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Hydroponic Farming and Circular Economy - implementation of Circular Economy into Hydroponic Production

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Abstract

Vertical hydroponic farming presents an emerging industry that could soften the blow of conventional farming. Hydroponic farming is a form of controlled environment agriculture, which is usually situated indoors, and the plants grow in the absence of soil. Hydroponic production brings several benefits to the food system especially in terms of water use efficiency, space efficiency, all-year production and productivity of the system. Despite a number of benefits highlighted in the literature, there are challenges of hydroponic farming like dependency on energy to grow, a limited range of crops that are suitable for hydroponic production and higher price of the product. This study analyses the challenges that occur when the plants are grown at Urban Oasis hydroponic farm located in Stockholm, Sweden and explains how the concept of the circular economy could be implemented into the hydroponic farming production with the aim to address the identified challenges. This thesis follows a qualitative research design with an inductive approach. Ethnographic action research is carried out since the generated knowledge helps to promote the improvements in the business processes. The analysis of collected data from interviews and observations at Urban Oasis showed that the Swedish hydroponic farm may have better potential to make its production more sustainable, compared to the farms located in other countries. In Sweden, energy comes mostly from renewable sources and consumers are aware of environmental problems. In case of Urban Oasis, implementation of the circular economy is conditioned by mainly environmental and economic factors and the principle of reusing, reducing and recycling the resources is emphasised throughout all phases of production. The shift towards the circular economy can be successfully achieved through collective effort. Therefore, this thesis points out the potential for uptake of the concept of industrial symbiosis where synergy among businesses is developed and businesses can make use of someone else´s by-products.

Abbreviations

3Rs	Reduce, Reuse, Recycle
CE	Circular Economy
CEO	Chief Executive Office
IS	Industrial Symbiosis
LCT	Life Cycle Thinking
LED	Light Emitting Diode
SBD	Sustainable Business Development
SDG	Sustainable Development Goals
UO	Urban Oasis

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1 Introduction

This chapter provides the reader with the requisite background of the topic that this thesis further analyses. Hydroponic vertical farming is the concept that will be explained throughout this thesis as well as the challenges associated with this production system. Consequently, problem and the aim of the thesis are described together with the research questions, a unit of analysis, and delimitations.

1.1 Background

Due to the growing population and increasing urbanisation, cities and its inhabitants put great pressure on environmental resources, both at a local and global scale (Benis & Ferrão 2017). In order to safeguard food security of people living in urban areas, food travels long distances before it reaches the consumer, resulting in the longer food supply chains that may be associated with inefficiency, losses and wastage and negative environmental impacts (ibid.). Conventional agricultural production is often connected to intensive use of fertilisers and pesticides, and emissions from the use of agricultural machinery affecting water, soil and human health (Tasca, Nessi & Rigamonti 2017). Unsustainable agriculture and harvest put biodiversity under the pressure due to habitat loss. The need for more sustainable use of natural resources is required, as currently agriculture uses up almost 70 % of global water withdrawal, which is projected to further increase considering the requirement to meet the food demand of the growing population. Moreover, due to agricultural intensification, forest areas are converted into agricultural land which results in dramatic forest losses (United Nations 2018).

Considering a large number of imports, especially imports of fruits and vegetables, to the Swedish market, Sweden contributes to significant environmental impacts in the countries where food is produced. Besides, as imports of vegetable and fruits have been continuously growing in recent years, these impacts on the natural environment are not expected to decrease in the foreseeable future (Cederberg, Persson, Schmidt, Hedenus & Wood 2019; Statista 2019). As a reaction to mitigate the environmental and social impacts of conventional agriculture at large scale, Mundler & Rumpus (2012) promoted the implementation of sustainability into the food system by reduction of intermediaries´ number and change in production and consumption location. Urban farming is therefore believed to partially contribute to build a more resilient food system and reconnect consumers with food production (EMF 2019). While urban farming can be defined as an agricultural production using arable land on or within the fringe of urban areas, indoor urban farming is a form of controlled environment agriculture where plants grow in water solution with nutrients and such farms are located in close proximity to, or within urban areas without the requirement for the soil (Despommier 2013; Benis & Ferrão 2017). Specifically, Despommier (2009, 2013) suggested vertical hydroponic farming as a suitable solution for problems related to conventional agriculture. He described these farms as indoor places where conditions for growing are controlled and production is possible all year long. Compared to conventional agriculture, vertical hydroponic farms use significantly less water, and amount of waste and transportation are greatly reduced due to locally produced food that does not require long-distance transportation. Moreover, production is situated in vertically stacked layers which ensure space efficiency.

Despite the aforementioned benefits of hydroponic farming system, this production system is accompanied by several shortcomings. The main challenge that is often highlighted by authors (Cox 2016; Pinstrup-Andersen 2018) is the high energy requirement. Compared to conventional farming, indoor growing systems cannot make use of sunlight, but the light represents a crucial condition that has to be met to grow plants indoors. Similarly, other conditions have to be adjusted when growing indoors. For instance, the temperature has to be controlled. Moreover, the variety of crops grown in vertical farms is very limited and the main focus of production is on leafy greens and herbs (Cox 2016). That is because most of the plant´s weight can be sold and eaten, while for example, tomatoes have leaves and stems which are inedible, hence part of electricity and space could not be used efficiently (ibid.). Another challenge that Cox (2016) highlighted is the fact that only a small fraction of population can be supplied with the food produced indoors and what is more, especially elite market is targeted since the food has usually higher price compared to conventionally produced one.

Bearing in mind all the aforementioned challenges of vertical hydroponic farms, they are nevertheless presumed to help to achieve a certain degree of self-sufficiency (Cederberg et al. 2019; Weidner, Yang & Hamm 2019). Sweden belongs to the most sparsely populated countries in the EU and moreover, the population is unevenly distributed throughout the whole country (SCB 2019). Contrary to the whole Swedish population, Stockholm region is densely populated, where a large fraction of population lives, thus the need for food supply is substantial (ibid.). Urban Oasis is a hydroponic vertical farm located in Stockholm, Sweden that grows leafy greens by using the hydroponic growing system. With the help of hydroponic farming, the amount of water used within the production is significantly reduced and such farming brings several benefits as well (Despommier 2013). Implementation of sustainability into production and finding new solutions on how to make farming activities of Urban Oasis less dependent on natural resources belong to the primary concerns of the management. By following the principles of the circular economy, increased efficiency, generation of less waste and cost savings can be achieved. The concept of the circular economy is generally understood as the circular flow of materials and resources with the emphasis on reducing, reusing and recycling of the resources (Lieder & Rashid 2016; Kalmykova, Sadagopan & Rosado 2018). The unit of analysis of this study is Urban Oasis and its production, to which the circular economy concept is strived to be implemented and thus, increase the sustainability of everyday production processes. Regarding circular economy implementation, the changes in the business processes have to be done at all stages of the production and thus follow the life cycle of a product. Even though the implementation of the circular economy into business activities is believed to enhance overall sustainability and viability of business (Jun & Xiang 2011; Lewandowski 2016), the suitable ways how to manage this shift towards circularity have to be found and explored. Especially in terms of circular economy implementation into the production of hydroponic farming, the knowledge is limited.

1.2 Problem background

Although there is no unanimous consent about the overall convenience of vertical farms in the literature, it is believed that they may contribute to increase the level of self-sufficiency and improve the resilience of urban areas (Weidner, Yang & Hamm 2019). Moreover, as future food demand from urban areas is expected to increase, hydroponic vertical farms present a food production system that is required to be scrutinized to a greater extent. While some authors underpin the benefits of urban production systems (Benis & Ferrão 2017; Weidner, Yang & Hamm 2019) and vertical production systems (Despommier 2013; Al-Chalabi 2015; Pinstrup-Andersen 2018), others focus rather on the challenges that urban farms face and maintain the opinion that vertical farms do not represent a feasible way towards more sustainable food systems (Hamm 2015; Cox 2016; Martin, Clift & Christie 2016). Mok et al. (2014) recommended finding a balance between urban and conventional production and assessing the contribution of urban farms to the food system because their limits had not been scrutinized. This demonstrates the need to scrutinize hydroponic food production to a greater level to see what challenges arise within this type of farming. In accordance with revealing the challenges of hydroponic production, it is necessary to find suitable ways how to shift the production towards more sustainable and responsible production that is more self-sufficient and less resource dependent. This is deemed to be a relevant step to do since this approach is lacking in the literature, even though some authors envisage urban hydroponic farming as a vital part of the future food system. Moreover, if shortcomings and challenges of the production are detected at an early stage, further negative environmental impacts can be avoided, and business can sustainably expand (Rainey 2006). The circular economy is believed to provide guidance on how to improve everyday business activities to achieve greater sustainability of the business because it emphasises responsible use of material and resources and closing loops which result into enhanced resiliency of the business (Jun & Xiang 2011). Even though several challenges of vertical farming system have been identified in literature, it is not demonstrated how these challenges could be solved. Moreover, there is a lack of literature on how companies should carry out the change of current operations into the circular ones. The drivers and barriers of circular economy implementation are illustrated in the literature, however, they are highly context-specific (Tura et al. 2019), therefore should be illustrated for the particular case of hydroponic vertical farms. These gaps in knowledge are addressed in this thesis. Similarly, in the literature, there is a consensus that more research about vertical indoor farming is necessary with respect to get more insights (Al-Chalabi 2015; Pinstrup-Andersen 2018).

1.3 Aim and research questions

Hydroponic vertical production presents an emerging industry that we have limited knowledge about, but it is essential to investigate it and critically reflect on this business context. Specifically, there is a lack of knowledge about the development of circular economy within the hydroponic farming, therefore this thesis investigates the implementation of circular economy into this production system. The aim of the thesis is to analyse the challenges that occur when the vegetable is grown in the hydroponic vertical farming system located in Stockholm, Sweden and explain how the concept of the circular economy could be implemented into the hydroponic farming production. Furthermore, the aim is to explore the drivers and barriers for circular economy implementation from the hydroponic farm´s perspective. The case of Urban Oasis is used to provide the reader with a detailed overview of the hydroponic production process and how the challenges within the production could be overcome in this particular case.

To achieve this aim, the following research questions were formulated:

- What challenges arise within the hydroponic farming production?
- What are the drivers and barriers for circular economy implementation for the hydroponic farm?
- How may the principles of the circular economy be applied within the hydroponic farming production?

1.4 Delimitations

This study is focused on the hydroponic vertical farm Urban Oasis which is located in Stockholm, Sweden. As the Swedish food market is highly reliant on food imports and the conditions created in the market differ from other countries (Cederberg et al. 2019), the opportunity for Urban Oasis to implement circular economy principles may be distinct from other similar businesses. The focus of this thesis is the production of this hydroponic farm and identification of the challenges within it, which could be overcome through circular economy implementation. It is worth mentioning that Urban Oasis had not fully embraced circular economy prior to this research, however, had been striving to introduce changes that followed the principles of circular economy (e.g. reusing of water). The challenges that occur in the production are identified and eventually addressed to demonstrate that this farm is economically viable while having a minimal impact on the environment. This is relevant considering the administration of a business on a daily basis. A thorough analysis of production processes is believed to enhance everyday business activities and enhance the overall sustainability of the farm. Considering the fact that the production is a crucial part of Urban Oasis´ business, it makes the production a vital part of the business to examine. As companies are increasingly under the pressure from the market to take responsibility for the negative impacts they have on the external environment, the implementation of circular economy principles is regarded as a way to embrace responsibility for the impacts and as a way to manage the company in a more responsible manner. Therefore, this study will be useful mainly to similar businesses, political actors or other businesses striving to implement circular economy, because it will show the relevant aspects that this type of farms has to deal with. This study does not quantify environmental performance or carbon emissions of the production of a hydroponic farm, as some other studies do, but this study provides insights into the business context.

1.5 Outline

The structure of this thesis is illustrated in Figure 1 below. The thesis starts with an introduction where the problem background, aim, research questions and delimitations are presented. Thus, the reader is introduced to the topic. Chapter two includes a literature review that is followed by chosen theories suitable for understanding the phenomenon of this study. Subsequently, theories are brought together as a conceptual framework. The methods applied in this study are presented in chapter three, where ethical consideration and limitations of chosen methods are addressed as well. Chapter four presents the empirical part of the thesis and starts with and empirical background and empirical data that was collected in the course of observations and interviews. After the collected data is presented, chapter five further analyses data according to the chosen theories. Results of the analysis are depicted, and the research questions are answered in this section. Chapter six presents conclusions of the thesis and summarises general understanding of the analysed topic. Moreover, suggestions for further research are noted.

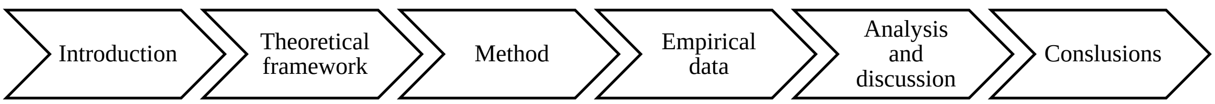


Figure 1 Illustration of the outline of the thesis

2 Literature review and theoretical framework

This chapter begins with a review of literature that describes different perspectives on vertical indoor farming and identifies what challenges are usually perceived by authors. The literature review serves as a base for comprehensive knowledge and therefore is an essential part of the thesis. Thereafter, theories suitable to investigate the topic are introduced. As suitable theories are deemed Sustainable Business Development, Circular Economy and Implementation of Circular Economy. These theories help to form a conceptual framework that this thesis applies.

2.1 Literature review

To begin with, it is important to distinguish between urban farming and hydroponic vertical farming, since the latter one is the primary focus of this thesis and differences are apparent. Urban farms are located within the urban boundaries and food is usually produced on arable land there. Food produced within the urban boundaries is intended primarily for consumption in the urban area. In most cases, urban farms are referred to outdoor farming which is dependent on soil (EMF 2019). Vertical hydroponic farming, on the other hand, is a form of indoor controlled environment agriculture, where plants grow in a water solution with nutrients with no requirement for soil. This farming system allows year-round production due to controlled conditions for growing. Such farms are located in close proximity to, or within urban areas, however, the hydroponic farm can be located anywhere regardless of outdoor conditions. The main requirement is the supply of water and energy (Despommier 2009, 2013; Benis & Ferrão 2017). The concepts of vertical, indoor, hydroponic urban farming are used interchangeably within this thesis and even though some authors consider for example rooftop greenhouses as urban indoor farming, this is not of interest because the hydroponic farming system is the main concern here. The literature is more extensive in terms of urban farming, which hydroponic vertical farms are a part of, however, there are authors who greatly discuss hydroponic vertical farming specifically (Despommier 2013; Cox 2016; Graamans, Baeza, van den Dobbelsteen, Tsafaras & Stanghellini 2018; Pinstrup-Andersen 2018; Romeo, Vea & Thomsen 2018). Even though there is not a consensus among the authors about the viability of hydroponic farming systems and some authors draw attention to the drawbacks that this type of farms has, while others highlight the benefits and potential advantages it has. Yet, it is important to turn challenges into business opportunities. Therefore more detailed analysis of the system is deemed to be essential, which is also highlighted in the literature (Pinstrup-Andersen 2018).

Although the production in vertical farms is associated with several challenges, so is conventional agriculture. Benis & Ferrão (2017) state that conventional agriculture occupies almost 40 % of arable land worldwide, depletes the significant amount of water, represents the largest water pollution source and importantly emits a great amount of greenhouse gas emissions into the atmosphere. Cederberg et al. (2019) also underpin other effects and pressures identified with agricultural intensification. The expansion of agricultural land results in massive biodiversity loss and increased use of fertilizers and other chemicals to enhance the production yields, which consequently lead to pollution of water and air. Some countries, for example Sweden, do not affect solely their own countries with these problems, however, they cause significant problems overseas. As a consequence of large food imports reliance, Sweden affects countries where the food is grown, thus increases the climate footprint of other countries (ibid.). As a matter of fact, food production takes place predominantly in rural areas, whereas food consumption is dominant in urban areas. The whole food system is greatly resource dependent, unsustainable and food supply chains have become longer (Benis & Ferrão 2017). Longer food supply chains lead to inefficiencies, food waste and loss and require extensive transportation of the goods. Furthermore, these problems will most likely increase due to the growing population (ibid.). It has been estimated that the components of a Swedish breakfast have to travel approximately “a distance equal to the perimeter of our planet before arriving to the Scandinavian table” (ibid. p. 784).

In regard to mitigating the impacts that conventional agriculture has, it was proposed by Benis & Ferrão (2017) to bring the food production closer to the cities and its inhabitants. By producing food within urban boundaries, Weidner et al. (2019) believe that global environmental challenges may be decreased while improving social and health conditions of the urban population. Not only people will gain access to locally produced food, but importantly it can relieve the pressure that is placed on land, water and biodiversity (Pinstrup-Andersen 2018). This idea is also shared by Romeo et al. (2018), who see this as an added value of vertical hydroponics and a possible way how to supplement people with nutrients with less harm done to the environment. Moreover, cities would achieve a certain degree of self-sufficiency because the need for transportation of the food, whose production had shifted to the cities, would decrease (Weidner, Yang & Hamm 2019). Similarly, the food supply chain would shorten and thus its efficiency would improve (Benis & Ferrão 2017).

Even though vertical farms bring various benefits to the food system, knowledge about overall viability is limited. Certainly, there are challenges associated with the indoor production of food and hence the researchers show both positive and negative sides of this emerging approach to grow food. The utmost factor affecting negatively the perception of such farms is the demand for energy required for lighting, heating and/or cooling (Ehrenberg 2008; Al-Chalabi 2015; Cox 2016; Chance et al. 2018; Graamans et al. 2018; Pinstrup-Andersen 2018; Romeo, Vea & Thomsen 2018). The majority of plants require sunlight for photosynthesis, however, indoor farms are forced to incorporate artificial light to ensure that plants grow appropriately (Ehrenberg 2008). Mostly LED (light emitting diode) lighting is utilized within hydroponic production because it is a very efficient solution from a biological point of view (Al-Chalabi 2015). Graamans et al. (2018) however came to the conclusion that indoor farms are in general more energy efficient compared to greenhouse production because closed systems can utilize resources more efficiently. Cox (2016) maintained the opinion that energy efficiency of the lamps can be improved in the future, but the improvement cannot be infinite, hence indoor farming will always be reliant on electricity and support from the industry. Romeo et al. (2018), Al-Chalabi (2015) and Pinstrup-Andersen (2018) came to the conclusion that hydroponic production had better environmental performance if renewable energy sources were used. As a consequence of using renewable sources, hydroponic farms gain competitiveness and new opportunities could be developed (Al-Chalabi 2015). In terms of productivity and efficient use of other resources, for instance, water and land area, the results are more favourable when production is shifted indoors (Graamans et al. 2018). On the other hand, Ehrenberg (2008) saw finding land as another obstacle that is related to food production in urban areas. Moreover, there is already a fierce competition with other sectors and considering that all agricultural, industrial and residential sectors require resources (especially land, energy and water) their expansion is limited and greater resource allocation management is necessary (Mok et al. 2014). Another challenge that vertical farms face is a limited range of crop species suitable for indoor production (Cox 2016). Predominantly, indoor farming production focuses on leafy green or herbs due to efficient productivity since the most of the plant´s weight can be sold and eaten, whereas some other plants have stems, leaves or roots which are inedible therefore some of the resources used to grow the plant came in vain (ibid.). This obstacle is identified also by Pinstrup-Andersen (2018) and Chance et al. (2018) who highlighted the importance of combining conventional and indoor agriculture since some crops are not suitable to cultivate within the urban boundaries or indoors. This is in accordance with the aforementioned idea that indoor farming production could ensure some level of self-sufficiency of cities, however, it is indisputable that production of all crops could not be shifted to the cities and be viable at the same time. The last challenge discussed in the literature is that the main market targeted is the elite market, thus low-income consumers cannot obtain benefits from fresh and local produce (Cox 2016; Pinstrup-Andersen 2018). This opinion may be possibly influenced by the existence of higher price stemming from the price premium required to make vertical hydroponic production economically viable (Pinstrup-Andersen 2018).

Although there are various challenges associated with vertical hydroponic farming, there is an agreement to scrutinize this system to a greater extent to estimate its viability (Ehrenberg 2008; Al-Chalabi 2015; Pinstrup-Andersen 2018). Vertical farming is a concept that is still in its infancy, therefore future research is essential because it presents a solution to mitigate the impacts caused by conventional farming and urbanization, moreover such farms "hold promise for future cities" (Al-Chalabi 2015, p. 77). Similarly, Pinstrup-Andersen (2018) called for the necessity to acquire more evidence to estimate the feasibility of vertical indoor production and believed that its full potential could be revealed with detailed research. Moreover, he believed that it would be a mistake if its benefits were ignored, while on the other hand, it is too early to draw some conclusions about its contribution to micronutrients deficiencies in urban populations. Likewise, by further exploration of the vertical indoor production system, it may become easier to anticipate its feasibility, reveal other possible challenges that occur within this system while likely discover other benefits. In this case, it is deemed convenient to overcome the notion that the negative aspects will always outweigh the benefits because only a small fraction of knowledge is available. Some people may argue that it is more important to improve the efficiency of the current production system instead of paying attention to the new system, however, the researchers underpinned the importance of future research.

Finally, it is essential to know the perception of consumers and how they view this emerging production system. A barrier that was identified by Al-Chalabi (2015) is the lack of knowledge about hydroponics. Consumers do not know how food is grown in this system and often consider food and production as not natural and believe that chemicals are used in such production. This notion could present a barrier for the uptake of hydroponic vertical farms. On the other hand, when consumers assessed the differences among lettuce produced in the open field, greenhouse and vertical farm, they failed to detect the differences, however, remained sceptical about naturality of vertical farming (Pinstrup-Andersen 2018). In accordance with what was stated previously, the efficiency of indoor farms is higher compared to conventional production and in case of the plant nutrient efficiency, the same applies too (ibid.). Since the plants are placed in a water solution with nutrients, they are able to capture virtually all the nutrients provided. Thus, food grown indoors can still fulfil the nutritional criteria and surely present a part of a healthy diet. In some cases, the hydroponically grown vegetable can be even nutritionally superior to conventionally produced ones, because the number of nutrients can be adjusted easily (Egan 2016).

Ehrenberg (2008, p. 19) stated that "vertical farms would soften the blow of traditional farming… giving injured land the chance to heal" and this is an advantage that cannot be neglected. The current landscape is not diverse to thrive as it could, but by shifting production indoors, more space for biodiversity will become available. Also, Romeo et al. (2018) highlighted that this type of production without agricultural land occupation can be seen as an advantage of vertical hydroponics.

2.2 Sustainable Business Development

To assist navigating national plans and strategies towards the more sustainable and resilient future, the United Nations issued in total 17 Sustainable Development Goals (SDGs). They were introduced in 2015 as a part of The 2030 Agenda for Sustainable Development that presents a shared vision towards prosperity for people and the planet (United Nations 2018). This Agenda provides a guideline on the transition of societies to better future through addressing challenges like climate change, inequality, environmental degradation and rapid urbanization. The Goals are interrelated and require the involvement of different stakeholders due to their complexity. It is believed that the quality of life is affected by the ways how natural resources are used and managed (ibid.). Therefore, the promotion of sustainable production and consumption have been identified as one of the Goals of the 2030 Agenda. The idea here is to "decouple economic growth from resource use and environmental degradation, notably through improved resource efficiency, while improving people's well-being" (United Nations 2018, p. 26). Over the past years, some companies have embraced the scope of their responsibilities and competencies (Rainey 2006). This shift stemmed from the pressure from customers, stakeholders and society that became more conscious about the impacts that companies, as well as other actors, can have on humankind and the natural world. Therefore companies moved beyond their core business activities and started to focus on the implementation of sustainability into their processes (ibid.). To achieve this, the promotion of SDGs and their visions is believed to help companies to integrate dimensions of sustainable development into the business' activities. Sustainable production and consumption promote resource and energy efficiency while reducing future economic, environmental and social costs. The notion to attain more sustainable production may be applied to every business that became more conscious about its impacts. Hence vertical hydroponic farm is no exception and values proposed by SDGs are emphasised to some level as well. Since the idea of The 2030 Agenda is decoupling economic growth and environmental degradation by increased resource efficiency within all phases of product or service, life cycle thinking approach should be promoted (UNEP 2010). "Life cycle thinking expands the traditional focus on the production site and manufacturing processes and incorporates various aspects over a product´s entire life cycle" (ibid. p. 33).

The increased awareness of the impacts that production and consumption of products have, led to growing concerns to develop a method that addresses environmental impacts and allows a better understanding of them (ISO 2019). Therefore, life cycle thinking (LCT) approach was developed to assist companies in identifying the life cycle of the products and thus address challenges. Especially the emphasis is on the environmental impacts that occur throughout the life cycle of a product. The life cycle generally spans from raw material acquisition, production, use, end-of-life treatment, recycling to final disposal (EEA 1998). The concept of LCT is perceived as the way to shift production and consumption towards a more sustainable future (Notarnicola et al. 2017). LCT can be defined as a methodology "for examining, assessing, and improving technologies, products, and processes" and can be used for decision making (Rainey 2006, p. 507). It examines the flow of inputs and outputs and their impacts over the entire life cycle from cradle to cradle (Rainey 2006; UNEP 2010). With the help of LCT, companies are able to make improvements of the product to avoid defects, decrease environmental impacts that the production possibly has and shift value proposition in the direction that the customers currently demand (Rainey 2006). Over the years, consumers are becoming more aware of the environmental impacts that companies have, hence they have the power to affect the way companies act in the market (van Leeuwen, Nijkamp & de Noronha Vaz 2010). Companies have to act upon the consumer's reactions because they are the ones who make the buying decisions. LCT formulates operational considerations, while enterprise thinking is concerned with the strategic considerations, however, LCT has an influence on the entire business due to its focus on discovering new and enhanced ways to utilize inputs and processes to get better outcomes (Rainey 2006). By analysing the life cycle of products, services or processes, companies get a better overview, where the most inefficiencies occur and respond to them by taking an action. Consumers call for an extended responsibility of companies for their products and LCT offers to expand the responsibility beyond the standard boundaries (Rainey 2006; van Leeuwen, Nijkamp & de Noronha Vaz 2010). Companies must be aware not only of their actions but also of the actions of suppliers, distributors and consumers to ensure the full scope of improvement. Thus, companies have to involve multiple stakeholders when creating a life cycle framework since by involving only internal stakeholders it would not be possible to address all aspects of the life cycle. The vision of LCT is the elimination of negative impacts, however, to achieve such a complex goal, it has to be integrated into business´ philosophy (ibid.).

2.3 Circular Economy

The concept of the circular economy (CE) has a high priority on the political agenda. Agendas, policy documents and investment strategies are being developed with the aim to promote CE (Kalmykova, Sadagopan & Rosado 2018). CE is an approach that goes beyond the traditional linear economy model of "take-make-waste" and entails circular model that views sources as scarce (EMF 2017). Figure 2 illustrates the linear economy model that is prevalent in terms of production.

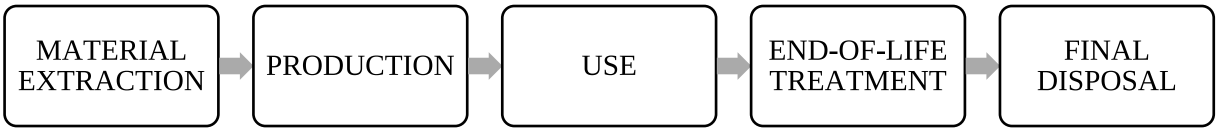


Figure 2 Linear production model; source: author

The traditional linear model uses resources irresponsibly and considers them as infinite. Therefore the whole system puts the global ecosystem under pressure due to high demand for materials (Rizos et al. 2016). Lieder & Rashid (2016, p. 37) called this linear consumption behaviour as "throwaway mindset" which is seen as a cause of a number of environmental problems. There is an agreement that CE presents a way how to achieve sustainable development between economy and environment (UNEP 2010; van Leeuwen, Nijkamp & de Noronha Vaz 2010; Jun & Xiang 2011; Rizos et al. 2016; EMF 2019). The concept of CE is seen as an approach for overcoming the linear economy model, which is followed by remarkable ecological and social impacts, and suggests closing the loop of material within the product´s life cycle (Ritzén & Sandström 2017; Toop et al. 2017). The ideal vision of CE is illustrated in Figure 3. CE criticises the traditional linear approach and underpins the core activities like reducing, reusing and recycling as the main principles. It is restorative or regenerative by intention and the aim is to use products and materials as long as possible so that the maximum value can be obtained from the extracted material (WEF 2014; Kalmykova, Sadagopan & Rosado 2018).

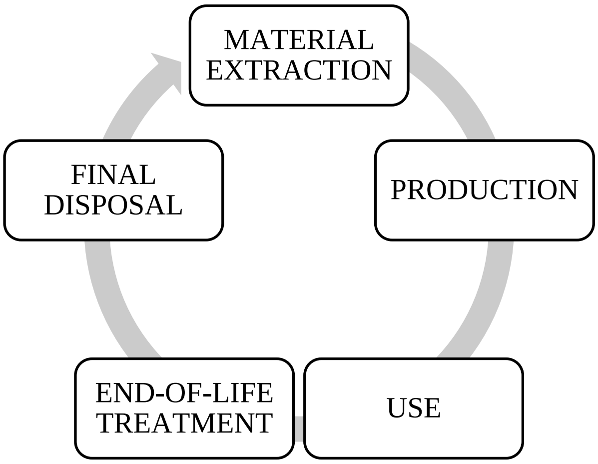


Figure 3 Circular production model; source: author

Despite the fact that there are various definitions of CE in the literature, they share common principles. Firstly, the maximization of the value of the resource is highlighted. This notion is based on the recognition that the natural resources are limited hence the idea not to discard products until their value is entirely utilized is commonly shared by authors (Jun & Xiang 2011; Lieder & Rashid 2016; Rizos et al. 2016). Secondly, consideration of eco-efficiency is stressed in literature. Eco-efficiency can be defined as "an approach of minimization and dematerialization, that is based on the "minimizing the volume, velocity, and toxicity of the material flow system"" (Kalmykova, Sadagopan & Rosado 2018, p. 194). Bearing this in mind, the generation of cyclical flow is considered as favourable and can be usually found in the literature as the cradle-to-cradle flow of material. Lastly, the mechanism enabling value maximization and waste prevention is the implementation of the concept of Reduce, Reuse, Recycle (3Rs), which is another feature shared in the CE definitions. Although these 3Rs belong to the main terms, there are plenty of other relevant terms that are often used as well. These include Repair, Remanufacture, Refuse, Repurpose, Remarketing or Recover (Kalmykova, Sadagopan & Rosado 2018). Altogether these ideas present the strategy on how to shift business activities from the linear system to the circular one, i.e. how to achieve CE. For this study, CE is seen as the circular flow of material and resources which is enabled predominantly by the principles of reducing, reusing and recycling that are implemented throughout the business activities and life cycle of products.

By introducing circularity into businesses, economic development, environmental protection and resource saving could be achieved at the same time (Jun & Xiang 2011). In regard to limited resource supplies, the necessity to change the economic principles has been emphasised in order to comply with the natural environment. In other words, the linear consumption system (cradle-to-grave) should be replaced by a closed-loop system (cradle-to-cradle) by implementing the methods of 3Rs (Lieder & Rashid 2016). CE is a driver of value creation for the global economy and simultaneously limits the risks associated with resource price volatility, resource competition, change in consumer demands and new material technologies. Implementation of circularity into the business, opens up new opportunities for corporate growth, due to the potential to save resources, gain competitive advantage and deliver the macroeconomic benefits (WEF 2014). Chance et al. (2018) also shared the opinion that even with the partial reusing of material back into the process, substantial material and cost savings could be achieved. Every company has unique processes, thus potential to reuse material vary. However, considering agriculture and farming, an example following the circular flow of material could be a compost that is created from the by-products generated in the course of production and eventually the compost can be used within the farm again as a fertilizer.

Cities, together with businesses and the governments “have a unique opportunity to spark a transformation towards a circular economy for food” due to the number of reasons (EMF 2019, p. 24). Amongst others, the existing network of skilled workers is a precondition for the uptake of innovation and cities are considered as hubs for innovation. Moreover, cities are seen as an important element of the food value chain since they can interconnect consumers with the farmers and they can spark the shift towards closed loops and drive a new stream of revenues (EMF 2019). The food system presents a fast-moving sector which is dependent on natural resources and is affected by price volatility and lack of supply. Socio-demographic trends prove that not only businesses have a crucial role in the food system, but cities play an important role, too. It is expected that 80 % of the food will be consumed in cities by 2050 which is associated with an increase in urbanisation (ibid.). Therefore, it is essential to catalyse the change towards circularity. Urban farming could contribute to closing the loops and as a result of that, resources could be used more efficiently (Romeo, Vea & Thomsen 2018; EMF 2019).

2.4 Implementation of Circular Economy

It is expected that the interest in CE will continue to grow in foreseeable future and more companies will strive to implement circularity into their production (Lieder & Rashid 2016). Unfortunately, the literature does not provide a comprehensive guideline on how to implement CE. Therefore the implementation of CE still remains a challenging task intensified by the fact that linear mindset of the industry is prevailing (ibid.). The companies that strive to move towards CE are required to do a fundamental change that runs through the whole organization and moreover, the stakeholders have to be considered and involved (Ritzén & Sandström 2017). Although the customers are increasingly aware of the negative consequences that businesses have on the environment, further development of their awareness is required because customers are seen as an integral part of CE. People´s mindset has to be modified and such change is supported by educational programs, public campaigns and seminars highlighting the performance of the products instead of condition and state-of-art of the products (Lieder & Rashid 2016).

In order to start the transition towards CE, it is necessary to understand the drivers and barriers that companies face in terms of CE implementation (Ritzén & Sandström 2017; Tura et al. 2019). This understanding is important especially to avoid problems arising from integrating sustainability into the businesses activities (Ritzén & Sandström 2017). As drivers are seen the factors that support the implementation, while barriers are the factors hindering such process (Tura et al. 2019). The barriers for moving towards CE are most often interconnected with each other, which further proves the fact that CE is complex hence it requires multi-dimensional transition (Ritzén & Sandström 2017). Tura et al. (2019) presented seven categories of drivers and barriers identified when a business strives to develop or implement CE. These categories are demonstrated in Table 1 and include environmental, economic, social, institutional, technological and informational, supply chain and organizational factors. These drivers and barriers will be further discussed in this chapter.

Table 1 Drivers and barriers for CE implementation by Tura el al. (2019)

Drivers and Barriers	Environmental	Economic	Social	Institutional	Technological and informational	Supply chain	Organizational

Similarly, Ritzén & Sandström (2017) introduced five categories of barriers for shifting towards CE, however, some differences occurred compared to the ones depicted by Tura et al. (2019). The categories are financial, structural, operational, attitudinal and technological and they cover the same aspects as the categories proposed by Tura et al. (2019) even though they call the categories differently. For instance, the operational barrier includes supply chain management which depicts barriers associated with various supply and distribution systems that are unique to every company. Financial barrier is predominantly understood as a lack of tools on how to measure benefits achieved by CE implementation and difficulties with anticipation of financial profitability.

Since all companies operate in a different setting and their operations vary to a great extent, it is believed that individual barriers and drivers for CE implementation are highly context-specific (ibid.). Hence it is essential to analyse the business environment to realise what factors are the most significant and might affect the process of implementation. The framework of barriers and drivers proposed by Tura et al. (2019) is assumed to better serve as a base of knowledge. That is due to its more extensive approach and inclusion of both perspectives, drivers as well as barriers, for CE implementation. Therefore, this framework will be introduced more in-depth.

Environmental factors

The first category identified, involves the environmental factors that are summarised in Table 2. The main driver for the implementation of CE is the recognition of resource scarcity. That is in accordance with the notion that natural resources are limited and should be utilized responsibly. Furthermore, the reduction of negative environmental impacts can be seen as a driving factor. Similarly, Lewandowski (2016) pointed out that reasons to incorporate CE are a significant reduction in the negative impacts on the natural environment. Environmental benefits of CE implementation are emphasised frequently in the literature (Lieder & Rashid 2016; Kalmykova, Sadagopan & Rosado 2018) and can therefore be seen as one of the main drivers for implementation. On the other hand, environmental barriers had not been clearly recognized (Tura et al. 2019).

Table 2 Environmental drivers and barriers

Environmental	Drivers	Resource scarcity
		Reduced environmental impacts
	Barriers	Not recognised

Economic factors

The economic drivers and barriers are presented in Table 3. The economic drivers to shift production from a linear system are mainly opportunities to get new revenue streams and overall potential to improve cost efficiency (ibid.). CE is based on the notion that all material should be used as effectively as possible, hence costs are reduced, and companies can save resources. New value can be generated if the companies aim to reuse the material which would otherwise be discarded. This may be also seen as an opportunity for companies to address new business development that will be in accordance with customers' demands (ibid.). Generation of additional value and increased profitability belong to the main economic drivers (Lewandowski 2016; Lieder & Rashid 2016). Even though CE brings cost saving, initial investment costs are high, especially for smaller companies, and companies perceive economic risk related to the transition to CE, which is regarded as a barrier. Companies may also become doubtful about the circular production model since there is no existing tool or method on how to measure the benefits of closing loops within the production (Tura et al. 2019). In case companies cannot obtain more facts, their motivation is not stimulated, and they rather remain with existing processes. Economic indicators are still dominant and have an important role in determining the economic feasibility of any business (Ritzén & Sandström 2017). As a result of that, when it is not certain how revenue will look like after CE implementation, owners who pay attention to financial results will not be willing to undergo the change. Thus, any change in the system is neglected.

Table 3 Economic drivers and barriers

Economic	Drivers	Cost saving
		Value creation
		Business development
	Barriers	High investment costs
		No existing method to measure the benefits of CE
		The dominance of economic indicators

Social factors

The social factors have a crucial role as well and Table 4 illustrates what social drivers and barriers have an influence on the implementation of CE. As it was mentioned previously, the implementation of CE involves stakeholders, where customers have an important place. Some customers are increasingly aware of sustainability needs and put companies under pressure to act upon the environmental problems. Therefore, external pressure makes companies adjust their procedures. There is an increasing number of projects and campaigns highlighting the importance of sustainable development, therefore companies are provided with guidelines and can make use of available documents supporting the incorporation of sustainability into the business (Tura et al. 2019). Moreover, it is believed that new job opportunities could be created (Kalmykova, Sadagopan & Rosado 2018) along with other societal benefits (EMF 2017). On the other hand, despite the fact that customers are becoming more aware of the negative consequences that companies have on the environment, there are still large numbers of customers who are difficult to convince about the benefits of CE (Tura et al. 2019). Customers may reject products with better environmental value and prefer conventional products, based on for example the price of the product, making it difficult for companies to anticipate customers’ demands. It also depends on the customer´s mindset whether the CE transition will be favoured or not (ibid.). Each region has specific standards which are affected by local culture and also some countries are more advanced in terms of sustainability implementation.

Table 4 Social drivers and barriers

Social	Drivers	External pressures
		Promotion of sustainable development
		Increase in employment
	Barriers	Low customer´s understanding of benefits
		Region-specific standards and local culture

Institutional factors

Laws, regulations and standards have an influence on CE implementation, which may be generally called institutional factors. Institutional drivers and barriers are shown in Table 5. A growing common desire to mitigate environmental burden leads to new regulations aiming at increased business transparency and implementation of more environmental solutions (Lewandowski 2016; EMF 2019). This may be seen as a driver for CE implementation since taxation or subsidies nudge companies to comply with favourable behaviour and further demand that companies create new solutions to current problems (Tura et al. 2019). Nevertheless, companies are uncertain about the consistency of political decisions making it more difficult to trust in the legislation and base investment decisions upon that. Besides, in terms of CE implementation, there are several documents informing various actors about CE, what it is and how it works but since the conditions for implementation are highly context-specific, the support and know-how related to some specific industry are lacking (ibid.).

Table 5 Institutional drivers and barriers

Institutional	Drivers	Growing legal support
		Demand for new solutions
	Barriers	Inconsistency of political decisions
		Lack of knowledge about CE implementation

Technological and informational factors

Table 6 demonstrates technological and informational drivers and barriers that affect the implementation of CE. Due to the advancement of technology, it is easier for companies to collect data from a wide range of sources and improve existing operations and processes. Customers´ behaviour may be analysed easier, as well as the optimization of business processes and management activities. This is also related to enhanced information sharing which is enabled predominantly by the advancement of technology. Wide range of information is accessible and can be easily shared among different sectors (Lewandowski 2016; Tura et al. 2019). On contrary, lack of technical skills may be seen as a barrier, since it may not be possible to use the whole potential of existing technological advancements or it may be costly to introduce new technology into the business (Ritzén & Sandström 2017; Tura et al. 2019).

Table 6 Technological and informational drivers and barriers

Technological and informational	Drivers	Advancement of technology
		Enhanced information sharing
	Barriers	Lack of technical skills

Supply chain factors

Building relationships with actors along the supply chain may result in increased transparency and better information sharing, which can consequently lead to the creation of CE opportunities. That is because in order to introduce CE innovations, various stakeholders have to take part in this transition and mutual collaboration is surely a vital part of it. This may, however, not be easy to carry out, since the linear production model seems to still be dominant in industry and some companies may not be willing to change their production. This and other differing interests in the supply chain hinder opportunities for CE solutions. Companies within the supply chain can have different attitudes and visions, hence finding a consensus may be a great barrier (Ritzén & Sandström 2017; Tura et al. 2019). Table 7 illustrates supply chain factors affecting the implementation of CE.

Table 7 Supply chain drivers and barriers

Supply chain	Drivers	Willingness to collaborate
		Information sharing
	Barriers	Focus on linear production model
		Differing interest in the supply chain

Organizational factors

Organizational motivation to engage with CE is a possibility for fostering a sustainable company brand and can be seen as a driver since it is increasingly important for companies to take responsibility for a broader scope of consequences they have. Customers have the purchasing power and thus affect the company´s decision-making. Companies should react to sustainability demands from the market and be proactive in finding new solutions (ibid.). Lewandowski (2016) stated that team motivation and organizational culture are internal factors affecting the adaptation of circular economy, however, it may be in both ways. It may be seen as a driver if these components are shaped and developed according to the company´s vision or as a barrier if neglected. On the other hand, as the implementation of CE is not straightforward and since every company operates in a unique setting, some risks arise and have to be considered. In case the company is averse to take the risk, implementation of any change is more difficult. This may be caused also by the lack of knowledge and skills related to CE and impossibility to see the long-term benefits. Conflicting opinions within the company can result in making the transition unfeasible due to lack of internal cooperation. CE implementation has to run through the whole company´s operation, therefore, the shared vision is essential. Existing operations and processes that mainly follow a linear production model may be difficult, costly and time-consuming to change. It depends on the company´s setting whether such a change is viable or not (Tura et al. 2019). Table 8 below illustrates organizational drivers and barriers.

Table 8 Organizational drivers and barriers

Organizational	Drivers	Foster a sustainable company brand
		Increased understanding of sustainability
		Organizational culture
	Barriers	Fear of risks
		Lack of CE knowledge and skills
		Lack of internal cooperation
		Existing operations and processes

To some extent, urban food needs could be satisfied with indoor urban farming methods. Barriers and drivers to implement circular economy are highly context-specific, however, it is known that even hydroponic farms face challenges to become fully circular (EMF 2019; Tura et al. 2019). This is specifically because the production uses liquid fertilizers to provide plants with nutrients and high demand for energy. The energy is a crucial source since the effects of the sun have to be replicated considering the lack of sunlight. The energy generally comes from fossil fuels making it challenging to introduce circularity (EMF 2019). It is important to analyse the context of hydroponic farming system to be able to find out how CE could be implemented and discover what are the drivers and barriers in this industry.

2.5 Conceptual Framework

Theories described above (Sustainable Business Development, Circular Economy, Implementation of Circular Economy) have been brought together to build a conceptual framework. The conceptual framework departs from the Sustainable Business Development (SBD), which is seen as a complex concept that increasing number of companies incorporate and embrace (Rainey 2006). Customers realise that companies bear a great deal of responsibility for environmental, social and economic aspects through which they contribute to sustainable development (van Leeuwen, Nijkamp & de Noronha Vaz 2010). As a reaction to market pressures to address the scope of issues, companies look for options on how to incorporate sustainability into their business. The concept of Circular Economy is regarded (Ritzén & Sandström 2017; Tura et al. 2019) as a way to enhance the sustainability of the companies due to the efficient use of resources and materials. However, since the companies operate in a context-specific environment and conditions for circular economy implementation are unique (Tura et al. 2019), it is necessary to analyse factors influencing the uptake of this concept. Drivers and barriers for CE implementation into the setting have to be discovered to successfully embrace the circular economy. As the unit of analysis is Urban Oasis and its production system to which circularity is to be implemented, the conceptual framework will help to analyse this phenomenon. Figure 4 demonstrates the interconnectedness of the theories and mutual reinforcement.

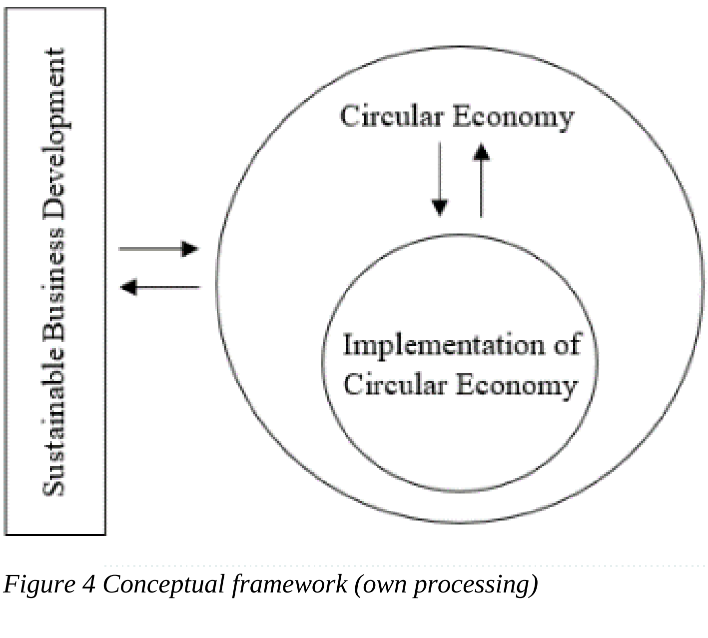


Figure 4 Conceptual framework (own processing)

3 Method

This chapter presents the methodology that was used to realize the aim of the thesis and answer the research questions. Description of the research strategy is deemed to be essential since the results of the study gain trustworthiness and research becomes more transparent. Research approach, data collection, data analysis and ethical considerations are addressed in this chapter.

3.1 Qualitative approach

The qualitative research approach was chosen for this study because it is concerned with explanation and detailed account of the setting that is being scrutinized (Bryman & Bell 2011). This is relevant primarily to understand the context and social setting of the research where values and behaviour must be clarified due to the specific environment. In the qualitative approach, the researcher has an opportunity to interact with the people or setting studied and consequently the comprehensive and deeper understanding can be achieved. Even though some researchers may see this as an advantage of this approach, others criticise qualitative research and maintain the opinion that this approach is too subjective and impressionistic because the researcher is involved to a great extent. However, the involvement of the researcher in the investigation is crucial in order to seek contextual understanding of the natural environment (Golafshani 2003). The qualitative approach is particularly important for this study, where a broad understanding of phenomena is required. Qualitative research may be seen as a less structured approach where there is room for flexibility. Yet, this flexibility leads to the delivery of results which may be notable, compared to researches with definitive concepts. Although this open-ended method may have an influence on the direction of the research, it is not perceived as a limitation but as an advantage due to its potential to arrive at intriguing results. The great number of discussions about the lack of transparency of qualitative research could be overcome when the process of the research is clearly explained. The methodology of the research should be stated and depicted in order to ensure transparency. Thus, also the possibility of replicating the study´s results is enhanced because the process of research could be more easily implemented for other settings (Bryman & Bell 2011).

Qualitative research emphasizes an inductive approach in the relationship between theory and research (ibid.). In terms of the inductive approach, the theory is generated from the research and data collection, hence qualitative research is, in most of the cases, associated with generating theories. On the other hand, quantitative research employs deductive approach where theories are tested through the research which is not of interest of this study (ibid.). The aim of this study is to analyse the challenges that the hydroponic farm faces and explore the drivers and barriers for circular economy implementation within the farm´s production process. Therefore, qualitative research with the inductive approach assists to carry out the research with the theory as a result (ibid.).

Epistemology is the theory of knowledge and determines the sources and limits of knowledge and its justification. The choice of epistemological consideration affects what can be confirmed as acceptable knowledge (Carter & Little 2007). This study views social and natural sciences as diverse concepts where each of them has different requirements for knowledge generation (Bryman & Bell 2011). Interpretivism is the epistemological position that distinguishes the differences between people and the objects of the natural sciences, so it does not apply the same principles for natural and social sciences. Interpretivism is mainly associated with qualitative research, where the close interaction with the respondent is enabled, and the researcher has the opportunity to get insights into social action. The epistemological position of this study is interpretivism because the close interaction is essential in order to form the theory. Knowledge, to form the theory, is developed through the gathering the information. To answer research questions and be able to meet the objective of the study, epistemology and methodology have to be internally consistent (Carter & Little 2007).

Ontology is concerned with the existence of the social phenomena and dependency of social actors on it (Bryman & Bell 2011). Constructivism is an ontological position where the phenomenon is in constant change due to the social interactions with social actors who are therefore seen as an internal part of reality. The social actors influence the reality by interactions and communication which results in constantly changing social order (ibid.). For this thesis, it is assumed that knowledge is constructed by active interaction with the observed setting.

3.2 Data collection

Data collected for this study includes both primary and secondary data. While secondary data represent high-quality data that have been collected by other researchers, primary data is collected to meet the specific aim of the study (Davidsson 1997).

3.2.1 Primary data

Ethnography is a qualitative research design that studies interactions and behaviours occurring within groups, organisations, or communities. Investigation in ethnographic research may focus only on one case that is analysed in detail (Reeves, Kuper & Hodges 2008). Hence, the foremost advantage that ethnographic research provides is a holistic description and interpretation of the culture-sharing group which allows to get a much broader picture of the situation (Creswell 2013). The case analysed here was chosen with the help of purposive sampling, which is a non-probability sampling approach (Etikan 2016). It is useful when the researcher has a specific goal in mind, therefore, the chosen sample is deemed to be relevant to understand the phenomenon. Even though purposive sampling does not allow generalization, due to a limited number of existing cases, purposive sampling has the ability to contribute to the study (Bryman & Bell 2011). Ethnography is typically based on the researcher´s involvement in the setting being studied and common technique used is participant observation (ibid.). To collect data for this study, the researcher was introduced to everyday activities which allowed to get valuable direct insights from the field. Over the extended period of time, the researcher engaged in the organization. Thus, the researcher used conversational interviews as a source of data along with other formal research methods, for example, semi-structured interviews. Being present at the farm significantly helped to perceive the setting naturally and objectively. Moreover, the ethnographers usually pay attention to specific features within the organization which altogether with the immersion of researcher into the setting enables gaining essential information that is normally not available for the public and could be rather considered as hidden (Reeves, Kuper & Hodges 2008). The use of material and resources within the production of the farm was observed, altogether with production processes. Thus, valuable information about the hydroponic farming could be gathered and analysed. The result that is achieved through this method is a rich understanding of the case and therefore this approach is believed to be best suited to fulfil the aim of this study.

The possible problems that may arise in relation to ethnography are researcher´s detachment rather than involvement (ibid.), gaining the access to the setting in focus and the choice of the role that the researcher should adopt when observing the setting (Bryman & Bell 2011). This study applies a covert role, where the participants are aware of the researcher and researcher´s role, because the access to the vertical farm is essential to evaluate the production processes. Thus, the problem of access, identified by Bryman & Bell (2011), does not present the obstacle. Nevertheless, the covert role is believed to possibly hinder the researcher´s involvement as the participants may feel insecure because their privacy may be potentially violated (Reeves, Kuper & Hodges 2008; Bryman & Bell 2011). Since the unit of analysis is a vertical farm and its production system, the attention is paid to the processes and employees are not the main focus of this research, however, they present a vital part of the processes and have to be taken into consideration. Notably, it is assumed that the processes of production cannot be modified with the purpose to present it differently to an outsider, therefore the collected data are deemed to reflect reality.

Action research is an inquiry done in collaboration with the insiders of an organization and it is oriented towards addressing some problematic situation through the action (Herr & Anderson 2005). As Herr & Anderson (2005) stated, the particular problem of interest can be efficiently tackled in collaboration with someone who has a stake in the problem and hence provides the outsider with necessary resources and skills. As a result, action research involves both research and action. While the former generates knowledge from the practice, the latter promotes the improvements in the practice (ibid.). The mode of participation, applied to achieve the aim of this thesis, could be defined as the cooperation of insiders with an outsider (researcher) (ibid.). By applying this mode, the best possible outcomes are likely to be achieved and the researcher has an opportunity to take an insider´s perspective. Due to the close cooperation with insiders, it is necessary to address how potential bias is dealt with. In order to avoid bias, critical self-reflexivity is an essential skill that the researcher possesses. Overall validity and credibility of the research can be also enhanced with triangulation of methods which combines different methods or data sources to overcome weakness associated with the single method used (Bryman & Bell 2011; Herr & Anderson 2005).

The author of this study gathered data through observations of processes within the production of the vertical farm system with the aim to obtain information on where is the possibility of improving the process by implementation of the circular economy. Active participation and cooperation with insiders are assumed to be the techniques which lead actors towards the achievement of desirable outcomes. Observations took place in Stockholm, Sweden, where the vertical hydroponic farm is located, meaning that the observation of natural setting was facilitated. Ethnographic action research entails an extended period of observation and for this study, observations were carried out as many times until the data was assumed to be reasonably saturated. Observations were always accompanied by semi-structured interviews in order to get the most accurate data. Table 9 shows the scheme of observations and interviews done to collect data. In January and February 2019, two meetings with the CEO of Urban Oasis had been scheduled in order to assure that both sides knew the purpose of the research and its process. Even though these meetings were not solely focused on data collection, which the latter ones were, they were essential to gain background information, get to know the production processes and be introduced to the production of hydroponic farming. During the observations, some follow-up questions were asked, which could be also described as unstructured interviews and it is seen as an extension of observation because it occurs during the observation fieldwork (Zhang, Y. & Wildemuth 2009). An unstructured interview is a flexible approach used to explore the particular context, questions are generated in the course of the interview and the interaction between interviewer and interviewee is extensive (Bryman & Bell 2011). On the other hand, for the semi-structured interviews, lists of questions were prepared in advance (see

Appendix I and II). Thus, there was a possibility of focusing on the requisite outcome from the interview because the structure was known and it was possible to get into the detail of the specific case (ibid.). On contrary, during unstructured interviews, the outcome of the interview is usually highly dependent on the ability of the interviewer to ask relevant questions and moreover, the interviewer is expected to have extensive knowledge about the context to enable smooth flow of the interview. Since unstructured interviews were used during the observations, in-depth understanding of the phenomenon was enabled (Zhang, Y. & Wildemuth 2009). Even though interviews were recorded, note-taking during the interviews was deemed to be essential. Recorded interviews were transcribed with the aim not to omit any vital thoughts and insights.

Table 9 Interviews and observations scheme

Date	Method	Duration	Form	Respondent
30th Jan 2019	Interview + Observation	50 min	Face-to-face	Albert Payaro, CEO
20th Feb 2019	Interview	30 min	Face-to-face	Albert Payaro, CEO
28th Mar 2019	Interview	25 min	Face-to-face	Albert Payaro, CEO
28th Mar 2019	Observation	35 min	At the farm	
24th Apr 2019	Interview	30 min	Face-to-face	Albert Payaro, CEO
24th Apr 2019	Observation	30 min	At the farm	

This combination of observations with unstructured and semi-structured interviews was perceived as the most suitable to realise the aim of this thesis. Access to the setting (farm) could be in some cases perceived as a constraint (Bryman & Bell 2011), however, data collection for this study was enabled according to the author´s needs, so that the number of visits at the farm reflects the need to collect the sufficient data.

3.2.2 Secondary data

Secondary data is a source of information from existing literature that serves as a base of knowledge about what is already known about the topic (ibid.). With the help of review of literature, it was possible to find concepts and theories which were relevant to the area of the study and thus helped to choose suitable research approach and method to realise the aim. Even though the literature may be extensive on some topics, there may still be some unanswered questions which are vital to address (ibid.). Compared to primary data, the advantage of secondary data is that it requires less time and cost to obtain data thus they can be easily used as a supplement to the own collected data (Davidsson 1997). Primarily, they help to form general understanding, background and support an argument and by using various sources of secondary data, the analysis and understanding can be extensive (ibid.). Secondary sources used to answer the research questions of this study were peer-reviewed articles, reports and other documents. According to Bryman & Bell (2011), the strength of the qualitative study is positively affected when several sources of data are implemented.

3.3 Data analysis

In the course of qualitative research, a large amount of data is most probably to be involved. The researcher has to carefully choose what data is relevant and manage the analysis of data accordingly (ibid.). Field notes and interview records gathered during the observations and presence at the farm were analysed altogether with other documents. Qualitative content analysis was employed to examine patterns and meanings (Zhang, Yan & Wildemuth 2009). Qualitative content analysis was defined by Zhang & Wildemuth (2009, p. 1) as "a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns". From this definition, it is clear that the researcher´s involvement was extensive and allowed subjective understanding of social reality. Within the qualitative content analysis, the focus was on unique patterns of the phenomenon and by using inductive reasoning the patterns emerged after the researcher´s examination and constant comparison (ibid.). In this study, the whole process of analysis started already during the early stage of data collection since it helped to navigate the following data collection, thus research questions could be addressed successfully (ibid.). The first step done to analyse data was the analysis of interview transcripts and other forms of written text. Naturally, the more complete transcript, the more valuable information can be obtained. Therefore, the interview should be examined as a whole and not only as a summary and additionally other perceptions got during the observations should be noted and analysed (ibid.). Since qualitative research is considered as interpretive, the description of the background and context was essential, and this was subsequently complemented with the interpretation of understanding of the phenomenon. However, it is challenging to present research findings and the success of the research depends on the researcher´s ability to uncover the patterns and meanings (ibid.). For this study, it was deemed important to carefully prepare for data collection to ensure trustworthy analysis, which would support the development of a theory. Altogether with existing theories, provision of a broad description of the setting was enabled.

3.4 Quality assurance

To assess the quality of this qualitative research, the four criteria of trustworthiness are further specified. Criteria of credibility, transferability, dependability and confirmability help to evaluate the overall quality of the research.

Credibility

The study can be regarded as credible if the research is carried out according to the principles of good practice and findings are confirmed by the actors engaged in the research. In other words, research ought to "demonstrate that a true picture of the phenomenon under scrutiny is being presented" (Shenton 2004, p. 63). The research´s findings have to be believable and appropriate and the understanding between researcher and research participants have to be achieved. Credibility can be established and enhanced through respondent validation, where the research participants are provided with an account of the findings that had been arrived at (Bryman & Bell 2011). To seek confirmation of the researcher´s findings, the draft of the study was sent to the interviewee to assure that it was congruent with the reality (Shenton 2004; Bryman & Bell 2011). Another method to increase the credibility of the study is a technique of triangulation. Triangulation involves using more than one method to collect data (Golafshani 2003). This study entailed observations, interviews and secondary sources as a source of data. Ethnographers usually use interview questions to avoid possible misunderstanding that may have arisen during the observations (Bryman & Bell 2011) and this approach was adopted also within this study. Thus, it is believed that the phenomenon was reflected according to the reality and a complex picture of the setting was achieved. When more than one source of data are employed, the greater confidence in findings is safeguarded (ibid.).

Transferability

Transferability proposes the idea of application of the study to other situations and contexts (Zhang, Yan & Wildemuth 2009). Generally, the findings of a qualitative study are unique for a particular setting and cannot be applied beyond the specific environment. Although the purpose of qualitative studies is not to generalise the findings to the population, providing a thick description of the setting is convenient to form a basis for the creating the context knowledge (Bryman & Bell 2011). The thick description enables possible transferability to other environments since the proper understanding of the specific case is the priority. The results of the study could thus be transferred to or compared to other situations (Shenton 2004). The description of the Urban Oasis´ production in this thesis is considered to be detailed and comprehensive.

Dependability

Dependability parallels with the concept of reliability in quantitative research and entails with the consistency of the research process (Golafshani 2003). Dependability can be verified in the course of research by other actors or peers who assess the procedure of the study and completeness of the records (Bryman & Bell 2011). In accordance with this, the draft manuscript was discussed with peers and supervisor to increase the trustworthiness of the study.

Confirmability

The last criterion of trustworthiness is confirmability that is concerned with ensuring the objective findings that are not affected by the researcher´s personal values but are the results of the natural setting and experience of the interviewee. Ensuring the complete objectivity is not possible, however, it must be shown that the researcher acted in good faith (ibid.). Researcher´s predispositions cannot affect the course of the research and its results. Some extent of the researcher´s bias is believed to be inevitable because the interviews and observations are conducted by human but the concept of triangulation helps to reduce the researcher´s bias (Shenton 2004).

3.5 Limitations of chosen methods

One of the primary limitations of qualitative research is the close interaction between the researcher and research participants that may be a basis for some criticism (Bryman & Bell 2011). Since the ethnography is based on observations and involvement of the researcher in the setting, which are believed to provide the rich understanding of the environment, possible detachment of the researcher may occur (Reeves, Kuper & Hodges 2008). In that case, the researcher is not provided with complete and requisite information and the findings may be skewed. It is, however, assumed that the production processes and the use of resources cannot be modified during the presence of the researcher at the farm. Moreover, the researcher´s personal opinions can affect the empirical findings because it is very difficult to completely eliminate the researcher´s bias in qualitative research (Bryman & Bell 2011).

Qualitative research has been criticised for the lack of transparency (ibid.). This limitation could be overcome by providing the thick description of the setting. The methodology of the research should be stated and depicted in order to ensure transparency. Thus, also the possibility of replicating the study´s results is enhanced because the process of research could be more easily implemented for other settings (ibid.).

Semi-structured interviews were conducted with only one person (the CEO of Urban Oasis), therefore the perspective on the phenomenon might be affected to some extent by this limitation. Nevertheless, there was no other relevant person at Urban Oasis that could be interviewed due to the low number of employees. Since this thesis aims to provide a detailed description of one hydroponic farm and its production processes, it is assumed that interviewing other companies would not contribute to this research.

Interviews were held in English, which is not a native language of neither interviewer nor interviewee, thus slight misunderstanding might have occurred, however, both sides had a great opportunity to ask for clarification not only during the interviews or observations but also after the fieldwork had finished.

This study wishes to investigate the hydroponic production and provide the reader with a complex understanding of this production system. To achieve this, it is assumed that the chosen methods serve the best for this context despite the existence of some limitations.

3.6 Ethical considerations

Ethical aspects of any business research present a vital part that has to be considered because harm to participants, invasion of privacy and lack of informed consent are regarded as unacceptable (ibid.). Urban Oasis and individuals within it have been informed about confidentiality, anonymity and the purpose of observations and interviews. Possibility of anonymity was provided, however, it was agreed on using the company´s name in this study and its possible consequences were known. The purpose of this research was explained in advance during the meeting so that there was a sufficient amount of time to decide whether mutual cooperation is viable or not. Especially in terms of ethnographic research where interaction with the organization is extensive, it was difficult to give participants all information about research´s implications (ibid.), but as the organization employed only a small number of people, it was assumed that all participants had sufficient information about the research process. Due to the qualitative nature of research where the attention is to language and detail, recording of semi-structured interviews was essential since the researcher would otherwise be distracted by taking notes during interviews. Moreover, some answers might be possibly omitted. A more thorough examination was enabled since the limitation of one´s memory was overcome and the researcher could repeatedly hear the answers provided (ibid.). Due to these facts, interviews were recorded, while the interviewee agreed to be audio-recorded. The interviewee was provided with a broad overview of the purpose of the interviews and the research as a whole and was willing to provide data and information. The interviewee did not require to remain in anonymity and the interview guide was sent to him in advance to ensure that the areas of interest are known.

4 Empirical data

This chapter presents the empirical background and empirical results obtained from the interviews and observations, therefore this chapter provides essential information before the empirical findings are addressed.

4.1 Introduction of Urban Oasis

Urban Oasis (UO) is an urban vertical farm that grows primarily leafy greens by using the hydroponic growing system. The hydroponic system is a form of farming where plants grow in the absence of soil, and the roots of the plants lie in water with dissolved nutrients instead (Despommier 2013). The CEO of UO, Albert Payaro, considers UO as a food-tech start-up which aims to create a decentralized network of farms in Sweden and accelerate the transition towards sustainable food production. A start-up can be defined as an innovative business that is growing quickly and usually is highly dependent on outside financing. Moreover, start-up businesses are seen as high-risk businesses due to an unstable setting where the success is not obvious (Oranburg 2016). The farm is situated in a part of the unused parking garage located in Stockholm, Sweden, thus the proximity to the point of sale is very short. UO started off its production in September 2017 and since then, it had to tackle several issues associated with growing fresh produce in the city in an efficient and profitable way. The structure of UO is very simple since the CEO is responsible for all operations and sales at UO. Even though UO used to have more employees, due to the change of structure, the CEO and the Lead Grower are the ones who take care of the business and production. Payaro believes that this simple structure is beneficial to allow future expansion and growth. At the moment, the maximum volume of produce can reach 50 kilograms of leafy greens per week. Even though two other companies (Grönska and Plantagon) focusing as well on hydroponic production had existed in the market at that time when UO entered the market, the CEO has never seen this situation as an obstacle. He believes that the transition towards sustainable food production cannot be achieved by only one player, but more actors have to participate to achieve desirable results.

The main idea of running the business is to provide people with affordable, sustainable, local and fresh vegetable all-year long. This notion is propelled specially by the fact that in Sweden the import of vegetable is extensive (Cederberg et al. 2019). Therefore, UO strives to partly contribute to enhance the supply of vegetable. Due to the farm´s location, the need for transporting vegetable is reduced and consequently, the exhausted emissions during transportation are greatly reduced. Besides the CEO of UO believes that the vegetable grown indoors can offer a better taste to consumers than vegetable that is transported from far away. Good taste and quality of the product are the main factors that are regarded as the goal of the company. The vegetable grown at the farm is sold to the local supermarkets, restaurants, hotels or cafés located in Stockholm. Production and distribution take place only in Stockholm, hence the supply chain is shorter resulting in better response to market demands. In the foreseeable future, the UO plans to expand its production and increase the volume of harvested greens. In order to ensure that the production is managed sustainably and possible problems within the production are addressed at an early stage, it is crucial to have a closer look at the product life cycle and deduce some improvements.

Production process

Compared to conventional agriculture, the production of UO has a short supply chain, leaving more room for flexibility and efficiency. By analysing the production process, it is evident which phases of production occur and thus explore possible improvements for each phase. Moreover, it is easier to explore improvements in the production processes when the production cycle is clear. That is viewed as a precondition to realise the aim of this study and to see drivers and barriers for CE implementation. The variety of crops grown in UO has expanded since the start, however, mostly 5 types of greens and vegetable are grown, these are rucola, kale, salad, spinach and pak choi. Soon, herbs will be grown as well due to the planned expansion of the farm and high popularity of herbs by customers. The process of production is more or less unified for all crops which is seen as an advantage because the conditions for growing do not require any changes based on the particular crop currently grown. Although several inputs are required to construct the farm and the facility, those are considered as a one-time investment that does not change over time. The main inputs used in the production are seeds, nutrition, rockwool plugs, packaging, electricity and water, and these are the inputs that change in number according to the production and are variable. In Picture 1, the plugs made of rockwool used as a replacement for soil are illustrated.

Picture 1 Rockwool plugs; source: author

The seed is planted into the plug and subsequently grows in it throughout the whole growing process. These plugs are going to be replaced in the future, since UO makes an effort to use more sustainable option, therefore tests other possible ways. One option is to use biodegradable plugs, which are however costly. Another option is to reuse the roots that grew during the life cycle of the plants. The latter option will be described later in this chapter. The life cycle of greens and herbs grown at UO can be divided into 5 phases – material supply, germination, propagation, maturation, harvest and distribution – which are further described below, and the cycle is shown in Figure 5.

Material supply

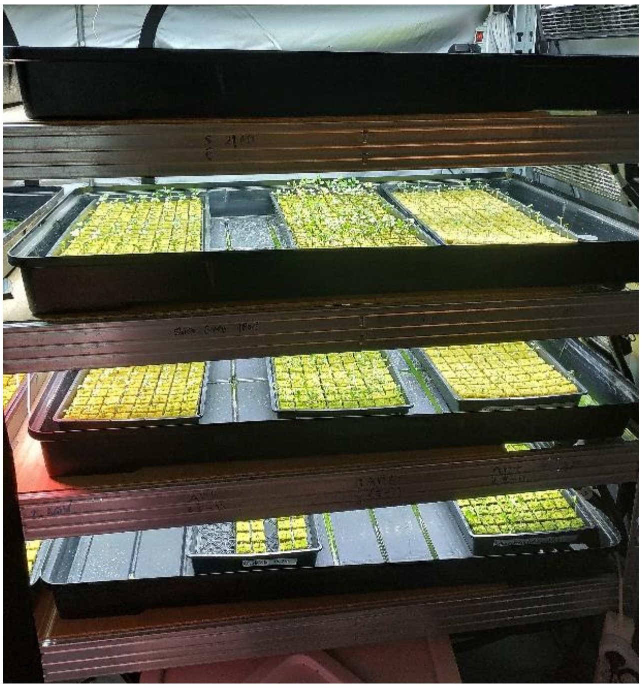
Materials are sourced from suppliers either from Sweden or other countries. For example, the plugs and nutrients are supplied from a Swedish company, however, in terms of these materials, the CEO strives to find a better solution that would be more sustainable. The seeds come from either Sweden or the United Kingdom and packaging, used for distribution of harvested vegetable, is supplied from a Swedish company. Packaging used to be supplied from China, which was seen as one of the main problems associated with sourcing the materials, hence this change of packaging is regarded as a good step. The supplier was changed as a reaction to the customers´ demands because they complained about the hard plastic package which was perceived as inconvenient. In terms of material sourcing, there could be some improvements done, however, considering the limited financial resources and time constraint, materials currently do not come solely from local or regional areas.

Germination

Once the inputs are present at the farm, the whole process of growing starts with seeding the seeds into the plugs, which is done manually with the help of other tools that ensure better efficiency and precision. The plates, where the plugs with the seeds in it are put, are placed into the large boxes where humidity is higher, and conditions are suitable to start the germination process of the seeds. This phase of the production is therefore called germination and that is basically a phase where the seed is still under the "soil". At this phase, seeds do not require nutrients, light or water. They need darkness and humidity, which is the reason why the plates are kept in the boxes with the moist environment. The germination process takes approximately 2 to 4 days.

Propagation

The next phase, where the plugs with seeds go to, is propagation. Propagation is the phase where plants receive some amount of light and water with nutrients, however, amount of nutrients is lower compared to following (maturation) phase and this phase is especially convenient for plants to get used to the new environment. At this phase, plants begin to grow above the "soil". There is also an option that this phase is omitted, however, UO uses this phase due to better effectiveness of production and space-saving reasons. Picture 2 shows how the propagation phase at UO looks like. Plants are left in the propagation phase for about 2 weeks.



Picture 2 Propagation phase; source: author

Maturation

The main phase is called maturation, where the plants are placed into the floating desks allowing the plants to lay their roots into the nutritious solution and thus absorb nutrients. Water is constantly rotating within the system. To ensure increased water efficiency, two dehumidifiers are used. These help to collect water that plants transpire, water is collected into a tank and subsequently reused in the maturation phase again. Thus, a large amount of water is saved. In soilless farming, nutrient management is important because a slight change can have consequences on plant growth and the quality (Tsukagoshi & Shinohara 2016). This is confirmed by the CEO, too. He is aware of the importance to monitor the conditions since there are many factors affecting the size and appearance of the plant. In comparison with the propagation phase, individual plants in the plugs are placed further from each other allowing them to grow in size appropriately. This is apparent from Picture 3 below. Maturation phase is about 3 to 4 weeks long depending on the need to harvest.

Picture 3 Maturation phase; source: author

Harvest and distribution

When the plants are ready for harvest, the whole plants are removed from the floating desks, which are cleaned and used in the system again. The harvested plants are placed into the package and distributed to the customers. The rockwool plugs are thrown away because they are not suitable to reuse. Roots of the plants are collected with the aim to use them instead of rockwool plugs. This still needs to be examined more to see the feasibility of using the roots. Possibly the roots could be used as a source of nutrients for another cycle of production within the maturation phase. The whole growing cycle takes about 6 weeks and once the plants are harvested, they are transported to the customers within just a few hours after the harvest time, thus the freshness is ensured. Transport from the farm to the customers is done by an electric car and only within the area of Stockholm. Distribution to the customers is done in two ways. While restaurants, hotels or cafés are supplied directly by UO in the area of Stockholm, supermarkets are supplied through an intermediator that is located in Tumba (Stockholm county). That is because the direct collaboration with supermarkets is difficult and it is time-efficient to use a subject that already has an established network in the market.

Implementation of sustainable solution into the business activities is crucial for the CEO of UO who is aware of some challenges of hydroponic farming. The challenges are further discussed in the next section of this chapter. Although it is challenging to find suitable ways on how to reuse, reduce and recycle materials and resources, new ways are still discussed and proposed as a new approach. Hence, some of the materials are already creating closed loops, however, other ways are essential to explore, too. Figure 5 illustrates the production model where the life cycle of the plants presents the base.

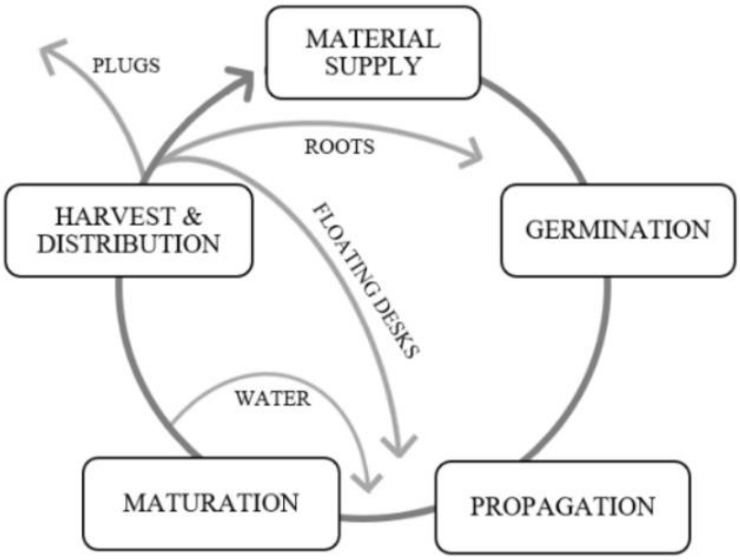


Figure 5 Production life cycle of Urban Oasis (own illustration)

4.2 Challenges of hydroponic farming

According to the CEO of UO, there are some problems within the production that should be addressed. The primary focus is on water efficiency, materials efficiency and sustainability of nutrients.

In terms of water used within the production, especially the maturation phase, the emphasis is on reusing the water in the system. Although the UO grows the crops that do not require much water compared to crops like rice or cotton, the efficient use of water is one of the priorities. The efficiency of water is ensured by using two dehumidifiers. Thus, water can be saved and reused. Dehumidifiers help to collect water that would be otherwise lost because of transpiration of the plants. By using dehumidifiers, water efficiency is significantly improved, making the production of UO less dependent on water.

The fact that the material and resource efficiency is one of the priorities can be perceived throughout all phases of the life cycle of the plants. Although this requires a significant amount of time to arrive at new solutions that would increase sustainability and had lower environmental impacts, it is seen as a crucial part of the business since the whole company is built on sustainability values. Therefore, there is a constant emphasis on scrutinizing every process involved in the business process and making it better.

There may be some level of scepticism amongst customers purchasing vegetable that grew indoors. However, it is believed that when customers understand the benefits, see the quality and good taste and overall freshness of the vegetable, the scepticism is overcome and willingness to purchase such product increases. It always depends on the knowledge the consumers have about hydroponic farming. There is no explanation of the growing method provided on the package, therefore some may not be aware of the meaning of the term “grown indoors” that is stated on the package. However, the main aim for UO is that consumers buy greens and vegetable because of the good taste and quality rather than the way it was grown.

4.3 Implementation of Circular Economy

The primary motivation for CE implementation is the economic benefits. Introducing circularity in the production could save a considerable amount of money and resources. By creating close loops, UO could achieve a higher profit. Some of the resources could be reused within the phases of production and thus allow enhanced use of material and resource, which is in accordance with the concept of CE. To illustrate, the roots could be used as a replacement for rockwool plugs. It is seen as a vital part of doing the business, to think about the consequences the production has. As a result of thinking about the impacts, new improved ways of production or processes are possible to explore and reveal. The main advantage of scrutinizing this is that these improvements are supposed to save money and resources, which can be obvious almost immediately after implementation. Economic benefits are therefore obvious and can be seen as a primary driver for CE implementation for UO.

However, since this start-up is based on sustainability values, the environmental factor is also a significant motivation that propels the process of looking for new ways how to make business activities less dependent on resources and with less environmental impacts. It is important that sustainable business development is considered and lies at the core of every phase of production. It is assumed that future development should be focused on sustainable practices and sustainable development presents a crucial part that business implements.

Social benefits are as well highlighted. The production of vegetable in urban areas enables that local people have an access to freshly produced vegetable, which is rich in nutrients, and taste of such vegetable is believed to be also superior compared to the one that had to travel from far away (Egan 2016; Pinstrup-Andersen 2018). UO highlights the taste of the vegetable and believes that the main reason why consumers buy their leafy greens, is the taste profile rather than the way it was produced. Nevertheless, there is an assumption that Swedish consumers are more tech-interested and more willing to accept new things hence, knowing how hydroponic farms work and vegetable is produced may be even perceived as an advantage.

The shift towards CE involves a change that runs through the company with the effect on several stakeholders who can benefit from such a change, too. UO perceives benefits from CE implementation for the company itself, planet, and ecosystem, resulting in the shared benefit for multiple stakeholders. On the other hand, in order to implement CE, several things both within and outside the company have to change. New ways have to be found out, but such a process requires a lot of time to discover new ways of reusing, reducing or recycling materials. Therefore, time constraint plays an important role in determining the implementation. Especially, considering the fact that UO started its production only less than two years ago, the main focus is on having the production under control or in other words, knowing that the business is economically viable. After some level of stability is achieved, there is some room to look for some improvements to existing processes. Another aspect is that people have only limited knowledge about hydroponic farming, and it may take time to make people buy products coming from this farming system. People may be averse to change and not willing to change their purchasing habits.

5 Analysis and discussion

This chapter analyses the empirical data in relation to the conceptual framework with the emphasis on presenting the results of the analysis. Thus, the aim of this thesis is addressed, and the research questions answered. Understanding of the results is discussed, as well as the contribution to the field.

This chapter aims to provide analysis and discussion which help to answer the research questions. Presented theories of Sustainable Business Development, Circular Economy and Implementation of Circular Economy lie at the core of the analysis and in conjunction with the conceptual framework help to grasp the collected data at the hydroponic farm.

The research questions were formulated in chapter 1.3 as follows:

- What challenges arise within the hydroponic farming production?
- What are the drivers and barriers for circular economy implementation for the hydroponic farm?
- How may the principles of the circular economy be applied within the hydroponic farming production?

5.1 The challenges within the hydroponic farming production

The first research question formulated to arrive at the aim of this study was "What challenges arise within the hydroponic farming production?". As it was stated in chapter two, several challenges that can be found when the production of vegetable has shifted indoors have been acknowledged in the literature. Among the primary challenges identified, belong the high energy requirement, finding suitable space in urban areas, a limited range of crops grown or the assumption of targeting at the elite market. These challenges can be found in the literature, however, the conditions of every market vary, hence it is assumed that the conditions in the Swedish market are unique therefore worth analysing. From interviews and observations at the UO hydroponic farm, it is apparent that these challenges are perceived in a different way and other challenges present an issue that is necessary to address.

In terms of energy used for the production, UO does not see this as the main problem. That is because in Sweden, energy is sourced mainly from renewable sources and the Swedish energy policies go beyond the law-making of the EU and are more far-reaching (Swedish Energy Agency 2018). The Swedish Government has adopted an ambitious goal where the target is sourcing 100 per cent of energy from renewable sources by 2040 (Regeringskansliet 2017). "Currently 58 per cent of Swedish electricity generation originates from renewable energy sources such as hydropower, wind power, biofuels and solar power." (Swedish Energy Agency 2018, p. 7). Over the recent years, there has been a significant increase in wind power as a source for generating electricity (Swedish Energy Agency 2018) and solar power is gradually playing an important role in the future of Swedish sustainable energy system (Regeringskansliet 2017). In order to achieve energy policy objectives, the Government prioritises energy and climate adaptation and therefore invests in energy infrastructure and supports the establishment of renewable sources of energy (ibid.). The benefits of sourcing energy for hydroponic production from renewable sources are undisputable. In accordance with Romeo et al. (2018), Al-Chalabi (2015) and Pinstrup-Andersen (2018) who highlighted the importance of using renewable energy sources, the Swedish hydroponic farm has a potential to have a better environmental performance because of the fact that Swedish energy originates from other sources than fossil fuels. Therefore, the CEO of UO does not consider energy dependency as one of the main challenges. However, he is aware of high energy consumption and presumes that the efficiency of LEDs will increase. This is a contrasting notion considering the review of the literature done. This proves the fact that every setting has diverse conditions and circumstances according to which the business viability is affected.

Another challenge recognised was the land occupation and difficulties with finding a suitable space for indoor farming because there is already a competition for urban land areas (Ehrenberg 2008; Mok et al. 2014). The production of UO is located in a part of a parking garage in Stockholm. Currently, the production does not occupy any parking spaces but only uses the facility of the garage. For the planned expansion, production would utilize the parking spaces that are empty therefore the production would not block any parking spaces that are intented to be occupied. In Sweden, there is a regulation according to which a certain amount of parking spaces has to be provided when a house is built. However, this does not necessarily mean that there is an interest from people in buying a parking space. Eventually, the parking cannot serve its purpose and part of it is left empty. The farm production is seen as an appropriate solution for using the urban land area to the full potential. Moreover, this hydroponic farm is situated in either five or three vertically stacked layers, hence the space efficiency is considerably improved, compared to conventional production situated in one layer only. As a result of indoor crop cultivation and the space efficiency, there is more available land that could be replanted to make the landscape more diverse. Thus, carbon emissions could be sequestered from the atmosphere while biodiversity was slowly improving (IPCC 2015). In this way, vertical hydroponic farms save space that could deliver benefits for society.

Hydroponic farming production is not suitable for all kinds of crops. Some crops require conditions that would be too costly to shift indoors. However, leafy greens and herbs are regarded as the suitable products, whose conditions for indoor production can be easily adjusted and monitored according to the needs, to supply the urban community with nutrients. Considering the fact that hydroponic farming is still just an emerging field that needs more attention, it cannot be assumed that the variety of crops will be very broad. Firstly, it has to be found out whether such production system has a potential and is economically feasible and then the variety of crops could expand. UO grows mainly five types of leafy greens but the expansion of the crops is planned.

In the literature has been an assumption that the production of hydroponic farms is being targeted at the elite market due to the price premium that raises the price of the final product (Cox 2016). Although UO strives to provide consumers with affordable products in long-term, targeting at the mass market is not seen as a manageable target at present. At this moment, the price of the products is higher compared to similar products. That is believed to level off more, once the production is more stable and viable. Nevertheless, the CEO of UO believes that the quality of their products is outstanding, and the taste is better, therefore the higher price is justifiable. This is, however, only a subjective notion that is not backed up by research, but by consumer´s perceptions and views.

On the other hand, the use of water has not been recognised as the challenge in the literature, rather as a benefit of hydroponic farming. But UO attempts to further enhance water recirculation and thus save an additional amount of water. With the use of dehumidifiers, water is collected from transpiring plants and can be consequently used again within the system. Moisture that has been carried from the roots to the leaves is released to the air and without dehumidifiers, some amount of water would be lost due to the process of transpiration. This loss of water is prevented through the recollection of water vapours. As a result of this, a closed water loop is achieved. This challenge has already been tackled at UO´s production since increased water efficiency is perceived as a vital thing to be implemented.

UO also sees the use of nutrition as something that needs to be improved. Currently, nutrition is bought from the supplier in the form of a liquid that is subsequently put into water. In this way, plants receive an essential amount of nutrients to grow. This is believed to be done in a more sustainable way, for example by using by-product or rest product of another company that would be used as nutrition. This approach is described and presented more later in this chapter. Even though this idea was not pointed out in the literature, sourcing nutrition from more sustainable and natural sources is regarded as one of the challenges that should be addressed and solved in the hydroponic farming system.

The main challenges identified by the CEO of UO are the use of water and nutrition. That is because these call for further investigation in order to find better ways for implementation of the 3Rs principle. The use of water and nutrition have not been mentioned in the literature as challenges, however, should be taken into consideration. These challenges belong to the everyday business activities that could be enhanced to a greater extent in order to ensure sustainable development of the business.

5.2 The drivers and barriers for circular economy implementation for the hydroponic farm

The second research question of this study was "What are the drivers and barriers for circular economy implementation for the hydroponic farm?". The concept of CE is defined as the circular flow of materials and resources which is enabled predominantly by the principle of reducing, reusing and recycling that is implemented throughout the business activities and life cycle of products. By implementing CE into the business, simultaneously a variety of benefits is delivered. For instance, resource saving, environmental protection, economic development, the potential for corporate growth or new employment opportunities can be achieved when the linear production model is transformed into circular production model (Jun & Xiang 2011; WEF 2014; Kalmykova, Sadagopan & Rosado 2018; Tura et al. 2019). There is an increasing number of companies that try to undergo such a transformation (Lieder & Rashid 2016), but the factor that may hinder this process of change is the lack of knowledge how to execute the shift towards more sustainable circular production. Every industry has unique conditions for uptake of CE. Therefore, the identification of drivers and barriers for CE implementation is an essential step to start with. For UO, CE presents a way how to incorporate more sustainability into the business. All three aspects, environmental, social and economic, of sustainability can be addressed and improved with the emphasis on the 3Rs principle that lies at the core of CE. Sustainability is a priority for UO, and several changes have been made to bring benefits to every stakeholder. Unfortunately, no guideline discussing CE implementation into hydroponic farming exists, making it more time-consuming to find new ways. Although sustainable production is highlighted in national strategies as a way to improve people´s well-being and resource efficiency, there is a need to gain insights into the production in order to draw some conclusions. Sustainable production, where the emphasis is on reusing the material and resources, is the utmost priority for UO. UO views CE as a way to increase sustainability and thus achieve better environmental, social and economic performance. Even though there is no specific guideline on how to achieve that particular material or resource is reused or recycled, thus knowledge about implementation is basically lacking for most of the businesses. With regards to UO´s production, the CEO of UO constantly looks for new sustainable options that could result in economic benefits.

Tura et al. (2019) identified seven categories of drivers and barriers for CE implementation. The categories are environmental, economic, social, institutional, technological and informational, supply chain and organizational and the discussion below underpins the drivers and barriers which are related to UO and its production. In chapter two, the drivers and barriers were described generally, which is vital to gain background knowledge. The aim of this study is to reveal the specific drivers and barriers that are associated with hydroponic production due to the lack of this approach in the literature. Even though this farming system presents an emerging industry that is necessary to scrutinize more into detail, it is important to provide insights into this specific context. Especially, by identifying challenges, drivers and barriers related to the transition towards the CE, which is believed to increase sustainability (Toop et al. 2017), it is possible to see how a business is affected by different factors that come both from inside and outside of the business. In the course of interviews and observations at the hydroponic farm, the deep understanding of the phenomenon enabled to gather information about the factors that either support or hinder the implementation of CE.

UO´s environmental drivers and barriers

The environmental drivers and barriers for CE implementation that were identified for UO are illustrated in Table 10. As was stated in the previous chapter, environmental benefits, which are achieved when CE is implemented, present the primary driver for UO. Environmental performance of the business could be significantly enhanced when the dependency on natural resources and materials is reduced. That is one of the priorities for UO. The more material is reused or recycled within the production, the less need there is for sourcing material. This approach is in accordance with the values of UO because the CEO of UO says: “Ideally, we try to reuse everything and minimize the things we are buying” (Payaro 2019, personal communication). From the life cycle perspective, introducing CE has several benefits not only for UO but as well for the environment, as one of the stakeholders. Inputs for the production are transported mainly from Sweden or other European countries, which requires long-distance transportation. Transportation is associated with significant carbon emissions (Benis & Ferrão 2017) and if some other ways of sourcing the inputs occur, the environmental performance improves. Similarly, as Tura et al. (2019) stated, environmental barriers were not identified or at least were not obvious from the interviews and observations, while the environmental benefits are generally easy to comprehend.

Table 10 UO´s environmental drivers and barriers

Environmental	Drivers	Reduced dependency on the natural resources
		Reduced environmental impacts
	Barriers	Not recognised

UO´s economic drivers and barriers

As a consequence of the lower need for supplying material, costs can be significantly reduced if the alternative way to “take-make-waste” approach is discovered. Production of UO is not extensively dependent on a large variety of resources, however, the circular flow of material can have positive impact on financial stability. Moreover, some new material can be generated in the course of production, specifically the roots of the plants that could be reused. After the plants are harvested, the roots that grew can be collected and serve as a replacement for rockwool plugs. Hence, the new value is created, while also decreasing the amount of waste. Similarly, this is seen as motivation for Payaro who expressed the attempts to decrease the amount of waste due to subsequent potential to save financial resources. When financial resources are spent effectively, the business can thrive due to possible investment into the developments that used to be neglected. This is seen by UO as another motivation for CE implementation. Introducing new ways in production is associated with some level of uncertainty about the feasibility of the change, therefore the costs of such chance affect the decision about its realisation. Naturally, there is a need to keep business economically viable and therefore the core business activities always have to be taken into consideration and consequently, look for more appropriate solutions. This may greatly hinder the process of uptake of CE because it is highly subjective to distinguish when it is an appropriate time. Table 11 shows economic drivers and barriers for circular economy implementation that were identified by UO.

Table 11 UO´s economic drivers and barriers

Economic	Drivers	Cost savings
		Value creation
		Business development
	Barriers	Associated costs
		The need to keep business economically viable

UO´s social drivers and barriers

Considering the social drivers, Payaro agrees with the view stated by Tura et al. (2019) that consumers have an important place and their demands may affect the business practices, however, the main driver for CE implementation does not come from outside the company, but directly from the management. Therefore, the mindset and values of the manager greatly affect the everyday procedures within the business. Nevertheless, the growing discussions about the promotion of sustainable development propel the transition towards better opportunities, making the benefits more convincing. Even though Tura et al. (2019) placed region-specific standards and local culture as the social barrier, speaking of Sweden, it might be regarded more as a driver. Compared to other countries, Swedish consumers are more aware of environmental problems, environmental protection and consider these topics as important (European Commission 2017). From 2017, Swedish consumers steadily became more aware of the term CE and either know what the concept is about or are familiar with the term (SB Insight 2019). Moreover, it was stated that the Nordic countries have a certain precondition for the circular economy implementation which stems from the emphasis on social equality policies. Swedish consumers believe that the main responsibility for a circular transition bear citizens, companies and the government (ibid.). On the other hand, consumers do not have an opportunity to tell whether the company employs CE or not, unless it is promoted by the company. Therefore, consumers may possibly not fully appreciate the effort made by the company further conditioned by their knowledge about the CE concept. Table 12 summarises social factors that have an influence on the uptake of CE.

Table 12 UO´s social drivers and barriers

Social	Drivers	External pressures
		Values of company manager
		Promotion of sustainable development
		Region-specific standards and local culture
	Barriers	Low customer´s understanding of benefits

UO´s institutional drivers and barriers

Even though the main driver for CE implementation stems from an internal set of values, external pressures and demands play a significant role in influencing the business activities since company tries to comply with the regulations (Tura et al. 2019). Table 13 demonstrates the set of institutional drivers and barriers. Payaro is aware of existing growing sources of information regarding the CE, which may enhance the knowledge about the possibilities, however, the challenge associated with CE implementation is the uncertainty about how to implement CE since no specific support is provided for hydroponic farms. Thus, new processes have to be undertaken and consequently modified according to the needs of production. For example, implementation of dehumidifiers had to be tried first to see whether their implementation is justifiable. This process may be time-consuming with no assurance about the feasibility of an introduced change. A barrier perceived by UO is that it is difficult to go against the norm and look for more sustainable and circular options. The market or actors within the supply chain may not be willing to change the processes. Especially in terms of packaging, it is difficult to find new options fulfilling the demands of customers to avoid plastic packaging. Plastic packaging can be recycled by customers, however, no better options for reusing it are existing yet. Therefore, aversion to change and difficulties with finding new options that would be convenient for all interested parties present barriers identified by UO. Moreover, the knowledge about the CE implementation is disseminated to the public through the campaigns, documents or projects but the desired outcomes are conditioned by the interest of companies that have to look for the information. The process of getting to know more about the CE is time-consuming and requires a great amount of time to make a decision about the new process.

Table 13 UO´s institutional drivers and barriers

Institutional	Drivers	Demand for new solutions
		Growing legal support
	Barriers	Aversion to change
		Difficulties with finding options
		Lack of knowledge about CE implementation

UO´s technological and informational drivers and barriers

Advancement of technology helps with transforming the production system. The fact that the CEO of UO has technical skills and academic background in engineering is seen as a competitive advantage because otherwise some technical innovations possibly would not be discovered. "If I was not an engineer, it would be probably very hard to do these things" (Payaro 2019, personal communication). For instance, using the dehumidifiers to collect water, requires knowledge about correct use to enable increased water recirculation. It may be assumed that someone who lacks technical knowledge and skills would not engage with some innovations that can have a positive impact and increase the circular flow of resources. Most of the intended changes at UO are based on testing phases, where the change is implemented despite the limited knowledge about the outcome and its development is monitored to understand the results. After it has been tested and understood, the full implementation can commence. By introducing innovations solely in-house, the whole process is slower and more challenging, but compared to outsourcing it is cheaper, too. Technical skills are therefore regarded as an advantage for UO that positively affect circular principles and their implementation. The fact that the information is available and easily accessible, greatly enhances the possibilities of getting requisite information that could advance the circularity. Currently, production automatization could be regarded as the barrier because it requires a substantial amount of financial resources, which have been depicted above as the economic barrier. Automatization of production could ensure better circulation and monitoring thus, production efficiency and effectiveness would greatly increase. For the future, automatization is of high interest which would simplify everyday business activities. Technological and informational factors are presented in Table 14.

Table 14 UO´s technological and informational drivers and barriers

Technological and informational	Drivers	Advancement of technology
		Enhanced information sharing
		Technical skills
	Barriers	Financially extensive automatization

UO´s supply chain drivers and barriers

As Rizos et al. (2016) stated, the transition towards the circular economy can be successfully achieved only through collective effort. In other words, stakeholders within the supply chain have to exchange and disseminate knowledge and willingly collaborate with other actors within the supply chain to enable the circular flow of material and resources. If subjects were willing to collaborate, industrial symbiosis could be introduced. Industrial symbiosis can be defined as “a method to increase efficiency of material- and energy flows and develop circularity by allowing industries to use other actors’ waste as their own resources” (SB Insight 2019, p. 17). Industrial symbiosis (IS) may be proposed as a way to create local circular economies thereby decrease resource use and develop new revenue streams. Different businesses can create closed loops and make use of someone else´s by-products or waste. By doing this, substantial cost savings could be achieved (Chance et al. 2018). This concept of IS is of high interest for UO since the positive consequences of such collaboration are apparent and believes that “it is good to work with companies or people who share the same values” (Payaro 2019, personal communication). Although, it requires a lot of time to start the discussion with other actors and find a common voice for long-term collaboration, the benefits it brings are the driver for this urban food sustainability effort. Hydroponic farms could use nutrients coming from food waste resources or other nutritious by-products that other business cannot further use. UO also maintains the opinion that collaboration is easier with actors who share the same values about sustainability. However, these actors may face similar problems in terms of keeping the business viable, which is the main priority for emerging businesses. Naturally, collaboration with actors who pertain to differing interests and values is challenging also because they engage with the linear production model and may have no interest in implementing circularity. Even though the collaboration with partners who are aligned as much as possible with the company´s values is easier, in some cases, it is important to collaborate even with those who are thinking differently. Factors within the supply chain affecting transition towards CE are shown in Table 15.

Table 15 UO´s supply chain drivers and barriers

Supply chain	Drivers	Benefits of mutual collaboration
		Industrial symbiosis
		Information sharing
	Barriers	Focus on linear production model
		Differing interest in the supply chain

UO´s organizational drivers and barriers

Organizational factors are mainly considered as the factors stemming from internal values, setting and motivation, and are presented in Table 16. Organizational driver for closing loops is that this concept fulfils the criterion of sustainable production and thus overall sustainability of the business may be enhanced. Fostering a sustainable brand is important for UO that takes responsibility for its business practices and strives to make them better and less dependent on natural resources. UO closely analyses every phase of the production to ensure that the flow of inputs and outputs is examined, and hence associated impacts caused can be monitored and mitigated. This is an important part because by monitoring UO can reveal challenges within the production and react upon them. Thus, improvement can be made to avoid undesirable impacts on other stakeholders. Organizational culture is influenced by the views and values of the management and in case of UO, consideration of sustainable options always takes precedence over the conventional ones. Tura et al. (2019) described the fear of risks, lack of CE knowledge and skills and lack of international cooperation as barriers for CE implementation. These may be relevant in some cases, especially when complicated processes within the company would have to be modified but considering UO, the will to be a good actor in the food industry is a priority. On the other hand, some existing operations and processes are expensive to replace and cannot be changed in the short run. Moreover, every change has to be carried out carefully with bearing in mind the need to keep the production and growing the vegetable viable and generating the sales. The last barrier identified is the limited amount of time that is available in order to look for new options and ways that could be implemented. CE may be seen as an extra effort made by companies since it is not legally binding to implement principles of CE, and what is more it is not something that consumers or other actors can see from outside of the company, unless the company itself promotes its circular activities. Although it is the main aim for UO to have sustainable production and be a good actor, an extensive amount of time is essential to exert to discover new ways of reusing and recycling the resources within the production. Time could be therefore seen as a limiting factor for CE implementation.

Table 16 UO´s organizational drivers and barriers

Organizational	Drivers	Foster a sustainable company brand
		Being a good actor
		Organizational culture
	Barriers	Existing operations and processes
		Time constraint

From the observations at the farm, it became apparent that principles of circularity are constantly being developed. Firstly, water recirculation is further enhanced by dehumidifiers. In the course of the maturation phase of production, two dehumidifiers ensure increased water efficiency as water is either absorbed by the plants or used within the production again to deliver the nutrients. Thus, water within this hydroponic production system is used as efficiently as possible with no losses. Within conventional agriculture, on the contrary, the amount of water used is alarming and moreover causing its pollution (Benis & Ferrão 2017). The pressure that is placed on water worldwide, could thus be mitigated with this controlled production (Pinstrup-Andersen 2018). Secondly, the ways how to replace plugs for the seeds are of concern because using the rockwool plugs is economically challenging and does not allow repeated use. Although some other options exist, they have not fulfilled the criteria for feasible use within the production and some challenges have occurred. Therefore, in terms of plugs, there is still an ongoing process of looking for an alternative. Thirdly, using more sustainable nutrition that comes from other than artificial sources is emphasised. An option would be to use nutritious by-products that represent waste for one industry, thereby engaging in industrial symbiosis (Chance et al. 2018).

5.3 Applying the principles of the circular economy within the hydroponic farming production

The last research question formulated was aimed to answer "How may the principles of the circular economy be applied within the hydroponic farming production?". Some of the principles of how to introduce circularity and principles of 3Rs have been already mentioned. In spite of that, these principles will be discussed more in detail with the focus on how circularity could be implemented into the hydroponic farm production. As Ritzén & Sandström (2017) stated, in order to move towards the CE concept, fundamental changes that run through the whole company have to be carried out. Due to the complexity of the changes, it is assumed to be more suitable if the phases of production are examined first and consequently, intended changes are introduced within each phase. Life cycle thinking approach is therefore a helpful tool to assess and improve processes which assists with making decisions (Rainey 2006). Phases of UO´s production can be divided into 5 phases – material supply, germination, propagation, maturation, harvest and distribution. Each phase was analysed to explore the possible circular flow of resources.

Material supply

In terms of sourcing materials, the long-term aim is to source material from as many local companies as possible, however, ideally, the things UO buys are minimized and reusing within the production is enabled at the maximum possible level. The will to react upon the demands from the customers is apparent because the packaging used to be different and consumers complained about it due to the use of hard plastic package which was perceived as worse compared to the light plastic bag, which is currently used for distribution of harvested leafy greens. The new packaging is sourced from the Swedish company and unfortunately, other improvements related to packaging are difficult to make because one of the requirements is that the packaging is transparent, so that consumers can see the content, which is achieved by using the plastic packaging. Packaging serves as a connection between production and consumption, gives a character to the product and has many functions, amongst others protection, distribution, advertising or waste-reduction functions are recognised (Pongrácz 2007). Consumers have an important role here, considering the recycling of the package once the food is consumed. The plugs are being steadily replaced by other methods that fulfil the criteria of reusing, specifically reusing of the roots of the plants to form the plug where the seed is planted. The plug made of roots provides the plant with a nutritious base and can grow the same way, possibly even with better outcomes. Nutrition is bought in a form of a liquid that is subsequently put into water and thus provides plants with a requisite amount of nutrients to grow. This is believed to be done in a more sustainable way, for example by using by-product or rest product of another company that would be used as nutrition. For instance, food waste could be used, however, this needs further research.

Germination and Propagation

Within germination and propagation phases, it is difficult to explore some ways of reusing or reducing resources because these parts of production do not require an extensive amount of resources or materials and are directly interlinked to other phases.

Maturation

Maturation phase is greatly dependent on water supply. Hydroponic farming is generally believed to save an extensive amount of water (Pinstrup-Andersen 2018), where theoretically 100% of water use efficiency can be achieved (Graamans et al. 2018), thus UO attempted to cut water use to the greatest extent possible. To ensure resource efficiency at this phase, water is constantly rotating within the system. This illustrates the process of water recirculation, which was enhanced by two dehumidifiers that help to collect water that would be otherwise lost because of transpiration of the plants. Thus "only water that goes away is the one in the plants" and the rest is reused (Payaro 2019, personal communication). By using dehumidifiers, water efficiency is significantly improved, making the production of UO less dependent on water.

Harvest and distribution

When the plants are harvested, the plugs with the plants are removed from the floating desks. The floating desks are designed to be used again within the maturation phase so that after they have been cleaned, they are used in the system again. In accordance with what was stated previously, the roots from the plants are collected and used as a replacement for the plugs made of rockwool. These plugs have to be bought and transported from the supplier, therefore there is a motivation to find a more suitable solution for the plugs. By using the roots, this nutritious resource could be reused within the production and a certain degree of UO´s self-sufficiency was achieved. Moreover, it makes economic sense because the costs are reduced. However, to fully implement the plugs that solely come from natural sources, it has to be repeatedly tested to see its feasibility. Delivery to the restaurants is executed in the plastic boxes that are reusable and UO gets them constantly back. If the delivery is intended to the supermarkets (through the intermediator), small individual packaging is used for the leafy greens. Recycling of plastic packaging is influenced by the consumers´ behaviour and attitude towards recycling.

As it was proposed previously, industrial symbiosis refers to the exchange of by-product resources between companies, while achieving a mutual benefit. With the increased interest in the CE, industrial symbiosis has gained increased interest, too (Harris, Mirata, Broberg, Carlsson & Martin 2018). Although the process of utilising by-products is not a new practice, several opportunities have not been developed and realised due to the lack of knowledge and awareness or lack of policy incentives. A symbiotic relationship is often developed among geographically concentrated companies and it is assumed that in Sweden the development of

IS is suitable because of collaborative business culture, existing examples and supportive policies. On the other hand, lack of facilitation and communication hinders its development (ibid.). By working together, resource consumption and costs are reduced which point out the economic and environmental benefits. It is believed that IS is primarily built on economic benefits eventually propelling companies´ interest and engagement. Exchanged resources can be used as a replacement for products that would otherwise be supplied from elsewhere or possibly wasted (Nilsson 2016). Creation of local circular economy is the main advantage with several associated benefits.

One example where the concept of IS is utilized to increase urban food sustainability is *The Plant* in Chicago, USA (Chance et al. 2018). *The Plant* refers to an industrial building that is home to several food businesses where the closed loop model is promoted. Tenants of *The Plant* mainly focus on agriculture, farming or production of food or beverages and in total around 16 tenants are operating within the same facility. An indoor hydroponic farm is also a part of *The Plant*. Businesses exchange resources like spent grains, compost, ash, barm or burlap where some of the businesses benefit more than others, however, the synergy is apparent. Thus, material waste can be reused to a great extent by engaging in industrial symbiosis. Chance et al. (2018) are aware of the fact that urban communities may not become independent of rural agriculture because the production of some products cannot be shifted easily towards urban areas. Yet, urban communities can assist in raising awareness about the environmental impacts of the food.

Similar concept to the hydroponic system of production is the aquaponic system. The aquaponic system combines aquaculture and horticulture, where the recirculating aquaculture system for fish is brought to the land and fish water delivers nutrients to hydroponic production of plants. The advantage of connecting these two systems is that “fish wastewater contains relatively high concentrations of nitrate and phosphorus, which are essential macronutrients for plants” (Kloas et al. 2015, p. 180). Moreover, waste treatment is significantly improved because by-products from one species serve as inputs for other species while offering fish welfare, water quality and nutrient recycling (Martins et al. 2010). Kloas et al. (2015) state that negative environmental impacts are reduced due to recycling nutritious water from fish tanks for plant growing. Hence, a combination of multiple use of water with waste recycling is believed to be a step towards sustainable food production, where resources are treated efficiently.

From examples of industrial symbiosis and aquaponic system, it is evident that nutrients for growing plants could be sourced in a more sustainable manner, which, however, requires the collaboration of multiple actors. In terms of use of mineral fertilizers for hydroponic production, it is easy to anticipate the outcome but there is an interest in finding organic wastes that could be used as a replacement for mineral fertilizer that is currently used. In Stockholm, a sharp increase in the volume of food waste it is expected by 2026 (SVOA 2017). According to *Waste management plan for Stockholm*, the city aims to increase the collection of food waste, which is eventually sent for anaerobic digestion to produce biogas and digestate. The digestate can be used as biofertilizer on arable land (ibid.). In this form, it is not convenient to be used for the hydroponic system. However, Michelet (2016) tested the digestate, generated from kitchen waste, to discover the feasibility of this fertilizer for hydroponic system. When the digestate was pasteurized and diluted, similar quality in comparison with the commercial hydroponic solution was obtained and the optimal use of resources was thereby allowed. The growth rate of the plants was however smaller. It is necessary to scrutinize the use of organic waste more in detail, but anaerobic digestion is seen as a convenient waste management practice considering the increasing amount of organic waste (ibid.).

5.4 Summary of the chapter

Theories of Sustainable Business Development, Circular Economy and Implementation of Circular Economy have helped to comprehend the collected data. The presented conceptual framework departed from the Sustainable Business Development which is seen as a complex concept. In general, SBD assists companies to embrace a bigger deal of responsibility for environmental, social and economic impacts that may negatively affect other stakeholders. Achieving more sustainable production belongs to one of the conditions of SBD and since UO and its production was strived to become more sustainable, the theory of SBD has helped to make sense of the necessary background. An essential notion here is that it is seen favourable to detect shortcomings within the production at an early stage so that negative impacts can be avoided, and the development of the business is enabled. Considering the production of UO, SBD has helped to understand the interconnectedness of different business activities that influence various actors outside the company thus have to be taken into consideration, too. The concept of Circular Economy helps companies to enhance their sustainable performance and especially resource efficiency. As a result, more sustainable production can be achieved when CE is implemented and embraced. Other business activities are also affected if the circular flow of materials and resources is incorporated. The emphasis is on shifting production from the linear model to the circular one, where most of the inputs can be used again or recycled and cradle-to-cradle flow of material can be greatly achieved. It is also highlighted that the maximum value can be obtained when the resources are handled in a responsible manner. UO has already implemented some solutions that make the production more sustainable and less dependent on natural resources. However, further analysis was done to explore other solutions that could be introduced and what factors influence the uptake of CE. Implementation of circularity can be associated with many benefits, primarily environmental and economic, but gaining company growth is also perceived as a new opportunity conditioned by gaining a competitive advantage. Drivers and barriers for CE implementation showed that the main motivation for closing loop comes from the management of UO, but it is hindered by the lack of time and financial resources. Moreover, even though awareness about CE is increasing and projects and documents are being published, the more context-specific knowledge about CE implementation is lacking. Since every company has different production processes and uses different materials, the implementation of CE requires a lot of time and effort. Life cycle thinking approach has been applied in order to analyse all phases of production and discover the way how to move it towards more sustainable future. Life cycle thinking assists in decision making and due to this perspective, it is more apparent how the production processes and techniques are established and consequently see what inputs are essential for each phase of production.

Analysis of the data was done with the emphasis on avoiding possible bias that could interfere with the results and findings. Especially, in terms of ethnographic research, where the researcher´s involvement is great, it is important to provide a holistic description and interpretation of the situation without involving researcher´s own values that could skew the findings. The advantage of ethnography is that valuable information that is commonly hidden to the public is revealed and a rich understanding of the setting is enabled. Everyday production processes at UO could be fully understood in order to deduce improvements and during the fieldwork, the setting was perceived in its natural environment. This thesis was undertaken by the application of action research method, which targets at the particular problem that could be tackled in collaboration with someone who has a stake in the problem (Herr & Anderson 2005). Specifically, this thesis employed the mode of collaboration where the outsider works with insiders in order to deliver the outcome. This approach not only generates knowledge about the phenomenon but also promotes possible improvements to the addressed challenge. The aim of this thesis was focusing on the implementation of the circular economy into the hydroponic production system. Some challenges and critique of this production system have been identified in the literature which was perceived as the basis for doing this research. The limitation with doing the action research is that the outsider is provided with information by insiders who may, to some level, affect what information is shared and uncovered. This limitation cannot be completely overcome but by the employment of other methods for data collection can reduce the effect of this limitation. Since the data was collected from only one company and one key informant, there might be some information that remained hidden, however, this obstacle is deemed to be overcome because of observations done in person at the farm. The author of this thesis is not aware of any obstacle that could affect the trustworthiness of the findings and no information was intentionally undisclosed.

To safeguard the quality of the results, the following steps had been made. To demonstrate a true picture of the setting and production of UO, findings were validated by Payaro, either during interviews or by sending a draft manuscript which allowed commenting or clarifying possible inconsistencies. By validating the study, the complex understanding of the phenomenon is deemed to reflect reality. The limitation that only one key informant provided insights into the setting could not be avoided due to the small size of the business. However, owing to the use of several methods as sources of data, the increased confidence in the findings is believed to be achieved. It is believed that the thick description of the hydroponic production system was provided, therefore possible comparison with other similar cases could be carried out. The procedure of the study and completeness of the records was assessed by external actors to assure that the study is consistent and reliable. The author of this study acted in good faith to arrive at the results with the emphasis on avoiding any bias that could affect the trustworthiness of the research. During the whole process of the research, it was emphasized to follow the research objective and avoid possible reluctance to be critical.

This research contributes to the field with detailed knowledge about the hydroponic farming production in Sweden. Similar research was done by Romeo et al. (2018) who analysed the environmental impacts of the hydroponic farm in Lyon, France by using Life Cycle Assessment method. Their research quantified emissions and evaluated the environmental performance of the vertical hydroponic farm. The research also proved that hydroponic farming performs better, compared to a heated greenhouse or open field farm. Yet, the focus of this research was on how the circular flow of material could be implemented into hydroponic production. Chance et al. (2018) on the other hand, investigated the sustainable urban food system and presented the concept of industrial symbiosis as the strategy for introducing sustainability into the food system. A hydroponic farm, in this case, is a part of business synergy where local circular economies are created with the benefits arising for engaged actors. Although this concept of industrial symbiosis is believed to function in the Swedish market, too, the case of hydroponic farm and its role within the synergy is not clearly presented by Chance et al. (2018) because other businesses have a better position to collaborate with others. This research is especially suitable for hydroponic farms or similar controlled environment agriculture businesses that strive to implement circular flow within their production. By having knowledge from this research, they can more clearly see how their production could be done more sustainably. Secondly, this research is suitable for policymakers who can reflect upon the lack of support and guidelines that were identified and provide these businesses with more extensive backing and incentives to raise the motivation for departing from the linear production model. Thirdly, other businesses striving to implement circular economy can deepen their understanding about this concept and lastly, general public and consumers have an opportunity to understand soilless indoor farming, which is an emerging field and will possibly become more common in the foreseeable future.

Growing vegetable and herbs hydroponically is not unanimously seen as a sustainable solution for food production, but it is evident that resources are utilized efficiently and the quality of production is ensured (Graamans et al. 2018). It is expected that in the future, Swedish consumers will demand high quality, ecological and tasty products and the factor influencing the purchasing decision could be based on the geographic location of production. But imports of food will still play a significant role because Sweden cannot become self-sufficient in food production (Melander, Dubois, Hedvall & Lind 2019). This study does not evaluate the feasibility of hydroponic farming as a whole but focuses on the way how its production could be done more sustainably, which became obvious that there is a room for some improvements and collaboration with other actors that are believed to build up sustainable urban food production. Improvements that could make the production of the hydroponic farm more sustainable could be closer collaboration with other actors in the market, reusing the roots either as the replacement for the plugs or as a source of nutrients and continue the research on finding an alternative solution to plastic packaging that is currently used.

6 Conclusions

The results of this study are presented in this chapter. A combination of evidence from the literature and the empirical evidence from the case company have assisted in arriving at the results. The implications for theory and practice are addressed, as well as a suggestion for future research.

Hydroponic vertical farms are an emerging field that is believed to contribute to increasing the sustainability of the food system. Production of this controlled environment agriculture focuses mainly on leafy greens and herbs where the efficient use of resources is significant. As Sweden is highly dependent on imports of food and especially on imports of vegetable and fruit, urban hydroponic farms could contribute to increasing self-sufficiency in terms of supply of leafy greens. Even though the hydroponic production focuses only on a small fraction of crops, it has the potential to reduce the dependency on food imports. While conventional agriculture is criticised for inefficient use of water, hydroponic farming overcame this challenge by allowing water recirculation. On the other hand, hydroponic farming is greatly dependent on the use of energy whereas conventional agriculture can use natural sunlight. It is clear that both conventional agriculture and hydroponic farming face different challenges but it is proposed to ensure a balance between hydroponic and conventional production.

Hydroponic farm operating in Sweden may be considered as more competitive because energy is sourced mainly from renewable sources and this proportion is going to increase because the Swedish government strives to source 100 % of energy from renewable sources by 2040. When the production is situated in vertically stacked layers, space efficiency is high, and the agricultural land is given a chance to heal, can be replanted thus deliver benefits for the society. Moreover, Urban Oasis, the Swedish hydroponic farm, makes use of empty space in the parking garage and thus uses the potential of urban land area. The vision of Urban Oasis is to provide consumers with affordable, tasty and quality products. At this moment, the price of the vegetable grown indoors is higher and targeting at the mass market is not feasible. The fraction of consumers who choose to purchase these products is expected to increase as the price of the product decreases. The advantage of the hydroponic farm located in Sweden is that Swedish consumers have better knowledge about environmental problems and environmental protection and are willing to make some effort in order to become more responsible and not to cause harm to the environment.

Swedish consumers are also increasingly aware of the concept of the circular economy, yet they are not able to see company´s attempts to introduce circular flow of material unless it is promoted, thus they cannot fully appreciate the effort made by the company. The circular economy is associated with several benefits. For instance, the self-dependency of a business is enhanced, while saving costs and allowing business growth. This thesis showed that especially environmental and economic benefits are highlighted as the main drivers for circular economy implementation for Urban Oasis. However, also values of company management and local (Swedish) culture proved to have considerable influence on CE implementation. Sustainability is regarded as a core value of Urban Oasis´s business and new production processes are constantly being developed with the aim to have more sustainable production. Therefore, the circular economy is seen as a way to obtain the maximum value from the resources used within the production, while cost saving is achieved. On the other hand, barriers were recognised especially on economic, institutional and organizational levels. More specifically CE implementation is hindered by the lack of financial resources to implement changes, lack of time to look for new options and lack of knowledge about necessary steps.

6.1 Future research

This thesis explored the challenges that Urban Oasis faces and analysed how the concept of the circular economy could be implemented while focusing on the description of drivers and barriers for implementation of the circular flow of resources. This thesis addressed the knowledge gap about how to address the challenges associated with hydroponic farming and provided the reader with an extensive account of not only general background but also of drivers and barriers for circular economy implementation into this specific context. Since this thesis highlights that the collaboration with other actors within the supply chain is crucial in order to deliver the best results, the concept of industrial symbiosis is regarded as the area that needs further research. Hence, a suggestion for future research is to explore the possibility of uptake of industrial symbiosis in Stockholm where the hydroponic farm could be part of the synergy. Moreover, this research analysed hydroponic farming solely from the business perspective. Thus it would be interesting to analyse it from for instance a technical perspective, since managing technical skills proved to be essential and indivisible part of hydroponic production. Additionally, similar research could be done with the use of different methods to explore other aspects of hydroponic farming.

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Unpublished materials

Albert Payaro, interview by Denisa Pozníčková, Stockholm, 28th March 2019
Albert Payaro, interview by Denisa Pozníčková, Stockholm, 24th April 2019

Appendix I: Interview guide

Following and other questions were covered during the interview on 28th March 2019 taken at the Urban Oasis

General background
How did you start the business?
What was the situation in the market at that time?
What does make Urban Oasis unique?
Is the legal environment (in Sweden) in favour or against such farming system?

Production
How would you describe the production process?
What kind of phases does the production have?
How long is the life cycle?
How long does it take to grow e.g. lettuce?
What materials and resources you do need to run the business?
What problems do you identify as problematic within hydroponic production?
Do you perceive any unique or specific problems associated with your production?
What would you like to improve? And possibly how?
Do you perceive any unique or specific advantages associated with your production?
How does water system work?
How is water efficiency achieved?
How do plants receive nutrients?
What lighting do you use?
How did you find available land in Stockholm?
Do you know consumer´s perception about hydroponics?

Circular economy
What do you do to incorporate sustainability into the business processes?
What do you see as the main drivers for circular economy implementation?
What do you see as the main barriers for circular economy implementation?
What do you see as possible ways to implement circular economy into the business?

Appendix II: Interview guide

Following and other questions were covered during the interview on 24th April 2019 taken at the Urban Oasis

Production
What are the crops that you mostly grow?
Which crops are the most popular?
How do you decide which crops to include?
How many kgs do you produce per day?
What is your planned production after the expansion?
What is the price that you sell vegetable for?
What is the price compared to similar products?
Do you have any specific targeted group of consumers?
You said you would like to use more sustainable nutrition; how do you mean?
You said you see a problem with nutrient deficiency? In what way?
How many parking spaces are not used?
What would have to happen so that your production in the parking garage is threatened?
Is your priority for the future to source materials from Sweden only? Are there possibilities?
The seeds do not get water during the germination phase, what condition or nutrition do they get?
Do the plants lay in the water all the time during the maturation phase?
How many times a day is water pumped in the propagation phase?
How much water can you save by using dehumidifiers?
How far do you deliver?
Who are your most frequent customers? Where do you mostly supply?
What package do you use when you deliver to restaurants?

CE implementation
Is there any institutional support for CE implementation?
Are there any documents or guidelines that would be helpful for you?
Where do you source inspiration for CE implementation, how do you know what to do?
How do you manage technological knowledge?
Do you know whether other actors within the supply chain share the same values as you do, regarding sustainability?