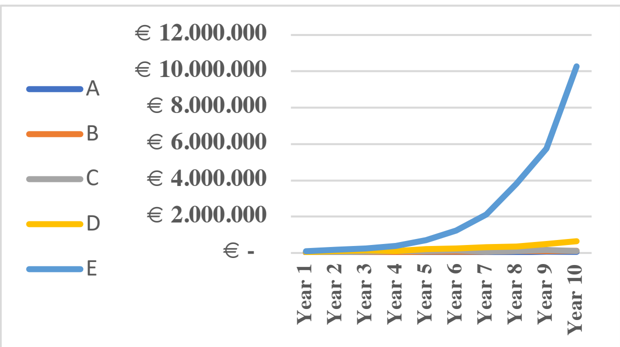

Figure 6: Budget to reinvest, scenario A-E

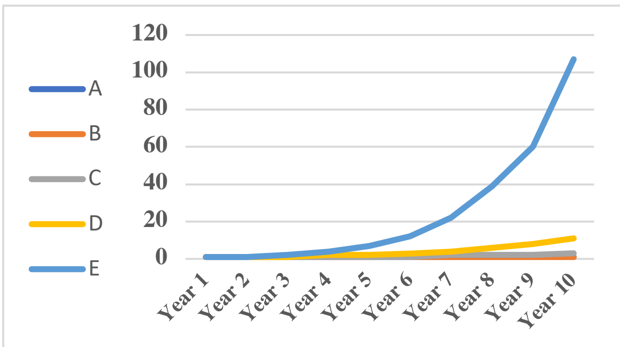

Figure 7: Number of facilities, scenario A-E

5. Summary and Discussion

5.1. Discussion

While the biological material flows of the operation work efficiently and according to the CE assessment in a high waste-hierarchy, other problems emerge that lower the outcome of the sustainability assessment: the packaging of the vegetables might be problematic as a plastic wrap (problem: recyclability and disposal) or paper (problem: water usage) will be used by entrepreneurs in store. A recommendation would be to either avoid the use of packaging completely or use packaging from recycled materials. Furthermore, the end-of-life of the facilities remains uncertain as the recyclability varies drastically depending on the system in place in different countries. One possible solution might be to consult the used market to exchange parts or focus on repairing facilities.

Also, even though the facilities of FF are designed to be as efficient as possible, the sustainability of the usage of electricity is source-dependent, which, again, dependent on the country and infrastructure, cannot be called sustainable if, for example, the energy source is fossil. That said, in the scenario posed as the outline of this thesis report, which is 2050, a global change to renewables is anticipated ('The Paris Agreement | UNFCCC' n.d.). But along the way, an application of the technology remains uncertain.

The core product of FF - Greenery S by FF - blocks scalability (for the first years regardless of the profit) as the price is high (122,473€) compared to expected earnings. However, with versions of the container farm not as advanced or DIY with similar or comparable yields scalability is more easily reached. Those, however, are not high-tech and might have negative implications to Smart Cities as interconnectivity is not the focus.

Also, scalability begins by having 3-4 (366.000-488.000€) facilities in place which would embody the character of medium-scale investments. If the business model works perfectly and yields more than 48,000€ per year (high yield scenario) consistently, it is possible to slowly grow and scale.

The webinar and interview with both the FF user Rademaekers and Trenchard from FF have limitations as the perspective of a successful client was given. No information about failed attempts was shown. Consequently, FF has the interest to sell their facilities, so cautions need to be taken and independent research be done. Even Rademaekers acts as a brand ambassador and might have an agenda to help FF to sell more units.

Rademaekers said it is crucial to work with the business model and commit to the prices as only then entrepreneurial success can be ensured, but this poses a challenge as many of the plants need above-market prices for profitability.

5.2. Conclusion

The environmental sustainability of VIF has significant advantages compared to conventional agriculture despite open issues such as technical material flow of facilities or packaging. The energy question is equally open as currently, most energy sources come from fossil energy. In Europe, the chance is or is approx. 50%/50% to be supplied with fossil or renewables ('State of the Energy Union 2021' n.d.). Using a renewable energy source the sustainability of one VIF application would be further leveraged. The business model of one VIF is crucial to its success and the leverage with high unit (fast-growing) yields is higher: Salads, Pak Choi rather than spinach with low outcome (spinach monthly outcome of 338 units, compared to romaine with 4044 units) ('Investment Calculator' n.d.).

The FF Greenery S is rather expensive, justifying why scalability through CF cannot be reached that fast and takes at least three years (presented in the scenarios in Chapter 4.2). Wisentaner states that the usual payback period is three years for her clients, but this is according to the analysis of this report optimistic. Therefore, FF for CF funding is not recommended. However, DIY VIF would be an alternative that needs more investigation. Exponential growth starts to happen at 4-5 facilities, so a higher initiative funding would be plausible. But the high price of the FF facilities might be worth it as the components of interconnectivity, automatization and high efficiency of Smart Cities are fulfilled.

In conclusion, all the obstacles provided suggest that FF is a use case that helps to plan end explore the business of VIF but might not be the best alternative to launch a business to fund from cash flow. However, the characteristics of Smart Cities in terms of interconnectivity, the autonomy of food production and the fulfilment of the quality of life are strong.

5.3. Answering the Research Question

To answer the RQ "How to create value by entrepreneurially using sustainable innovations in Smart Cities?" and the specific case RQ: "How to fund a business from cash flow?" in one sentence: by choosing the right VIF firm as a business partner or check for alternatives like DIY farms or sets and perform proper market research about the initiating market.

In terms of sustainability, as the CE assessment proves, because of significant improvements to conventional agriculture, the technologies can be considered sustainable.

The environmental sustainability, the interconnectivity (potential integration with IoT/industry 4.0) and potential for automation and decentralization of VIF provides a food source for autonomous Smart Cities/Smart City districts

In terms of funding, small business owners might work with partners such as Freight Farms that offer ready-made systems that can be easily adapted to certain markets but are expensive or might use DIY systems to faster reach critical scale. The cash flow computation, however, should not be done simply by trusting the estimates of the firm but by researching hyper-regional markets.

Finally, focusing on value creation, the application of VIF itself provides value because of the sustainability-related aspects. The competitiveness, however, strongly depends on the market. An entry point might be a platform like the one from J. Bröhrmann where high-prized goods are sold, and the shipping is done by the vendors. Later by establishing contracts with local stores and by increasing the scale and bargaining power a more robust and long-living value creation can be done.

5.4. Further Development

All the aspects of the RQ (mentioned in the previous chapter) can be explored in further research and development. This way, it would also be possible to overcome some of the limitations listed in the next chapter.

Following the personal motivation, bringing this project to life by developing a business plan, research in my hometown Bargteheide to get more detailed estimates of competitors (or collaborate with J. Bröhrmann's food vendor Platform Tahibi or/and launch a collaborative venture with Y. Chehade), and start and funding the first facility would be the ultimate further development. Following this procedure, a personal contribution by value creation, protecting the environment and doing business for good would be possible.

6. Limitations

Since this thesis report tries to explore many fields, limitations are prevalent in all of the concepts applied, as would the report have a more precise focus, fewer topics but more in-depth analysis would be possible.

Furthermore, there are limitations based on the frameworks identified to assess sustainability aspects: CE focuses on visualising loops and leakages but has some biases (e.g. it was developed in collaboration with industries) by assessing flows of materials. To exemplify the limitation: The social aspect was not considered.

Additionally, the following limitations were identified: Technical analysis focuses on the idea and not the details; no business plan was created to answer the entrepreneurial aspect of the RQ; no clear market was identified (except for the calculations); only one VIF-technology was explored; the use case of FF might be biased as they want to attract business partners.

6. General Discussion

While some conclusions in this report can be derived from the results of the research, another aspect might have multiple viewpoints to them.

In all the individual cases, presented sustainability can be leveraged compared to their conventional counterparts but often that cannot be stated with precision. Mobility, VIF or BC are examples of technology, which need some energy input to function. So, sustainability assessment results need to be taken cautiously as sustainability can only be levered if certain requirements apply. The energy source needs to be of renewable sources, otherwise, the lever to save e.g. CO_2 emissions is low. By presuming all of the technologies presented in this thesis report supplied with fossil energy, the innovation could not be considered sustainable.

However, if the energy sources would be 100% renewable, this thesis would be also pointless as one of the biggest problems would be solved, which is the global change of energy. Rather, the transition towards renewables and towards more impactful (in terms of sustainability) technical solutions that create value on multiple layers (e.g. the mobility case provides public transportation, CO_2 reduction and gamified user experience) is the true contribution despite the uncertainty of the energy supply.

But energy is not the only aspect, which is source-dependent. E.g., the packaging of the plants sold from VIF or the system on which a BC is applied are uncertainties that might limit the impact of the innovations discussed. This limitation is also a disadvantage that needs to be considered along the way until 2050 in the sustainability assessment or the validation of value creation. However, this uncertainty might be a point that further leverages the impact of the innovation as uncertainty means that an entrepreneur can influence the development of the use of the sources. E.g., if the community of VIF-users agree to solely use paper wraps (or better no packaging at all) the impact would be increased.

Also, in all individual parts, the conclusion with regards to the sustainability assessment was positive and the innovation enhanced the status quo where applied. But that bettering the current state does not mean solving the problem entirely. In the introduction, the problem of climate change was addressed, and it is evident that this issue is among the most threatening problems we as humans face. Therefore, improving the status quo is not enough for the long run. The Paris Agreement states that CO_2 neutrality should be reached by 2050, which, in turn, mean for the innovations presented that CO_2 neutrality should be aspired. This does not necessarily mean that businesses that apply the innovations need to cut all the CO_2 polluters but to take the whole value chain into account and net around 0 (also after taking into account the biocapacity).

And here lies a big contrast: smart cities that use lots of technology to reach true interconnectivity, which supposedly should be sustainable might have worse CO_2 balances as the current best-performing country (and its cities) is Bhutan – an, according to western countries, poor country with less technology but committed efforts to reduce CO_2 emissions. This country is the only one to have reached CO_2 negativity (Munawar 2016) already and serves as a role model in terms of environmental sustainability. Therefore, the approach of using technology to solve CO_2 emissions is not wrong but not the only solution possible.

In the context of smart cities, it is important that the value of innovations can be increased by the interconnection with other technologies. Synergies in the case of this report might be Fintech, BC and smart mobility but there come some downsides to it. Each innovation and each perspective of one technology or business can be embodied by stakeholders that all have interest, which consequently mean that the more perspectives on an innovation exist and the more interconnections are prevalent within smart cities, the more interests there are. This might sound positive as more perspectives enrich the diversity but also lead to an increase in the complexity and possibly conflicting interests. Therefore, it is important to agree on a consensus that supports an agenda that is suitable for all the entities of a network that decides to collaborate. Naturally, the more entities there are, the more difficult it becomes to set the specifics of a common agenda. This applies to business practices but also to technology, sustainability or social aspects. However, the complexity is not a problem that is not solvable as the network of Smart Sustainable Cities with its decentralized entities (VIF or mobility) and interconnections is part of the value created by such a system (Smart city canvas).

The scenario of a full Sustainable Smart City in 2050 serves as a canvas for the innovations to build beneficial use-case scenarios for the inhabitants of a potential city but also poses significant uncertainty as the scenario is 29 years in the future and the potential technical, social and regulatory developments are beyond grasp at the moment. So, the applicability of the innovations discussed might be as presented and would truly work in such a scenario, but they might also not. On the one hand, the individual parts deal with technologies that can be considered progressive, as they approach the challenge of sustainability (representing a future challenge), and transitioning as with them come new standards (at least technical or economically) – on the other hand, those might not be the technologies that will be adopted by the markets. In the early 2000s, only a handful of people could imagine how we now (20 years later) would communicate: via WhatsApp. Therefore, predicting the future is almost impossible and perhaps BC is a technology that will get disposed by something more advanced.

However, one of the most influencing factors is the aspect of regulation. In all the five individual parts is concluded that regulation will influence the success of the innovation and represents one of the most relevant uncertainties. For example, the mobility case presumes that regulation will develop in favour of the idea (which is in the context of benefitting changes that promote sustainability to fight climate change, is rather likely in the next 10-30 years) meaning that subsidies benefit the shared use of EVs. The business model is based on the potential future development which poses some risks. In fact, the regulation might turn out to be sanctioning the business model (not likely but plausible) if priorities in a market are different than expected. The same happens for the application of BC to the EM. The key challenge that was tackled is outdated regulations, which prevent a tangible, city-scale, user-oriented application of this technology to this market. To base an enterprise on the hope of regulative improvements might not be the safest business idea but entails chances for future success, which, in contrast, is part of the purpose of this report. The business models of the other cases are not relying on the positive change of regulation but are susceptible to it. Especially the aspect of regionality in markets forces proper market analysis and negotiation with regulatory stakeholders to avoid too much uncertainty.

Some of the examples discussed revealed that regulation, in part, is behind the progression of the technology in terms of the benefits for positive change. In some cases, regulatory discrimination seems to slow down the development (Blockchain) and application of technology. This leads to the state where the market would be ready for adoption, but the incentives are missing. Therefore, it seems logical to invest in such technologies as an entrepreneur in the near future as it might turn out to benefit the business of the innovations. The problem is, however, that regulation often is not steered by one chancellor or president in terms of market condition as regionality plays a big role. Therefore, stakeholders of the regions are the important ones, and this poses a disadvantage for businesses as also the governance and regulation of Smart Sustainable Cities are complex. That means that a business based on a technology, that has multiple entry points to a or multiple markets, might suffer from the bureaucracy of different regulatory entities such as different district laws, communities, communes, provinces, cities, etc. This might slow the process of market adoption and development down and decreases the attractiveness for entrepreneurs to launch their business.

Because the numbers of the business cases (except mobility) are based on the current prices and units, and because the regulation is not yet favouring the concepts, the prices might be higher (in some calculations - mainly VIF and Biophilic Design - it is questionable if the market would already positively respond to sustainability alternatives and pay more than the benchmark, but to provide the same value (in terms of quality, e.g. fresh VIF vegetables as good as conventional ones; biophilic buildings as good as conventional ones) – plus sustainability advantage, is a value proposition that stands out from the conventional counterparts. The problem, rather, is if the product or service would be below the quality of the competitors despite an environmental or social benefit. Then, adoption is less likely as clients would not adopt technology that is lower in value and cost more. But higher prices are in some cases inevitable (Biophilic Design) as it is the natural cycle of development and market adoption. The problem is that there are no alternatives to sustainable solutions as the threat of climate disasters poses too much danger to society (and all other beings). That means that some sustainable solutions will become the new benchmark with the openness to the kind of innovation.

6.1. Answering the Supporting Questions

As mentioned in the beginning of this report, to answer the Research Question as precisely and as accurately as possible, it is necessary to answer supporting questions first. The objective of the supporting questions is to ensure a clear understanding of the individual aspects/concepts presented. This methodology aims at summarizing and verifying the conclusions from each chapter before objectively answering the research question.

For what do sustainable innovations create value?

As previously shown, each individual innovation leads to its own singular output, and the key areas of focus are mobility, biophilic design, vertical farming, blockchain in the energy market and the fintech industry. It is interesting to notice that although these topics have such different final products, the stakeholders that each one of it affects are fairly the same – citizens, the city and governments are not only extremely affected by each innovation, but also essential for their existence.

Are current Smart Cities already applying/adopting these technologies/digital services?

The extent to which Smart Cities are already adopting the analyzed technologies varies. The cases of mobility and fintech are the most proven, meaning that there are several applications of the models proposed. Even so, these are two areas that are constantly growing in number, complexity and impact of applications. On the other hand, for biophilic design and vertical farming, the scenario is different. The technology already exists and several business models are available, but only for higher-level fringes of society. As so, the focus is on applying the innovations to people in medium to low class and to small-scale markets, respectively. Finally, Blockchain in the energy market has been theoretically proven and tested in real life with several B2B applications, but regulations prevent it from being tested at the necessary scale to allow individuals to become prosumers.

What are the key challenges of the innovation?

General challenges that affect all innovations are the complex governance models of key stakeholder entities that are required to be on board and regulations that prevent the innovations to be implemented with a higher level of flexibility. Even so, this paper assumes the necessary level of enablement of the innovations, as the focus is on the entrepreneurial and sustainable value rather than the legal ramifications. Depending on the implementation location or overall context, other specific barriers to entry exist.

Are these innovations in these Smart Cities truly sustainable?

Another very important point, after analyzing the possible value creation, implementation and risks, is to assess whether the listed innovations really have a positive environmentally sustainable effect on Smart Cities.

The frameworks utilized to perform individual sustainability assessment ensure a minimum level of positive environmental impact. Even so, since this paper considers a time delimitation based on the European Green Deal's (2050), caution must be kept with regards to the long-term impact and the appearance of other solutions (that do not necessarily require a sophisticated technological level) that better meet sustainability requirements.

After this final validation through supporting questions, it is time to provide a definite answer to the research question.

6.2. Answering the Research Question

To answer the RQ "How to create value by entrepreneurially using sustainable innovations in Smart Cities?" in one sentence: by applying disruptive technology that leverage environmental sustainability without sacrificing price, value or other advantages and, if they surpass the requirements of the Smart City Canvas and the rating, which was part of the report (this would not exclude the ones below 5 but these are the ones selected as part of the report), by integrating them to Smart Cities. This way, value for the common key stakeholder can be assured: the citizens of Smart Cities represent the clients of the applied technologies presented which also benefits the entrepreneurs using the innovation to provide that value.

Because of the diversity of the innovations and the specificity and the multitude of the RQ the RQ will be answered in the sections Sustainability, Smart City and Value Creation.

Sustainability: Depending on the technology and its application a sustainability assessment (either based on CE, SDG or CO_2 emissions calculations) was performed to ensure a standard that significantly improves environmental or social concerns compared to the conventional counterparts that represent (for the majority of applications) the today's standard in 2021. The selection of the 5 innovations assessed is based on the (potential) environmental and social impact and the assessment for the innovation confirms that a significant value in terms of sustainability is guaranteed, given a correct integration of the technology. The methods led by the concepts of the innovations and its value propositions vary drastically. To exemplify:

Fintechs can influence companies and policy makers to leverage financial inclusion and benefit the efficiency of economic operations, while the application of biophilic design leads to better mental health or passive heat regulation of buildings – the outcome, however remains the same. New standards are set and boundaries are relocated to a higher level (despite the acknowledgement that the innovations have different sustainability standards). Ultimately, this is a value created to the customer and to all the stakeholders, that suffer from the current climate disaster, which are all the organic entities in the biosphere.

Smart Cities: Also, in the category of Smart Cities it is important to note that a high standard to the preselection of the innovations (before the development of the thesis report), was set to guarantee that the technology fit the requirements of Smart Cities. As expected, different innovations have different focal areas, which, in the end leads to a portfolio of strengths when it comes to the integration of all the innovations. Still, common themes as decentralization, a benefit to the quality of life or interconnectivity are prevalent. To exemplify: the application of BC in the EM has the highest impact on the categories quality of life, effectiveness of urban services, competitiveness and especially interconnectivity due to the potential for integration with IoT/industry 4.0 and for automation and decentralization. This has a similar fit to Smart Cities as Fintechs benefit social sustainability, improved quality of life, interconnectivity, automation and decentralization for autonomy, which, again, has a similar effect as vertical indoor farming.

Value creation: This aspect is the most uncertain of all researched areas as regulation until 2050 can drastically vary due to the time until 2050 but also due to regional effects and different markets. This has implications on the competitiveness and scalability of one innovation (e.g. BC, mobility, VIF). But as first regulators benefit more sustainable options, e.g. carbon tax, this uncertainty is expected to unveil to the favour of the innovations (besides that climate emergency and social movements e.g. Fridays for Future pressure policy makers and regulators into this direction).

As mentioned in the sustainability paragraph, the value is created by sustainability-related factors such as CO_2 emission reduction but also by the non-sustainability-related aspects (it remains questionable if the term is correct as every value that contributes to the thriving of humankind is somehow benefiting sustainability values.). The value provided are diverse, but through the interconnectivity of Smart Cities and through the frameworks used, related. To exemplify: Smart mobility concepts and Fintech could be improved by the application of BC. The same applies to potential synergies of VIF and biophilic design (e.g. potential to breed settlings at the same nursing station), which leads to the conclusion that in different values are lots of similarities.

7. Main General Conclusion

The initial goal of this research was to understand the potential that certain fields of innovation can have on cities, to make them smarter and more sustainable. For that, a broad initial exploration was done, and parameters for a preliminary potential assessment were defined. The chosen innovations focused on the following areas: Mobility, Vertical Farming, Biophilic Design, BC, and Fintechs. These concepts may sound like jargon, but after in-depth study, it is clear that the benefit they bring to citizens can essentially change the way we live within cities in current and future days. After proving the entrepreneurial and environmentally sustainable value that these innovations generate and understanding the structural changes that would be required to implement these changes within a city, it is important to reflect upon the Sustainable Development Goals (SDGs) that will be affected by them, not only individually, but as a whole. In fact, out of the 17 SDGs, 15 of them are at least partly affected by at least one of the innovations, being Decent Work and Economic Growth (SDG 8) the one that is tackled by every analyzed innovation. This means that all of them contribute to promoting sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all (United Nations n.d.), which has been verified in the value creation analysis for each of the five innovations. By building a MaaS solution that fosters the use of the public and shared transport networks, it is not only the solution itself that is benefiting from growth, but also – and most importantly – the networks, which can then improve in qualitative and quantitative terms due to the success of this solution. Furthermore, enabling vertical farming for small-scale players means not only enabling every player to use more environmentally friendly solutions, but also giving the same opportunities for economic growth to all. The same happens with biophilic design architecture which, as previously explained, is a type of architecture from which only the most privileged fringes of society can benefit. But, at its core, the goal is to integrate nature and human beings and, through finding solutions on how to enable it for everyone, steps are being taken towards a more inclusive economic growth. On a more individual sense, Fintech solutions can increase financial inclusion through higher access to financial services, boosting SMEs and entrepreneurs' success enabling mobilization of domestic savings, allowing long-term investments and ultimately increasing economic growth. Finally, applying BC to the energy market not only opens space for more players in the sector, fostering competitiveness and growth, but also creates new opportunities for several players in the city context, and even a potential new revenue source for citizens if they choose to become prosumers.

Although SDG 8 is touched upon by every subject approached in this research, it is not necessarily the key one for all of them. In fact, when talking about mobility, the main one is SDG 17 – Partnerships for the Goals, as enabling a MaaS solution in the city context requires a strong alignment between private and public players – not only in terms of transport modes but also, and mainly, with regards to technology, and a solid and flexible governance model. When talking about Vertical Farming, one of the main aspects is the fostering of Responsible Consumption and Production (SDG 2) – by enabling small business owners to use such technology in the sourcing of their products, production becomes sustainable (not only economically, but also environmentally), allowing a cycle of responsible consumption and production to be generated. For the application of biophilic architecture, the main focus is SDG 11 – Sustainable Cities and Communities, as it works towards making these types of buildings accessible to all, thereby aligning with "making cities and human settlements inclusive, safe, resilient and sustainable" (United Nations n.d.). Applying innovative Fintech solutions in the city context mainly contributes to SDG 1 – No Poverty as, as discussed during the in-depth analysis, reducing payment costs and enhancing access to capital and investments leads to higher financial inclusion and literacy. Finally, applying Blockchain technology to the energy sector mostly contributes to SDG 7 – Affordable and Clean Energy, as it leads to higher transparency of the energy infrastructure due to the decentralized nature and traceability of Blockchain.

Technology is constantly evolving. Ages ago, the fire appeared. Then, eventually, the Man invented the wheel. Later, the light bulb and the printer became part of our lives, and today we all live connected through the Internet. Things that we never thought could exist have much more than the direct application that can be initially assumed from it. As so, pursuing this kind of exploratory research and potential assessment is key to ensure not only the cities' improvement but the evolution of mankind.

8. General Limitations

The limitations concerning research find some points in common and others of difference between the various subtopics. A group work articulated in five different areas that converge in a single objective leads to clashes with difficulties that are mainly technical and research-related, and with others that are consequences of the former. Sustainability is one of the most discussed and researched objectives of the last century and will be what mankind will have to achieve to survive. Smart Cities, on the other hand, represent the future starting from the small steps that man and technology take today, trying to build around it a welcoming and stimulating environment that reacts to human stimuli and guarantees a high quality of life. From this we can deduce that the topics dealt with are extremely topical and in particular, subtopics such as the Blockchain in the energy context or Biophilic Design from the point of view of cost analysis or the use of new architectural technologies lack numerous relevant academic articles that can provide further information as they are fields that are sometimes still unexplored. However, it is the future that will provide answers to our proposed solutions. In the course of the research, different frameworks were used, and sometimes it was not possible to obtain the desired results from them. From the point of view of Vertical Farming, we were not able to obtain a business plan and a real market research with real identification of the latter. The reason for this is purely due to the scarcity of quantitative data obtained and the large amount of qualitative information, which led to conclusions that were not based on numerical/analytical evidence. A similar problem was faced in the Fintech sub-topic where we have no information on the cost structure, in the Biophilic Design sub-topic where we have a qualitative analysis with some assumptions on the cost data due to the lack of architectural background and in the Smart Mobility sub-topic where we had to make assumptions on the public sector cooperation (even if its interest was quite validated) and on the costs/demand. The Smart Mobility area also encountered some limitations in using a survey: closed-ended questions limit the person's opinion to the options proposed by the research, with a risk of leading to distortions due also to a word-of-mouth sample. On the other hand, the number of interviews was not high enough to get a complete picture of the experts' opinions, however, also due to the lack of response and not to the lack of research and as previously mentioned, they are purely qualitative, therefore they mainly provide opinions, validated however by the experience of the interviewees. It would also have been useful to be able to elaborate on many other points relevant to the research, such as regulatory frameworks for Blockchain in the energy market, the wide range of applications that

Fintech provides today or quantitative analyses regarding the funding of this type of innovation.

9. General Future Research

According to Statista, the projected revenue generated by companies in a Smart City, offering products and services based on data technologies to increase the value creation, will rise to 241.02 billion U.S. dollars in 2025 ('Global Smart City Revenue 2020-2025' n.d.). Simultaneously, regulations and societal demand are increasingly pushing companies to focus on sustainability in their actions. These two developments show that in the future the topic of value creation through sustainable innovation in a Smart City will gain constantly importance and needs to be explored more deeply. This shows that this subject area must continue to be investigated.

To gain more insight into the value creation through innovations in sustainable Smart Cities, there are several options and approaches for future research.

The first option is to build on the limitations just listed. In the analysis of each innovation, some limitations limited the validity of the answer to the RQ. Future research could focus on these limitations and try to address them by collecting primary data. For example, focusing on the missing information about the business cost structure and discovering it through data collection. Another limitation, which can be solved in future research, is the limitation of the validity due to the limited field of view. The present work focuses on the value creation of five innovations. To analyze the value added by innovations in a Smart Sustainable City in a more precise way, a wider range of innovations of different types must be considered. The second possibility for future research is to focus on the impact of the innovations on the three pillars of sustainability separately. In this way, the value creation through innovations in a Smart City can be divided into society, economy and environment. This helps to go into more detail about the impact of a single innovation on a specific target group and to better understand how value is created. The third possibility would be to support the existing findings with primary data by conducting a long-term experiment to truly analysze whether the innovations lead to sustainable value creation in reality. Since the results will be depending on the micro and macro-environmental circumstances, the experiment needs to be conducted in different cultural areas, to be able to deliver independent research results.

In conclusion, there is still a great deal of research potential in this area and, given its enormous relevance, the study should continue to be carried out from various perspectives and with different approaches.

10. Review of the collaboration and motivation of this work

The theme of sustainability, assigned at the beginning of this course, was not only a motive for academic research but above all a way of making everyone feel part of a group that wants to have objectives to change the world in its small way, improving it, looking towards the future. So, research after research, providing ideas to our teammates and working on what seemed to be suitable with our profile, the structure of the project became increasingly clear. Collaboration was the main driver of the research. It led to a general knowledge of the drafting process in a homogeneous way, with each component being interested in all subtopics. The initial motivations were different for each of the team members. They reflected interests, passions, character and academic backgrounds related to the underlying topic. However, it was not easy to link interests to knowledge to keep the research business-oriented. Learning from areas completely outside the comfort zone has been challenging but at the same time interesting and educational. We achieved new knowledge, that have never before been explored in fields such as engineering, architecture, or agriculture. The greatest success is to see what in the beginning was just an idea born from a theme, that of sustainability, become a working project full of passion, creativity, and research. Through the choice of these solutions presented, it was a challenge to try to get to the heart of the matter: Can we create value? Can we in this way achieve sustainability goals linked to the SDGs that can one day give a better future to new generations, as the previous ones did not? This question was the driving force behind the research, which passionately tried to provide all the necessary points for as detailed an understanding as possible, albeit with significant limitations. All the subtopics could be explored in more detail. However, each of these innovations is more or less unexplored territory and this generated curiosity among the members throughout the drafting of the research. In the end, many points of initial prediction were mitigated by barriers that still drive society and governments. Personal motivations remain almost the same as at the beginning, albeit with much more awareness and knowledge of how processes work that are often taken for granted.

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Appendices

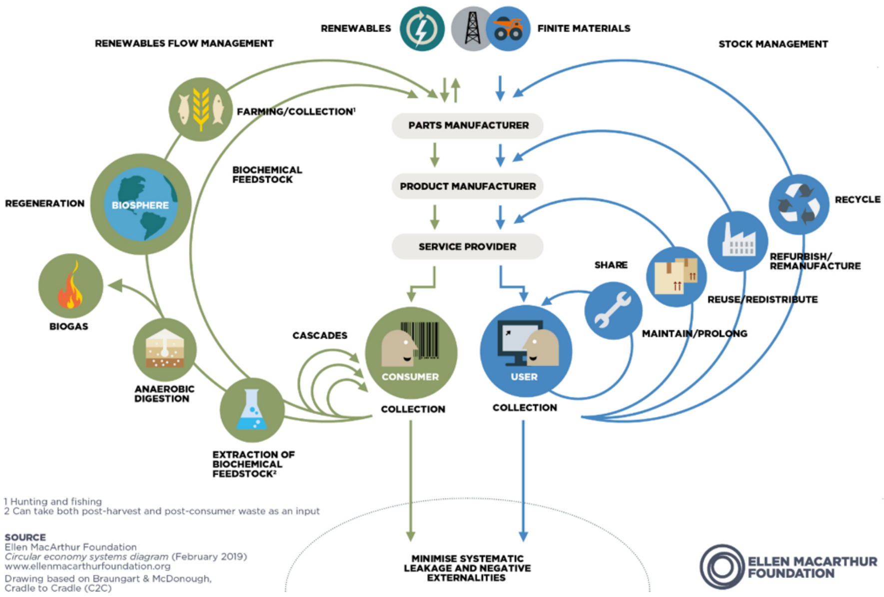
Appendix 1 General

Appendix 1.1. Innovations Scorecard

	Smart			Sustainable			Context	
	Quality of life (15%)	Efficiency of urban operation and services (15%)	Competitiveness (15%)	Economy (15%)	Environment (15%)	Society and Culture (15%)	Own Interest/Experience (10%)	Final Score
Cooperation for Smart Sustainable Mobility through MaaS solutions	3	3	3	3	2	2	3	2.7
Sustainable Fintechs	2	2	3	3	2	3	3	2.55
Blockchain for Renewable Energy Integration	2	3	3	3	2	2	3	2.55
Vertical Farming	2	3	2	3	3	1	3	2.4
Biophilic Design	3	2	1	2	3	3	3	2.4
Clean controllable onsite electricity for home or business through blockchain	2	3	2	3	2	2	1	2.2
IoT – oriented infrastructures	3	3	2	2	1	3	1	2.2
Pre-filled forms on central online portal for administrative services/ Data Usage for Administrational Things	2	3	2	1	2	3	1	2.05
3D printing for healthcare	2	3	1	2	2	2	1	1.9
Fully online medical advice	3	2	2	2	1	2	1	1.9
Technology to discover methane leaks quickly	1	2	3	2	3	1	1	1.9
App for tracking your carbon consumption	2	1	2	2	2	2	1	1.75
Plastics from carbon emissions	3	1	1	3	2	1	1	1.75
Solarpowerd railways	1	2	2	3	2	1	1	1.75
3D printing for food replacement	2	2	3	2	1	1	1	1.75
Wireless Sensors for autonomous driving	2	2	3	2	1	1	1	1.75
Circular economy solutions for food waste	2	1	2	1	2	2	1	1.6
Sustainable roof covering made from pyrolysis oil	1	2	2	2	2	1	1	1.6
Personalized travel experiences through advanced analytics	2	2	2	1	1	2	1	1.6
Special technique to dye clothing to reduce water consumption	2	1	1	2	2	1	1	1.45
Reusable packaging	1	1	2	1	2	1	1	1.3
Eco fibers to produce sport clotches and swimsuit as a replacement of neoprene	1	1	1	3	1	1	1	1.3

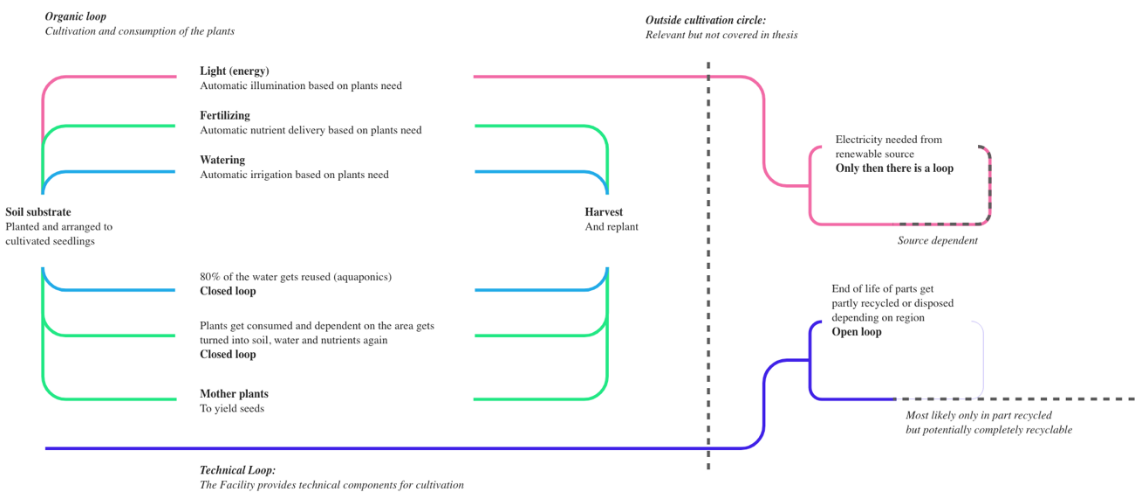
Appendix 4. Vertical Farming

Appendix 4.1. Circular Economy Framework



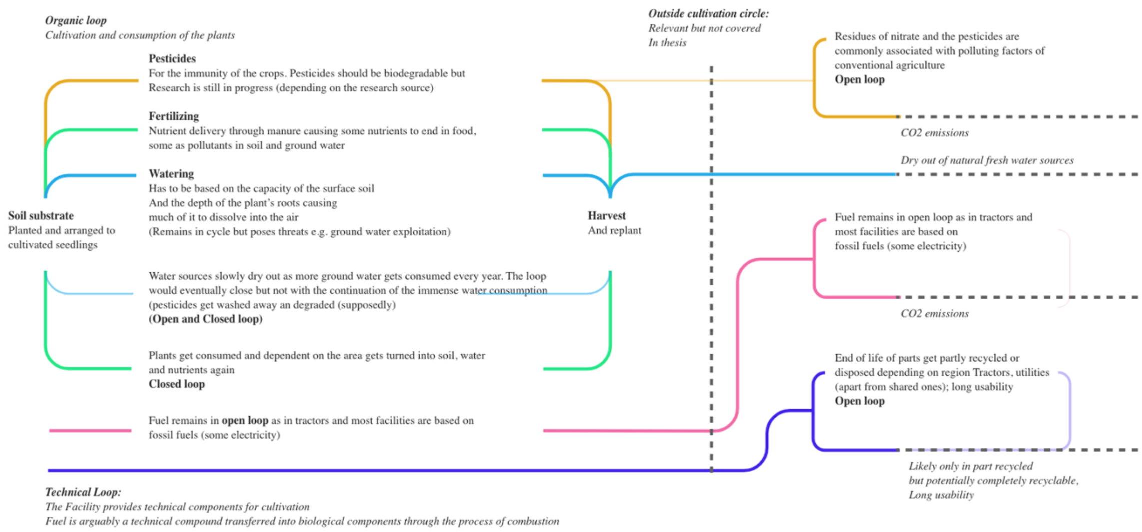
Ellen MacArthur Foundation, SUN, and McKinsey Center for Business and Environment; Drawing from Braungart & McDonough, Cradle to Cradle (C2C) ('Intelligent Assets: Unlocking the Circular Economy Potential' n.d.)

Appendix 4.2. Application of Circular Economy to the material flows of VIF (generic)



Own interpretation of the Framework Circular Economy to a VIF

Appendix 4.3. Application of Circular Economy to the material flows of Conventional Agriculture (generic)



Own interpretation of the Framework Circular Economy to a generic Conventional agricullture

Appendix 4.4. VIF Business Model Canvas

Key Partners	Key Activities / Key Resources	Value Proposition	Customer Relationships / Channels	Customer Segments
• End-clients or inhabitants of the smart city • Municipal policy makers / local authorities • Goveners and regulators • Staff: Farm managers • Staff: Distributers, Sales, Support, etc. • Business Partners • Suppliers • Clients: Large-scale traders; low-scale traders: Restaurants, firms, stores, whole sale traders	**Key Activities** • Planting and cultivating leafy greens • Plan and construct decentralized Vertical indoor farm facilities • sell to and partner with local stores • persuade and partner with the local authorities • negotiate long term supplier contracts • attract new business partner for collaboration **Key Resources** • Facilities with all its components per kind of plant • seeds and settlings • water • electricity, light • staff • regional distribution system	• Extremely fresh ingredients as products can be harvest before delivery or even inn store • hyper regional: almost no transportation needed • organic food with no use of pesticides • (price only a competitive advantage after scaling) • a truly sustainable product (no greenwashing) as it can be assessed e.g. Circular Economy • all sorts of leafy greens and some vegetables and fruits can be offered to the clients (regional exotic fruits and veggies possible)	**Customer Relationships** • Same quality in every user experience • subscription models for extending the custom life time value • growing brand awareness so that the clients can identify themselves with the brand • decentralized scaling results in the keeping of hyper-regionality • ad hoc reactions to contractors needs **Channels** • Direct sales to regional contractors: Grocery stores, restaurants, companies • regional ad promotion (FB, Google, IG Tik Tok, YT) • Subscriptions to medium contractors: clients, firms • B2C direct sales • B2C e-commerce: Brand Website featuring regional shopping experience, offerings and delivery	• end clients: inhabitants of smart city that would go to a store and buy VIF food • small to medium-contractors: restaurants, firms might value the quality of VIF food • large-scale-contractors such as grocery stores (competitive environment and potentially the most price-sensitive) • Business Partner that want to take ownership of facilities (pay a fee e. g. Franchise)

Revenue Streams	Cost Structure
• Capital expenditure (CAPEX) whenever facilities with all its components per kind of plant are bought • Regular costs: - seeds and settlings - water - electricity, light - staff - regional distribution system	• per good in whole-sale environment • per good in direct sale environment • subscription to B2B clients • Franchise fees for business partners

The business model Canvas is applied to the general technology VIF and its value proposition. Later, the business model refers to the calculation of free cash flow of one concrete VIF application

Appendix 4.5. Extract of 10 years of CF scenarios and scalability calculation based on FF Greenery S (estimates appendix 4.13)

Cash-Flow developmennt

Scenario	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
A	€ 6.000	€ 12.000	€ 18.000	€ 24.000	€ 30.000	€ 36.000	€ 42.000	€ 48.000	€ 54.000	€ 60.000
B	€ 12.000	€ 24.000	€ 36.000	€ 48.000	€ 60.000	€ 72.000	€ 84.000	€ 96.000	€ 108.000	€ 120.000
C	€ 24.000	€ 48.000	€ 72.000	€ 96.000	€ 120.000	€ 144.000	€ 69.527	€ 117.527	€ 165.527	€ 115.054
D	€ 48.000	€ 96.000	€ 144.000	€ 117.527	€ 213.527	€ 235.054	€ 304.581	€ 347.636	€ 486.690	€ 647.271
E	€ 96.000	€ 192.000	€ 261.527	€ 400.581	€ 705.163	€ 1.244.798	€ 2.132.069	€ 3.794.030	€ 5.757.370	€ 10.273.144

Amounnt of new plants

Scenario	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
A	1	1	1	1	1	1	1	1	1	1
B	1	1	1	1	1	1	1	1	1	1
C	1	1	1	1	1	1	2	2	2	3
D	1	1	1	2	2	3	4	6	8	11
E	1	1	2	4	7	12	22	39	60	107

*CS = Cash flow per month

Based on Facility costs (FF Greenery S)

€ 122.473

Full calculations can be provided upon request.

Appendix 4.6. Pictures of Freight Farm systems which are designed into Freight containers and represent aquaponics

Source: (‘Investment Calculator’ n.d.)

<u>Appendix 4.7. Picture of Aeroponics</u>

The roots hang through the air into the water where nutrients can be absorbed.

Source: (‘How to Grow Hydroponic Lettuce | High Tech Gardening’ n.d.)

<u>Appendix 4.8. Singaporean super firm “Vertivegies”</u>

Source: (Vertivegies, 2021)

Appendix 4.9. Interview Yasser Chehade, Entrepreneur

Phone interview, December 4th, 2021. Full transcript can be provided upon request.

Main insights: well, as an engineer and procurement lead dealing with mainly renewables energies I contribute positively to sustainability … In the practices of being an entrepreneur I mainly focus on software solutions … of course there are some aspects such as weight of data or electricity draw etc. but this is not the main concern… I am not the typical investor for VIF but the idea sounds tempting. In fact, I heard of it … if I would have the knowledge and would deal more with food this would be considerable … hurdle of buying the facilities might be prevalent but as an engineer, I might would set up my own VIF… I also think of software and its ingenuity of it as well as the brand-building as this technology might be too abstract for some clients …

Appendix 4.10. Interview Joscha Bröhrmann, Founder of Tahibi

Phone interview, November 13th 2021. Full transcript can be provided upon request.

Main insights: I see myself as a contributor to sustainability in 2 ways… First, I am an engineer focussing on renewables… second, our platform Tahibi benefits vendors, that produce regional … I heard about VIF and I believe in the benefits, in fact, I believe that this is a key technology that has positive environmental implications and this will, in the near future, lead to a more widely accepted application … if the quality and the freshness is even better than conventional food, then I would even pay a bit more as a customer … I could see vendors that base their business on VIF on Tahibi because of regionality decentralization and quality … Hurdles might be real estate and property …

Appendix 4.11. Interview Rick Trenchard, Lead Sales Freight Farms and Harrie Rademaekers, Founder of a business based freight Farms and audience

Interview between the professionals also answering the questions from the audience, webinar, November 23th 2021. Full transcript can be provided upon request.

Main insights: the great thing is that people can be successful with something environmentally valuable… the shipping is dependent on the country you live in challenging or not. You can either try to organize it yourself or FF will help you with that … also, the conditions for funding and launching a business abound to the local regulators, so establish a good relationship with them … The solidness of your business model should be absolutely spot on. I spent four months on it trying to capture as much value as I can. A lot of people fail because they don't achieve the prices but this is due to improper research on the business plan. Luckily FF will help you with that and supply you with all the necessary tools for your success. But doing your homework with the business model is crucial as this is a money-printing device… And don't focus on the grocery stores too much as they don't represent the best clients for VIF … rather end to end clients or high-class restaurants, or firms …

Appendix 4.12. Interview Rachel Wisentaner, Key Account Manager Freight Farms

Video call, December 7th 202. Full transcript can be provided upon request.

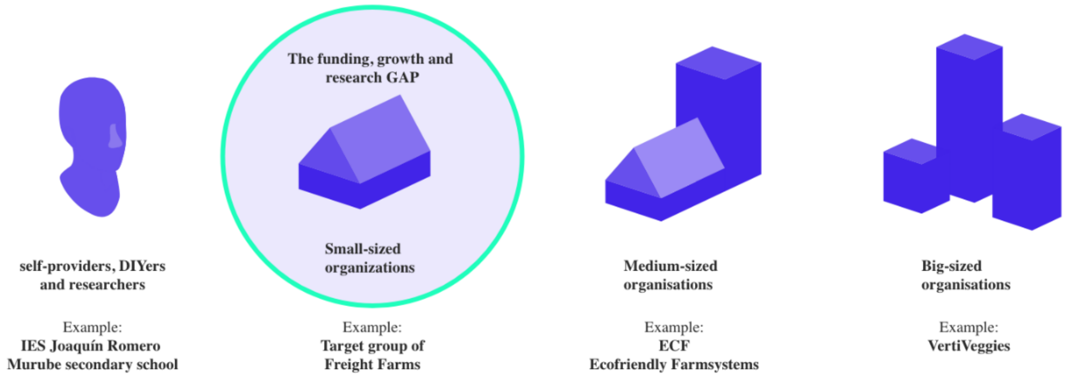
Main insights: the first thing to do is to develop a business plan and we will help the users free of charge… understanding the market is crucial… yes, the Greenery S has its price, in fact, next year it is going to be 20k more expensive, but consider what is included. Our service helps you build the business case, and we will serve you as consultants and educators … the payback period you calculated matches with our experience, which is usually 3 years but rather because in the first 1-2 years there are learnings and due to that losses occur … users that buy the VIF from us are rather diverse: some want to have a side business, some are families that want to be a self-and communal food provider, some want to create a profitable business and scale … lots of clients of VIFs from us are direct customers and high-end restaurants … tax benefits are a benefit that many can use to further increase profitability but that varies depending on region …

Appendix 4.13. List of estimates and measurements and its sources

Cost	$	€*	Unit	Source
Sell price of Pak Choi	$ 2,23	€ 1,99	Heads (250 grams)	('Pak Choi online bestellen & liefern lassen | Bringmeister' n.d.)
Electricity	$ 0,44	€ 0,39	kWh	('Stromanbieter Bargteheide 2021 - Strompreise vergleichen' n.d.)
Labour	$ 11,30	€ 10,09	Professional gardener	('Gärtner Gehalt - Alles Zum Verdienst' n.d.)
Rent**	$ 38,14	€ 34,05		('Grundstückspreise Stormarn - Stand: Dez. 2021' n.d.)
Delivery & Distribution	$ 112,02	€ 100,00		estimate
Packaging	$ 10,52	€ 9,39	1878	0,005 per unit (estimated)
Other Expenses	$ -	€ -		

Calculations and descriptions				
*Exchange rate from 24h of Nov. 2021	$ 1,12	€ 1,00		('USD to EUR Exchange Rate' n.d.)
**based on monnthly installment for ø price		€ 517,00	per m^2	('Grundstückspreise Stormarn - Stand: Dez. 2021' n.d.)
Container dimensions	2,4384	6,058	m	(Martin, Martin, and Lai 2019)
Container in m^2	14,7718272		m^2	
Years	20			
Interest	7%			

Appenndix 4.14 The Gap



Own illustration of the research and funding gap