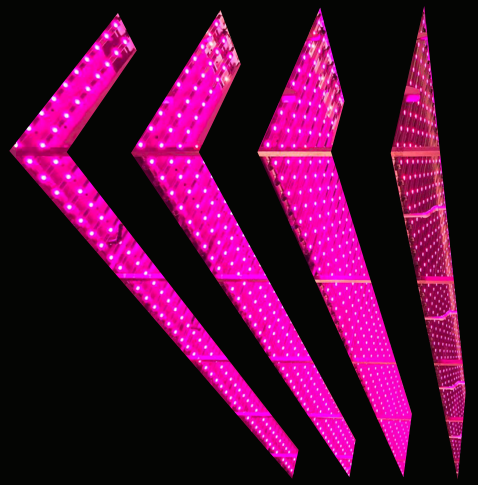
ENLIGHTENING HARVEST
IN THE CITY OF COPENHAGEN

AN EXPLORATORY RESEARCH ON LED VERTICAL FARMING IN COPENHAGEN



EXTENDED MASTER THESIS 2017
AALBORG UNIVERSITY COPENHAGEN
NICHOLAS JOHN WILLIAMS & TINE ØGAARD MADSEN

Title Page

AALBORG UNIVERSITY
DENMARK

Study Program and Semester

MSc Integrated Food Studies
4th Semester

Project Title

Enlightening Harvest in the City of Copenhagen
An Exploratory Research on LED Vertical Farming in Copenhagen

Supervisor

Niels Heine Kristensen

Authors

Nicholas John Williams _____
20151471

Tine Øgaard Madsen _____
20151473

Submission Date 9th June 2017

Style of Reference Harvard

Number of Pages 139 (332,313/ 2400)

Printed Copies 2

Report Size 45 ECTS

Number of Appendix 14

Wooden Leaf USB Stick Included With Appendix
Link: https://goo.gl/2LNMFT

QR Code for Appendix

Abstract

Copenhagen's urban population is increasing more than the current global average and the City of Copenhagen has set out the visions of becoming the world's first carbon neutral capital by 2025. Linking to these, it is important for the food infrastructure to be assessed critically to become more sustainable and productive for the future needs.

The LED Vertical Farming technology has shown potential to grow produce quicker in a closed environment, achieve higher yields per square meter, use little water, no pesticides and no soil. With this form of agricultural technology gaining interest globally, there has been a rise in companies involved within the development of LED Vertical Farming for commercial use but the city of Copenhagen has yet to see any active implementation from entrepreneurs setting up LED Vertical Farming within Copenhagen.

Therefore this master thesis sets out to explore how the new commercial agricultural technology of LED Vertical Farming could provide sustainable possibilities for Copenhagen in relation to the city's growing urban population, as well as contribute to Copenhagen's visions for the future.

Initiating the thesis from an explorative and qualitative approach, the literature surrounding the subject area of LED Vertical Farming and Copenhagen was investigated followed by a theoretical framework that is based on entrepreneurial perspectives with an understanding of the old and the creation of new paths as well as perspectives on actors, location and technology.

SWOT Analysis, Mapping Historical Discourses and Actor Mapping were methods used as pre analytical tools to understand the subject area further before conducting expert interviews, whereafter an analytical approach to the literature, theories and empirical data was used.

Concluding on the explorative research, it was found that although no clear visions to bring commercial agriculture into the city of Copenhagen were stated, LED Vertical Farming provides possibilities to reach other goals and visions. To reach these visions, all actors within urban, peri-urban and rural areas play an important role in working together to create new initiatives. Placing this technological food production in unattractive g*rey spaces* within the city and thereby shortening the food supply chain could lower the environmental impact and create sustainable possibilities. However, the conclusion raises the question of to what extend this control should be taken advantage of or whether the population should be educated rather than providing yet another technological advantage.

Acknowledgements

Firstly, we would like to thank Niels Heine Kristensen, our supervisor, for the help and guidance throughout the whole process. Special thank you to our close friends and family for providing us with moral support and being there to talk about the thesis, even though, at some points, the topic or subject matter being spoken about was hard to grasp.

Also thank you to Jan Ravensbergen (Alfred Pedersen & Søn), Katrine Heinsvig Kjær and Benita Hyldgaard (AU Aarslev, Aarhus University) and Marjolein de Bruin (BrightBox) for giving us the opportunity for an interview and provided us with tours of the facilities they were involved within. This provided us with a real life insight related to our research area.

Thank you to Natalie de Brun Skantz (Grönska) for contact and spending time from your busy schedule to do a Skype interview.

Finally Chris Nelson (Growing Underground), Mark Delissen (Deliscious), Casper Lehmann Nielsen (Coop), Lykke Leonardsen (The City of Copenhagen), Anne Rohde Sangers (Gasa Nord Grønt), Jens Nørgaard Poulsen (Global Herbs Denmark) and Torben Krusborg (System Frugt A/S), who all provided response to email questions we had during our thesis.

Thank you to Copenhagen FabLab for your help, time and use of facility.

Another important thank you goes to Troels Øgaard, whose experience, attention to detail and enthusiasm related to design helped create the front page for this thesis, as well as certain design aspects within it.

Finally we would like to thank one another for being by each other's side throughout the long process of exploring, discussing, researching, interviewing, discussing, writing, editing and again, discussing the thesis. It has been a fun experience with lots of knowledge gained throughout that will benefit both of us for our professional future career ahead.

It has been a challenging but fantastic process and without everyone that has been involved in some way or another, big or small, it would not have been able to work without you. Thank you.

Abbreviations and Translation

Throughout our thesis the use of abbreviations to shorten some of the lengthy words will be used. The following provides the reader with an overview of these.

ANT: Actor Network Theory
LED's: Light Emitting Diodes
n.d.: no date
PC: Path Creation
PD: Path Dependant
PFAL: Plant Factory with Artificial Lighting
UA: Urban Agriculture
UN: United Nations
WHO: World Health Organization
Z-Farming: Zero Acreage Farming

Danish organisations and ministries will be mentioned within the course of the thesis. Below, we will provide a translation of the names from Danish to English.

Dansk Gartneri - Danish Horticulture
Københavns Kommune - The City of Copenhagen
Landbrug & Fødevarer - Danish Agriculture & Food Council
Miljø- og Fødevareministeriet - Ministry of Environment & Food of Denmark
Miljøstyrelsen - The Danish Environmental Protection Agency
Skovpolitisk Udvalg - The Danish Nature Agency
Økologisk Landsforening - Organic Denmark

List of Figures

Table of Content

1

Introduction

"*We never write on a blank page, but always one that has been written on.*"

(Clarke, 2005: 261)

"Any system designed to be efficient at a point in time will not be efficient over a point in time."

(Garud & Karnøe, 2000: 6)

"*Copenhagen wants to be carbon neutral by 2025. It is a political ambition that Copenhagen as a Metropolis and capital must assume responsibility for the climate and show that it is possible to generate growth and progress while also reducing CO_2 emissions.*"

(The City of Copenhagen, 2012: 8)

We start the process of this research for our thesis by knowing little about the area of concern, which is LED Vertical Farming within the city of Copenhagen. We will quickly come to realize that there to our knowledge has not previously been any research published in the perspective that we want to take within this subject area. For that reason, we had to begin our process by exploring to enlighten ourselves on the harvest from this technology. We will be addressing the research question in the discussion but in order to reach a conclusion, you as a reader must come with us on the journey of understanding this subject area to try and create a thematic sense in the cluster of knowledge and unknown areas that go beneath LED Vertical Farming.

1.1 Background

This background section will be used to introduce the motivation behind choosing the subject area of LED Vertical Farming in the city of Copenhagen and why we find it relevant in the present day.

The Revision of World Population Prospects report published in 2015 by the United Nations (UN) has estimated the population of the world to be 7.3 billion people, but it will be set to grow to 8.5 billion by 2030 (UN, 2015). The World Health Organisation (WHO) stated that in 2014 over 54% of the world's population lived in the cities compared to 34% in the 1960's. The trend for this growing urban population will continue year after year with figures showing 1.44% to 1.84% increase between 2015 and 2030 (WHO, 2016), which could see up to 70% of the total global population living in cities (Eigenbrod & Gruda, 2014).

The trend of this growing population is also seen in Denmark and the capital city, Copenhagen. Since 2008 the Danish population has increased by 3.99%, from 5,488,269 to 5,716,240 residents, while Copenhagen has seen an even bigger increase of 13.63% people now living in the capital over the past eight years; on average a 1.95% yearly increase (Statistics Denmark, 2016). This increasing urban population that has currently been moving to Copenhagen is mirroring and exceeding the predictions made by the WHO above.
Denmark is an agricultural country and currently, over 60% of Denmark's acreage consists of farmland and is, together with Bangladesh, the most intensively farmed country in the world. Also, 1.75% of Denmark's acreage is taken up by cities, streets and other infrastructural facilities, which has doubled within the last 100 years (Holmstrup et al., 2016).

With this growing urban population ahead of us, the food infrastructure for the future needs to be assessed critically to become more sustainable and productive compared to the food infrastructure of today (Specht et al., 2014).

Every day additional resources are required to be brought into the city due to the demand from its growing population, as more people require more food. To keep up with this demand the produce has to be transported to the city over longer distances before reaching the consumer. As a result, more CO_2 is put into the environment (Ohyama, Takagaki & Kurasaka, 2008). Even before it arrives with the consumer the way the produce has been grown, prepared, packed, stored, cooled before and during transportation emits additional CO_2 as well as food waste being a sustainability issue and another contributor to CO_2 emissions (Kozai & Niu, 2016b).

To keep up with this growing urban population and to have the ability to feed them in a more sustainable and productive way the spaces found within the cities could be an area of consideration. Using empty locations within the urban environment has the chance to take pressure away from already overworked rural agriculture and at the same time help the environment by bringing the farming methods to the city (Eigenbrod & Gruda, 2015). Thus, reducing the distance that the food takes on its journey to the consumer, food miles, and growing the food within the city, also known as urban agriculture, may be a way to reduce some of the CO_2 being emitted into the environment and additionally helping to reduce the amount of produce wasted through the journey (Kozai, Niu & Takagaki, 2016b; Ohyama, Takagaki & Kurasaka, 2008).

Currently, the production and agriculture of today has many issues that need to be addressed, whether it is the poor soil quality, pressure on water availability, demand for more produce as well as reducing the environmental impact it causes. New farming methods such as LED Vertical Farming has been developed and ongoing research is being conducted as a way to try and overcome these issues and to create a more sustainable food production system (Eigenbrod & Gruda, 2015).

The LED Vertical Farming method has shown to have the potential to grow produce quicker in a closed environment, achieve a higher yield per square meter, use little water, no pesticides and no soil. It also can use waste products from other systems within the city, while producing little waste itself (Kozai & Niu 2016a). When growing, the light that the plant receives, whether it is from the sun (natural source) or LED lighting (artificial source) still works as being an important factor for the growth and development of that plant (Kozai, Niu, & Takagaki, 2016). LED's have started to be used more frequently over their older light counterparts within horticulture due to their compact size, giving off very little or no heat, higher energy efficiency and also a broader light spectrum for the plants (Kozai & Niu, 2016a).

The term urban agriculture can be used to describe various community, individual and commercial ways of growing within an urban environment. This term can include rooftop greenhouses, rooftop

gardens, indoor farms, vertical farming and many other style of building related forms of growing (Specht et al. 2014).

Copenhagen is relatively new to the urban agriculture scene compared to other cities around the world but around the city you can still see various forms of urban agriculture, whether it is communal gardens, school vegetable gardens or commercial businesses with raised beds on roof tops (Halloran & Magid, 2013). The city of Copenhagen has yet to see any active implementation from entrepreneurs setting up this new LED Vertical Farming Technology method within Copenhagen compared to other cities around the world, which makes it an interesting area to explore. Also, there has been a rise globally in companies involved within the production of lighting, equipment as well as research and development within the area of LED Vertical Farming for commercial use (Hayashi & Higgins, 2016).

The City of Copenhagen and the municipality have set out plans and initiatives for the future to make Copenhagen a more sustainable, green, smart and carbon neutral city. Also, the way the city deals with the lack of water sources within the city has been raised. One other suggestion put forward is the ability to reuse and recycle water so it does not have to be retreated (City of Copenhagen, n.d.). The city of Copenhagen is also looking at ways to lower its carbon dioxide emissions through using new methods and technology to create 100% renewable energy to be used for different public amenities (City of Copenhagen, n.d.).

In 2011, the City Council of Copenhagen set out that they wanted to achieve a goal that by 2015 there would be a 20% reduction in CO_2. In turn, a new plan was decided that by 2025 Copenhagen would be carbon neutral (The City of Copenhagen, 2012).

Ambitions of the city are to exploit going carbon neutral by creating new jobs, attracting new investments to Copenhagen, but by doing so acting smarter, greener and also being more open to new opportunities that could support this (The City of Copenhagen, 2012). The city council of Copenhagen understands that it cannot do it alone and in its publication, *CPH 2025 Climate Plan, A Green Smart and Carbon Neutral City*, highlights that the council are wanting to listen and work with others to create new solutions, technologies and suggestions as an important part to develop new green solutions (The City of Copenhagen, 2012).
Since LED Vertical Farming is presumably a sustainable commercial farming technology, it could be a viable solution to aid the growing urban population and be part of creating a more productive food infrastructure within the urban city environment.

For the purpose of this thesis, we wish to address sustainability issues affected by a growing urban population by exploring the farming technology of LED Vertical Farming within Copenhagen. This thesis will be written with the point of view of an entrepreneur looking at the options of this LED Vertical Farming technology within the city of Copenhagen and to analyse whether this form of farming technology could be an option to provide sustainable options for Copenhagen in relation to its growing urban population as well as contribute the city's visions for the future.

1.2 Research Question

Through introducing the elements found within the background section above leads us to the research question:

How could a new commercial agricultural technology of LED Vertical Farming provide sustainable possibilities for Copenhagen in relation to the city's growing urban population, as well as contribute to Copenhagen's visions for the future?

From this research question, these areas will be explored further with the use of the following sub questions:

- *Why could the city of Copenhagen be the place to utilize the technology of LED Vertical Farming or why not?*
- *The growing urban population of Copenhagen may entail more mouths to feed, but who should take the role of feeding these?*
- *How could LED Vertical Farming be utilized to address the current food supply chain, as well as environmental and sustainability issues within the city of Copenhagen?*

1.3 Definitions and Delimitations

With any research, the direction and area that can be explored has the ability to be broad with numerous aspects that could be considered. For the purpose of this thesis and to explore certain areas in more depth, there are certain delimitations that will not be included in this thesis. Urban agriculture can cover a wide range of practices, however, community, rooftop, communal and school gardens are not within the area of interest. With the city of Copenhagen being a developed Western capital, literature and research upon developing countries will not be used. Agriculture and sustainability related to and involving animals will also be excluded from any further research

as this is not an applicable area within LED Vertical Farming. However, literature that does not distinguish between the different agricultural types may be included.
The area of LED Vertical Farming and this type of growing technology that we are exploring could also have aspects related to social, health, community and consumer acceptance. However, it has been chosen that these areas will not be further investigated in this thesis.
During the thesis, perspectives from other countries may be brought in. This could be due to limited research or studies conducted in Denmark or with a Danish focus. When bringing in any other perspectives from outside of Denmark, research and studies conducted within Europe will be considered over developing countries or larger countries such as the United States of America. The overall focus for our thesis is to be on Copenhagen, Denmark.
The thesis will take an explorative and qualitative approach and will thus refrain from using quantitative methods.

Throughout the thesis we will be addressing the city of Copenhagen as well as Greater Copenhagen in later sections. For the purpose of this thesis, the City of Copenhagen includes the area that is within the district of Copenhagen Municipality. This also means that we acknowledge that when referring to papers written by Copenhagen Municipality this does not include Frederiksberg as it is its own municipality (The City of Copenhagen, n.d.). Although "*Greater Copenhagen is a metropolitan region that spans Eastern Denmark and Skåne in Southern Sweden*" (Greater Copenhagen, n.d.), we have a focus on Denmark so for the purpose of this thesis when referring to Greater Copenhagen it will be excluding Skåne in Southern Sweden.

As mentioned previously, this thesis will be written with an entrepreneurial viewpoint. For the purpose of this thesis, the definition of the term entrepreneur will be: "*one who organizes, manages, and assumes the risks of a business or enterprise*" (Merriam-Webster, 2017).

Next, we will clarify some of the definitions that will apply throughout the paper.
There are and have been put forward different definitions of what LED Vertical Farming is. From our exploratory research in later sections the reader will learn that we have found no universally accepted definition of LED Vertical Farming. Due to this, for the purpose of this thesis we describe LED Vertical Farming as a vertically stacked soilless growing method using LED lighting technology within a closed looped controlled environment that allows the most efficient growing conditions for the crop to provide reliable growth cycles (Despommier, 2010; Kozai & Nui, 2016b).

Throughout the thesis, the term Food Supply Chain will be used. To describe this, a definition published by the FAO within Agro-industrial Supply Chain Management: Concepts and Applications will be used;

"Supply Chain as a sequence of (decision making and execution) processes and (material, information and money) flows that aim to meet final customer requirements, that take place within and between different stages along a continuum, from production to final consumption. The Supply Chain not only includes the producer and its suppliers, but also, depending on the logistic flows, transporters, warehouses, retailers, and consumers themselves" (Vorst, Silva & Trienekens, 2007: 7).

Even though this is used as a term for supply chain as an overall definition, within this thesis it will be used with a focus on the food supply chain.

In the book, *Waste to Wealth, Creating Advantage in a Circular Economy* by Rutqvist & Lacym (2015) they highlight that the term circular economy has been around for many decades and define it as:

"…decoupling of economic growth from the extraction and consumption of constrained natural resources, i.e., scarce resources with negative footprints, like fossil fuels or hard-to-recycle metals and minerals, where dependency creates a competitive disadvantage over times. Instead, 'circular' approaches keep resources in productive use in the economy for as long as possible" (Rutqvist, & Lacym, 2015: XVII).

This definition will be used for the purpose of this thesis as it has relevance to the perspective that we take.

Food miles will be defined as

"*a measure of how far food travels between its production and the final consumer*" (Weber & Matthews, 2008: 3508).

1.4 Structure of the Thesis

The background, research question as well as definitions and delimitations have been explained earlier in this chapter.

In chapter 2 we will present the literature review and state of the art, where categories have been created to provide an overview of the information.

In chapter 3 the following theories used as the theoretical framework will be presented as well as explained in terms of how we intend to use each of them; The Diffusion of Innovation Theory, Path Dependency and Path Creation, Technological Determinism, Location Theory and Actor Network Theory.

In chapter 4 we will explain our research design and what perspective we take when gathering empirical data. The methods; SWOT Analysis, Mapping Historical Discourses, Situational Analysis and Actor Mapping that primarily will be used as pre-analytical tools will be explained before the expert interviewees are introduced.

In chapter 5 we will be analysing the literature, theories as well as empirical data. This will be done following the same categorical framework as seen in chapter 2.

Following the analysis, we will in chapter 6 open up the analysed data for discussion by making new categories. The theoretical and methodological frameworks will also be discussed as well as the interviews.

Lastly, we will be concluding on our exploration of the research area, hopefully having gained further enlightening insight to the LED Vertical Farming harvest in the city of Copenhagen.

2

Literature Review and State of the Art

This following section will present the current literature and research within our problem area. As LED Vertical Farming has not previously been researched within the context of Copenhagen, a literature review has been done to explore existing literature that is available, which in turn can be placed in connection with Copenhagen. These explored areas have been split into seven categories that we found relevant in order to provide an overview in the cluster of information. The literature found will in later sections be used exploratively alongside an analytical approach to the conducted expert interviews and theoretical viewpoints.

While conducting the literature review, among others, the following database search engines were mainly used; Academic Search Premier (Ebsco), Google Scholar, ProQuest and Bibliotek.dk. Using these search engines, provided us with a broader overview within different areas of literature related to our problem statement and search terms before narrowing it down. The City of Copenhagen and municipality's official websites were used to obtain their publications. To see an example of one of our literature searches see Appendix 1.

After a thorough search for the literature related to our research question, the references from this literature were looked upon as well as using the search tool "cited by" to find newer literature that had used the research paper. When considering this style of search method, we were aware to keep in mind that the research papers may have been cited numerous times due to criticism by other researchers. Within our thesis, literature found and used in regards to previous semester projects and curriculum were also used.

Research and literature were only used if they were available in either English or Danish language. There were no restrictions on the age of any material that was included within the thesis mainly due to exploring the history and evolution of LED's and the Vertical Farming technology.

The following sections will provide the reader with an understanding within certain areas of interest related to our topic and the literature that will be used to explore LED Vertical Farming further.

2.1 Environment and Sustainability

Sustainability can have various meanings depending on the context it is being used within, whether it is related to a business' future ambitions and forecasts, green workplaces, surroundings or environmental responsibilities (Morawicki, 2012). *The Handbook of Sustainability for the Food Sciences* describes that the term sustainability came around in the 1990's and defines it as;

"*a concept to reduce humans' environmental footprint and a way to assure the preservation of natural resources for future generations"* (Morawicki, 2012: 3).

The book looks upon various sustainability issues within the area of food science that the world faces and how each one of them plays a role within contributing to a complex subject area that require them to work and coordinate with one another (Morawicki, 2012).

The United Nations uses the definition for sustainable development from the 1987 World Commission on Environment and Development as:

"*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (UN, n.d.).

The United Nations sees that this sustainable development can be achieved through the use of three pillars: *economic* and *social* development as well as *environmental* protection.

In *Solution for a Cultivated Planet*, Foley et al. (2011) discusses how the global agricultural system needs to be reassessed and looked at, due to its current destructive manner and how it cannot keep up with the growing global demand. For a more sustainable agricultural system, Foley et al. (2011) states four key solutions:

- Cut greenhouse gas emissions from land use and farming by at least 80%
- Reduce biodiversity and habitat losses
- Reduce unsustainable water withdrawals, especially where water has competing demands
- Phase out water pollution from agricultural chemicals.

(Foley et al. 2011).

Looking for solutions to some of the above-mentioned issues related to the growing global population, Dr. Despommier, a retired professor from the University of Columbia in the United States, came up with the idea of vertical farming with his students in 1999. Subsequently in 2010, Dr. Despommier published a book titled, *The Vertical Farm Feeding the World in the 21st Century* (2010). The book is a personal voyage on how agriculture has evolved to the way it is being done today, how humans have played a major role within this and that the vertical farming technology could be a method of solving some of the agricultural problems the world faces today.

Dr. Despommier, who is seen as the pioneer within his field, believes that the vertical farms have the chance to change history within agriculture by achieving a true level of sustainability and believes that having this type of farming within the urban environment can be possible due to the role of technology. Using the resources, both new and old, within the urban environment, farming inside the city is possible and at the same time, sustainable, by using waste as a commodity (Despommier, 2010: 15 & 223).

With these visions of creating a more sustainable agricultural food system for the growing global and urban population, investigated research has started within the field of urban agriculture and food production. *Urban agriculture of the future: an overview of sustainability aspects of food*

production in and on buildings by Specht et al. (2014), investigate previously conducted research by using the three main areas of urban agriculture similar to those mentioned by the UN earlier; *Environmental*, *Social* and *Economic* (Specht et al., 2014). The potentials and limitations within these three areas, linked to this type of urban agriculture and how sustainable it could be to grow within an urban environment was collected by analysing 96 documents and provides areas with a sustainable viewpoint that will be relevant to explore within this thesis (Specht et al., 2014).

Globally, there has been increasing concern with climate change and consequences related to the rise in greenhouse gas (GHG) emissions. Carbon dioxide (CO_2) emissions are mentioned frequently when GHG are discussed due to CO_2 being one of the main contributors to this growing environmental concern (Li et al., 2016).

A report by The Danish Ministry of Food, Agriculture and Fisheries (2009) stated that: "In Denmark, agriculture contributes 14-16% of the total emissions of greenhouse gases" (The Danish Ministry of Food, Agriculture and Fisheries, 2009). Within agriculture the use of fossil fuels and how the land has been changed, such as clearing of forest, are also significant reasons for this increase in GHG (Nielsen et al., 2011). The way soil is cultivated within the agriculture sector also plays a role within its carbon storage with it either storing or releasing CO_2 into the atmosphere (The Danish Ministry of Food, Agriculture and Fisheries, 2009).

The emission of CO_2 is not only an area of concern related just to the growing stage of the produce but will still be a factor to consider throughout the whole journey throughout the food supply chain. Additional CO_2 is emitted during the processing, packaging, storage, cooling and transporting of the produce, all areas that play a role within the agriculture's CO_2 emissions (Kozai & Niu, 2016a).

In Denmark from 1985 to 2009 the amount of agricultural land has been reduced to make way for new urban development and infrastructure to be built (Nielsen et al., 2011). With agricultural land being displaced further from the urban developments, the increased distance that is required to travel to get to the consumer ultimately increases too that in turn puts more CO_2 into the environment (Ohyama, Takagaki & Kurasaka, 2008).

Due to the broad use of sustainability and numerous meanings, depending on what sector you are exploring within, for the purpose of this thesis the term sustainability will be used with a focus upon the LED Vertical Farming Technology that is executed within a Western urban city environment as well as relating to the food production and food supply chain.

2.2 Danish Farming, Land Use and Organic

Danish agriculture is the oldest and one of the largest Danish exports, which plays an important part in the country's economy (Statistics Denmark, n.d.). Adding to this, over 60% of Denmark's acreage also consists of farmland and is together with Bangladesh the most intensively farmed country in the world (Holmstrup et al., 2016).

At the same time, production of fruits and vegetables in Denmark, as well as in the other Nordic countries, face challenges due to the cold climate. In 2008 Denmark imported 68% of its total fruit and vegetable due to the limited growing seasons and conditions related to its climate. Within these imports, lettuce was among the five largest vegetable produce imported into Denmark (Chamber Trade Sweden, 2009).
In Denmark, the weather is not always optimal for all types of fruit and vegetable production. For that reason, greenhouses with controlled environments are, to a certain extent, able to compensate for the colder weather and thereby produce varieties that would otherwise be imported. However, the remaining required amount is still imported. It is notable, though, that 90% of the imported fruit and vegetables come from countries within the EU (Chamber Trade Sweden, 2009).

In 2012, the distribution of vegetables grown in greenhouses was 11%, whereas in 2014 it increased to 14% (Dansk Gartneri, 2012; Dansk Gartneri, 2016).
Greenhouse vegetables grown in Denmark have a relatively short transportation distance due to the small size of the country. According to *Fakta om dansk gartneri*, the Danish greenhouse farmers are currently actively focusing on sustainability in order to lower energy-, water- and pesticide consumption (Dansk Gartneri, 2016).
In Denmark, there are 153 greenhouse holdings spread out on a total of 438 hectares, where the greenhouse vegetables acreage takes up 109 hectares (Dansk Gartneri, 2016). The location of the vegetable grown in greenhouses are distributed to about 50% on Fyn, 43% on Zealand and 7% in Jutland (Dansk Gartneri, 2016).
A minimum of pesticide leftovers are found in greenhouse vegetables as biological pest control is mostly used and the demand for organic greenhouse vegetables is growing but currently it makes up 3% of the total sales of greenhouse vegetables (Dansk Gartneri, 2016).
When looking at the energy consumption in greenhouses they use about 20% of it on energy for the lights, which is mostly used during the winter whereas 80% is used for heating. However, within recent years the choice of energy sources has gone more sustainable by predominantly using district heating rather than coal or oil (Dansk Gartneri, 2016).

While the amount of greenhouse holdings growing vegetables have decreased, the acreage of the holdings has increased, which shows that the industry has moved from many smaller holdings to few but larger holdings (Dansk Gartneri, 2012). This is also mentioned in *Økologisk frugt og grønt* by Landbrug & Fødevarer (n.d.), that greenhouse farmers often choose to grow the same type of crop throughout their holding as needs change according to the specific crop. This in turn makes it difficult for the farmers to make the growing cost-effective (Landbrug & Fødevarer, n.d.).

In greenhouses in Denmark the season is between 1st of April to 1st of November and over recent years there has been an increase of organic greenhouses but they are seeing pressure from international competitors (Landbrug & Fødevarer, n.d.). Reasons for that could be that there are some challenges seen within growing organic in greenhouses. These include providing the plant with the right nutrients at the right time and to avoid yeast infections as well as pests. With each individual crop having specified needs in regards to the house construction and installations, it makes it difficult for a greenhouse farmer to create economic value when trying to grow more than one crop. For that reason, most greenhouses are mono-cropped, so crop rotation is a rarity, which in turn leads to increased risks or incidents of pests (Miljøstyrelsen, 2003).

Simultaneously, the largest threat against nature in Denmark is the lack of space due to intensive agriculture, draining of nutrient contents in the soil as well as city and infrastructure developments (Frostholm, Schjelde & Holmstrup, 2016). Despommier (2010) addresses this issue of space: "*If the world's population continues to increase and we need to place more and more land into agriculture, and if in doing so we are forced to cut down more forest, how can we expect the environment to heal itself*" (Despommier, 2010: 22).

This lack of space in turn serves to the loss of living spaces for species and the splitting of nature in many areas. Also, climate changes put pressure on the nature and the species living within it (Frostholm, Schjelde & Holmstrup, 2016). Certain chemicals that are harmful to insects are more often used preventively and routinely rather than used as pest control. Thus, some of the chemicals are taken up by the plants and the rest are released into the earth, water and air. It could take months or years before the chemicals are entirely decomposed (Holmstrup et al., 2016).
Also, over half of all disappeared or threatened species on "Den danske Rødliste" have their habitat in the forest (Frostholm, Schjelde & Holmstrup, 2016).
Despommier (2010) states a solution to this could be to change certain farming methods for specific crops into vertical farming. This would provide a larger growing surface area while at the same time utilizing less acreage. The old farmland could be returned into woodland and in doing so, would ideally assist in cleaning the air as well as increase biodiversity (Despommier, 2010).

In connection to this, Danmarks Nationale Skovprogram (Denmark's National Forest program) from 2002 already pledged that the forest area should be increased so woodland covers 20-25% of Denmark's acreage. The background for this is to increase the contribution to the climatic responsibilities and because forests provide a habitat for animals and plants, which plays an important role for the biodiversity. The forests also provide lasting bioenergy, storage of CO_2 in the wood of the trees as well as protection of groundwater due to its limited use of biocides and fertilizer (Skovpolitisk Udvalg, 2011).

CHAFEA (Consumers, Health, Agriculture and Food Executive Agency) in the European Commission shows that in recent years, Denmark has also become a world's leading organic nation with an 8.4% organic market share in sales (CHAFEA, 2017). This shows how Denmark has an increased demand for organic and has "*with organic food sales representing 10% of all food sales in 2016, moved organic from 'niche' to 'mainstream'*" (Fookes, n.d.: 1). As mentioned above, the Danish Agricultural system takes up 60% of the total land acreage and with this, 6.8% is organic acreage (Holmstrup et al., 2016).

Currently, Organic Denmark has a strategy for 2015-2020, in which they envision a world that both thinks and acts organically, to open for more and better organic system. In this, they have strategic goals in distributing organic to more fields and markets, involving more movement to create attitudes towards organic, as well as, working to make it profitable for the farmer to pursue sustainability and heightened quality. Also, they want to create a society rooting in the local (Økologisk Landsforening, 2015).

2.3 Food trends

The recent yearly analysis made by Landbrug & Fødevarer (2015) predicts the direction that food trends are heading and how these may look for the year to come. During this current writing process, Landbrug & Fødevarer (2016) published a second trend analysis for 2017.
This section will look at both of these published analyses and touch upon relevant points within their reports. To correlate Landbrug & Fødevarer findings with others, The Nordic Food Survey by EY (2015) is also used, a survey conducted within the Nordic countries; Denmark, Finland, Norway and Sweden. The report, *Our Food Future,* by the Food Standards Agency (2016) will be used to show food trends from the population in the United Kingdom to bring perspectives to the Danish and Nordic market analysis.

In the analyses for 2016 as well as 2017, Landbrug & Fødevarer (2015; 2016a) refer to eight important food trends that will gain interest from the Danish public during the up and coming year.

For both years, consumers demand more from the quality of the food, and have an increasing wish to know the content and origin of the product. The consumer would like to understand what is in their food and seek for transparency and a trustworthy farm-to-fork story. Also, an increase will continue in 2017 for Danish or region-specific produce. This leads to another trend that the demand for food quality will lead to an increased interest for less processed foods and for it to be closer to the natural source. Additionally, the consumers will distance themselves from a product, if the production methods seem incomprehensible and complex (Landbrug & Fødevarer, 2016a). Moreover, the responsible consumption is a trend that is addressed in both analyses. The desire from the consumer for transparency and the ability to understand where their food came from to make empowered choices, was also a common trend found within the population in the United Kingdom (Food Standards Agency, 2016). In the publication by EY (2015) this trend is also seen, in that consumers have become "*more interested, conscious and more demanding than ever before when it comes to food*" (EY, 2015: 5).

Landbrug & Fødevarer (2016a) mention a trend in the increased concern for nature, the conditions under which plants are grown and the increase of organic consumption, due to the wish for avoiding pesticides in fruits and vegetables to protect the environment (Landbrug & Fødevarer, 2015; 2016a). In this regard, the report stresses the trend of a growing consciousness regarding sustainability where importance is placed on quality over quantity, also concerning food waste, use of resources and the following environmental consequences. The consumer wants to be able to make a difference through their purchases (Landbrug & Fødevarer, 2016a). A reduction within food waste was a point brought up by the United Kingdom population as a food trend in the report by the Food Standards Agency (2016). The report highlights that consumers would like food waste to be addressed throughout the stages from farm to fork for a secure food future (Food Standards Agency, 2016).

In regards to sustainability, it is emphasized how the consumers demand for the producers and retailers to take responsibility and seek to better this through new developments and innovations. The analysis states that sustainability is not about reaching an achievable goal but rather seen as an ongoing process towards a production that protects the environment, climate, animals and humans (Landbrug & Fødevarer, 2016a).

A following trend is the demand of quality, transparency and growing consciousness on sustainability. This is expressed in a preference for locally produced products, which also includes the idea of shortening transportation. However, this could lead to the dilemma of foreign organic versus Danish conventional (Landbrug & Fødevarer, 2015).

Within the Nordic Food Survey Consumer Food Trends, EY (2015) found two new categories that consumers can fit into. One is the omni-channel, which is concerning the way consumers digitally shop for food (EY, 2015). The other one is the back-to-basics trend, which generally is a focus on food quality (EY, 2015).
Lastly, there is still seen an increase in the amount of people who class themselves as '*foodies*'. A term, which describes consumers that have interest in trying new products and investigating new directions for food (Landbrug & Fødevarer, 2015; 2016a).

These trends could give implications on what the needs of the Danish population are and thereby be part of providing reasons for and against LED Vertical Farming. Some of the trends found within the publication for the Danish population by Landbrug & Fødevarer are also found within the consumer food trends of the United Kingdom population within the Food Standards Agency (2016) publication Our Food Future (Food Standards Agency, 2016) as well as the Nordic Food Survey 2015 on Consumer Trends by EY (2015).

2.4 Urban Agriculture

Urban agriculture can be used as a term to cover a wide range of farming styles and locations, whether it would be rooftop greenhouses, rooftop gardens, indoor farms, communal gardens, vertical farming or using other building or spaces within the city related to farming (Specht et al. 2014).

Mougeot (2000), describes Urban Agriculture:

"*UA is an industry located within (intraurban) or on the fringe (periurban) of a town, a city or a metropolis, which grows or raises, processes and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area*" (Mougeot, 2000: 10).

In the guide by FAO (2001), they classify urban horticulture into three categories: *intensive horticulture systems*, where advanced cropping technologies are used; *mini- or microgardens* used to produce vegetables or cash crops; and *community gardens* that make use of subdivided land that is given by local administrators (FAO, 2001).

A new term for describing a type of urban agriculture has recently been used within literature known as Zero Acreage Farming or Z-Farming as a shorter abbreviation. Z-Farming is a way to describe how combining the food, architecture, design and production to produce food within buildings in the urban city environment while taking up smaller acreage space than conventional farming methods (Specht et al. 2014). A feature of urban agriculture can provide societal benefits through connecting communities, food security, education and transforming the local area (Eigenbrod & Gruda, 2015).

Relating to Copenhagen, in 2014, Østergro became Denmark's first urban agriculture company, when a group of people created a farm on the roof of a building in Copenhagen. The commercial urban farm sells some of the produce that it grows, such as vegetables, honey and eggs, as well as provides tours, events, workshops and dinners up on the rooftop. With this, they attempt to bridge a connection between the city and the farm (Oestergro, n.d.).
An urban agriculture initiative was created in May 2016 by Miljø- og Fødevareministeriet, who worked together with Styrelsen for Slotte og Kulturejendomme and Tagtomat within Kongens Have in Copenhagen. Here, a kitchen garden was set up for local residents to look after the produce being grown and to provide some inspiration for the development of future urban gardens within the city (Miljø- og Fødevareministeriet, 2016).

2.5 Light Emitting Diode (LED) Farming Technology

The reviews, literature and theories used throughout the thesis look at the lighting technology of LED's from a broad perspective. While this information gathered will still be purposeful to use, for the purpose of this thesis the main viewpoint will be LED's used within the horticultural sector.

Although this form of lighting technology has only recently been tested within horticulture, the introduction of LED's to the horticultural production have numerous benefits over the conventional lighting (Olle & Viršile, 2013). Some of the main benefits achieved with using LED's include the size, lightweight, lifetime of the lights, practicality and low lamp surface temperature (Massa et al. 2008). Another important benefit that LED's provide is the ability to select specific light wavelengths by changing the colour and amount of light. This allows for the LED's to be changed to suit the specific crop being grown (Massa et al., 2008: 1953).

The introduction of LED's, as with any new form of technology, will typically be more expensive to begin with compared to other conventional products that have been on the market beforehand (Drennen, Haitz & Tsao, 2001). However, the Haitz Law, although not a scientific law, aims to

demonstrate that over time the LED's technology improves while prices decrease as seen in figure 1. Alongside this, it is said that the cost of the LED's will decrease by around 10% each year, while at the same time the light efficacy will increase by 30% each year (Haitz et al., 2000). With these improvements, the future for LED's seems to be following a trend similar to the past 30 years, with increasing efficiency as well as decreasing prices. This trend has the ability to help the technology make future progress within the marketplace (Ton et al., 2003).

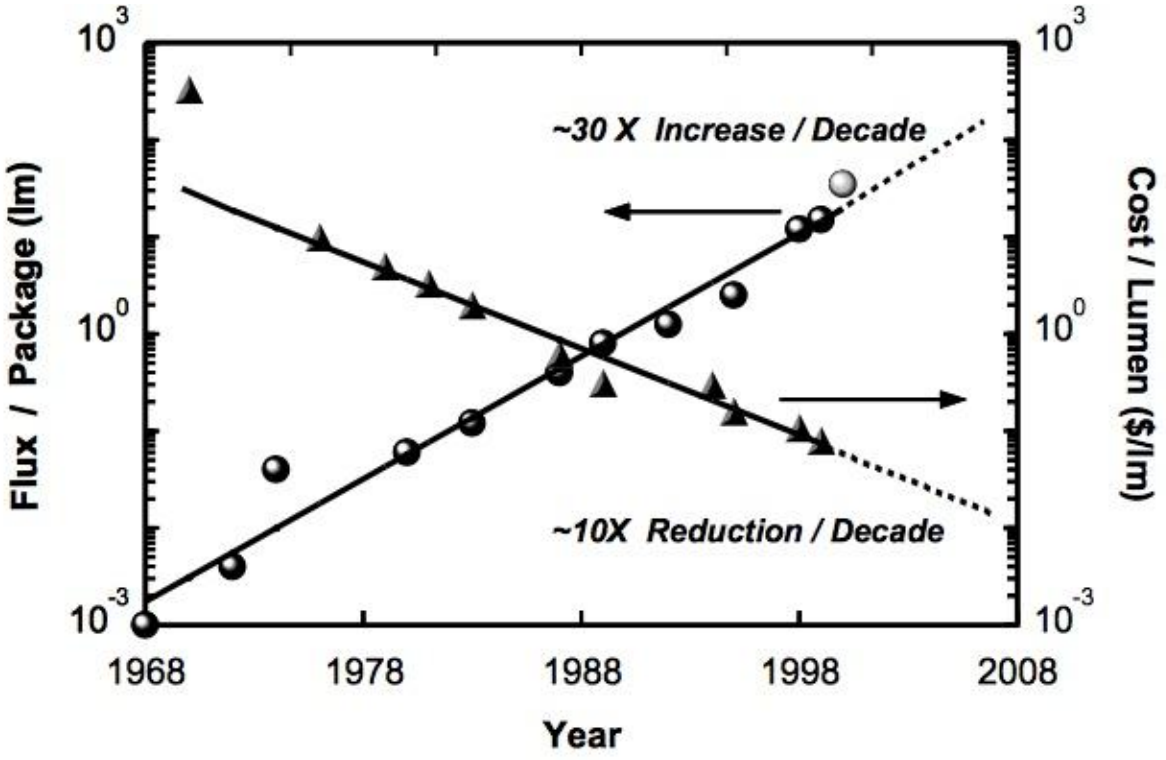


Figure 1. Evolution of red LED's over more than three decades (Haitz et al., 2000: 42)

The price and light production of the LED's are not the sole driver, but for the future market to reach its full potential, LED's are also going to be driven by economics, operational and maintenance cost, as well as the efficiency and lifetime of the technology (Slocum, 2005). However, price does play an important role for the consumer and within the demand for this form of lighting technology. With any market, supply and demand will help determine the price for the product because when the product is in demand companies can gain more experience through research and development with the production, helping future investments and costs for the product (Drennen, Haitz & Tsao, 2001).

2.6 LED Vertical Farming

As briefly mentioned in the Environment and Sustainability section 2.1, Dr Despommier within his research looked at some of the issues facing the world related to the global and urban growing population and put forward that growing vertically could be an important farming method for the future (Despommier, 2010).

Philips City Farming division defines vertical farming as; "*cultivation process involves growing crops in a small interior area, using multiple layer to maximize production*" (Philips Products, 2017). Building on this definition, we mentioned earlier on in section 1.3 that the thesis will define LED Vertical Farming as a vertically stacked soilless growing method using LED lighting technology within a closed looped controlled environment that allows the most efficient growing conditions for the crop, that allows reliable growth cycles.

Philips is one of the dominant and original innovators and producers of LED light solutions for the horticulture market. Also within their City Farming research centre in Eindhoven, The Netherlands, they are researching and developing this area of farming technology (Philips, 2016). Close to Eindhoven in Venlo, BrightBox research centre was created to explore the ideal growing solutions in connection with LED Vertical Farming to provide tailored information onto commercial growers and producers while using this farming technology to achieve the best results (BrightBox, 2016).

The produce grown through LED Vertical Farming technology is a major part of the growing system, however many other parts are still required to complete the whole system; LED lights, hardware, software, facilities and training to name a few. These are all vital parts because without one element the production cannot run to its full potential (Zip Farm, 2016).
Within the technology sector, whenever a new product comes to an existing market there will be businesses and companies establishing themselves to offer solutions and products to cater for this new addition, which can be seen globally within the LED Vertical Farming sector. If one is in need of a quick setup or have not found a location for their LED Vertical Farm then companies like *Freight Farms* and *Growtainer* supply portable converted shipping containers that have been fitted and customised to the grower's personal requests (Freight Farms, 2016; Growtainer, 2016). *Urban Crops* are a Belgium company offering personalised and ready-made facilities to start up a closed system hydroponic LED Vertical Farm (Urban Crop, 2016). While *Zip Grow* based in the US offers similar services, they also use their own designed vertical plane growing technology, which is integrated in their packages (Zip Farm, 2016).

Already established vertical farms like, *Aero Farms*, are also offering their services by providing their own patented growing solutions that have been tried and tested by themselves as an extra form of revenue and publicity to their brand and the LED Vertical Farming world (Aero Farms, 2016).

These above-mentioned businesses and companies are just the tip of the iceberg of those that are on the global market to cater to the various areas involved in and around the LED Vertical Farming technology. The market is continually growing and expanding with new companies establishing themselves due to this type of technology constantly being developed and advances being made within the field.

In the coming years, it may seem as if this area of the market is set to increase even more as a recent report conducted by Markets and Markets highlights the growing market around vertical farming and LED farming technology. The report predicts that by 2020 the global market share of vertical farming will reach 3.88 Billion US Dollars (Markets and Markets, 2016). While in another report they predict that the LED grow light market will increase by almost 27% by 2020 and will be worth 1.9 Billion US Dollars taking up a large share of the vertical farming market value (Markets and Markets, 2015).

2.7 Visions of The City of Copenhagen

In this section, we will present how The City of Copenhagen envisions the future for the city in regards to the ambitions they have for achieving goals. These agendas are presented in documents that will be presented briefly before being more thoroughly explored in the analysis section of the thesis.
The focus will be on documents that present visions in regards to environmental issues as these correspond to the aspects we wish to investigate further in this thesis.
Involving this visionary aspect in the thesis, allows us to see where the project may or may not fit into these visions and whether this new technology of LED Vertical Farming could help provide new aspects in contributing to these set out goals.

Since Copenhagen has put forth a major goal that by 2025 it will become entirely carbon neutral, this type of goal will require new initiatives focusing on environmental issues (Doody et al., 2016).
The document by Københavns Kommune (n.d.), *Bæredygtige sammenhænge – Agenda 21-strategi for 2016-2019* (Sustainable Connections – Agenda 21-strategy for 2016-2019) is based on

the agenda presented at the UN meeting on sustainable development in Rio de Janeiro in 1992 and emphasis was put on the importance of engaging the public in contributing to a sustainable future.
In this document, Morten Kabell, the minister for Technical & Environmental Administration, precedes by explaining the importance of pushing towards the future together in order to reach the goals. This document notes that it goes in conjunction with the plan-law (Planloven), which requires from the municipality that they make a strategy for how they wish to include the inhabitants to work with a holistic, cross-disciplinary as well as interdisciplinary approach (Københavns Kommune, n.d.).
In this document, several points are addressed including the issue of reducing CO_2 and making Copenhagen able to sustain future climate changes, which are some of the points that will be investigated within our thesis.
It is notable that emphasis is put on how the general Copenhagener actively must contribute in the interdisciplinary push towards these goals in order to reach success. It is about how the state can provide the best framework for different groups to work together on a long-term perspective (Københavns Kommune, n.d.).
Copenhagen Municipality envisions that it will work as a facilitator for the built partnership and that these partnerships must be supported.
Also, the annual report of 2014 as well as 2015 on Copenhagen Climate Projects, acknowledge the importance of inclusion of all parts in the society (Københavns Kommune, 2014; 2015a).

The document *Fællesskab København* (Community Copenhagen) shows the visions for Copenhagen for 2025 and states that "*Copenhagen will not and shall not be the same city in 2025*" (Københavns Kommune, 2015b: 2). Copenhagen is looking towards the future with ambitions of being a city stepping into a new league alongside other vibrant metropolises. It wants to show global leadership as well as have a dynamic edge, contrasting to Copenhagen's current description as being pretty, almost too pretty and predictable (Københavns Kommune, 2015b). Copenhagen envisions to reach these goals by thinking more out of the box and letting the creativity of the Copenhageners play a greater role in the development. It shows how there should be allowance for innovation and creativity (Københavns Kommune, 2015b).
This goes hand in hand with the previously mentioned document, *Bæredygtige Sammenhænge (*Københavns Kommune, n.d.), which also touches upon the importance of interdisciplinary work between the municipality and inhabitants of the city.
Fællesskab København presents three indicators, which this new 2025 Copenhagen should build on; "*A vivid city"* that invites for the inhabitants to use the open and public spaces (Københavns Kommune, 2015b: 6), "*A city with edge*" that should have its focus on creating the possibility to have courage to surprise, be creative and innovative so buildings can change its functions over time however without dividing the city (Københavns Kommune, 2015b: 9), as well as "*a responsible*

city" with the ambition of becoming the first CO_2 neutral city by 2025 including making use of available resources to be leaders in circular economy (Københavns Kommune, 2015b: 13).

Another publication, *Growing Smart Cities in Denmark*, written by *Invest in Denmark, Arup*, a global, independent consultancy that provides holistic and multidisciplinary solutions on management, planning, design and engineering, and *CEDI*, a company with expertise in digitizing the public sector, was written in collaboration with and funded by, amongst others, Ministry of Foreign Affairs of Denmark, City of Copenhagen and The Capital Region of Denmark (Doody et al., 2016).
On behalf of the Danish public authorities, this publication explores the opportunities cities in Denmark have in becoming smart cities to support Denmark's economy and how to approach it. Generally, smart cities entail initiating projects that utilize cutting-edge technology in an urban context that in the long run could be part of creating jobs and business growth. Also, it can give new opportunities for countries; "*the opportunity to improve urban areas*" as well as "*to grow the national economy*" (Doody et al., 2016: 11).
Although our thesis will only focus on Copenhagen, this document does show an important aspect of mirroring the experiences, results and ideas in one city on to other cities. In this way, the cities can work together so the smart city projects do not merely end as pilot project (Doody et al., 2016).

Similar to the *Fællesskab København* document (Københavns Kommune, 2015b), this publication by Doody et al. (2016) envisions how Denmark has a potential to become a world leader in smart cities but that it currently has some limitations. However, by using systematic and holistic approaches in becoming a smart city, Denmark has, according to Doody et al. (2016), the potential to become more efficient, environmentally friendly and liveable.
There is currently a hindrance in receiving investments for innovative solutions in the public sector as it is often associated with a higher risk, due to high investment costs, overall longer-term profitability and low municipal funding (Doody et al., 2016). Therefore, the digital solution must have a correlation between private and public sectors as well as commitment from the municipal side. Also, there must be a public acceptance of this innovation, which can prove slightly difficult as digitizing data also means sharing of data collected and that could be conflicting. Currently, the municipalities are the main representatives of implementing and operating smart city projects in Denmark (Doody et al., 2016).

This section has provided an overall viewpoint of the areas of interest found within this subject area for the thesis and creates a base for our further exploratory research. The following section will introduce the theories that will be used throughout the thesis as a way to explore the data collected.

3

Theoretical Framework

The theories that will be presented in this chapter are used in our thesis to understand and analyse the empirical data as well as the literature in section 5 and the discussion of the findings in section six.

The following sections will present the theories one by one and at the end of each of the sections we will explain what we intend to use the theories for in the later sections of the thesis. The theories will ultimately be used to provide perspectives to the analytical process of the literature and expert interviews.

3.1 The Diffusion of Innovation Theory

In this thesis, we are going to use the theory, Diffusion of Innovation by Rogers (2003), as a way to explore how new ideas and products are adopted by people. This theory has been picked due to Rogers' long term academic work within the field and because the Diffusion of Innovation Theory takes a theoretical framework within the area of new technology diffusion and adoption (Sahin, 2006).

The Diffusion of Innovation Theory suggests that media and certain opinion leaders within society play a role in creating knowledge and understanding of a new product or idea and in turn get others to adopt it through communicating information (Melkote, 2006).

Diffusion can be seen as something that has an influence on social change. When something new has been created, diffused and then in the end accepted or rejected by the consumers, it will most likely have some affect to society, whether it be intentional or unintentional (Rogers, 2003: 19).

Rogers mentions that diffusion is seen as a special kind of communication method, where the messages being produced are about a new idea. Due to the messages having this degree of newness to them, gives a level of uncertainty involved within the diffusion (Rogers, 2003: 6 & 12). Even though the new idea may not be brand new within society and could have been around for many years, if the individual feels it is new to them, then it will seem like an innovation (Sahin, 2006) as well as the newness will determine their reaction towards it (Rogers, 2003: 6 & 12).

When the diffusion of a new idea comes around, Rogers mentions that there are four main elements within this process of how this information will be transmitted from the idea to the end user: "(1) an *innovation* (2) that is *communicated* through certain *channels* (3) *over time* (4) among the members of a *social system*." (Rogers, 2003: 36).

Rogers (2003) demonstrates how new ideas are taken up by five different types of adopters in figure 2 and how these would typically be described:

- Innovators: venturesome
- Early Adopters: respect
- Early Majority: deliberate
- Late Majority: sceptical
- Laggards: traditional

(Rogers, 2003: 298)

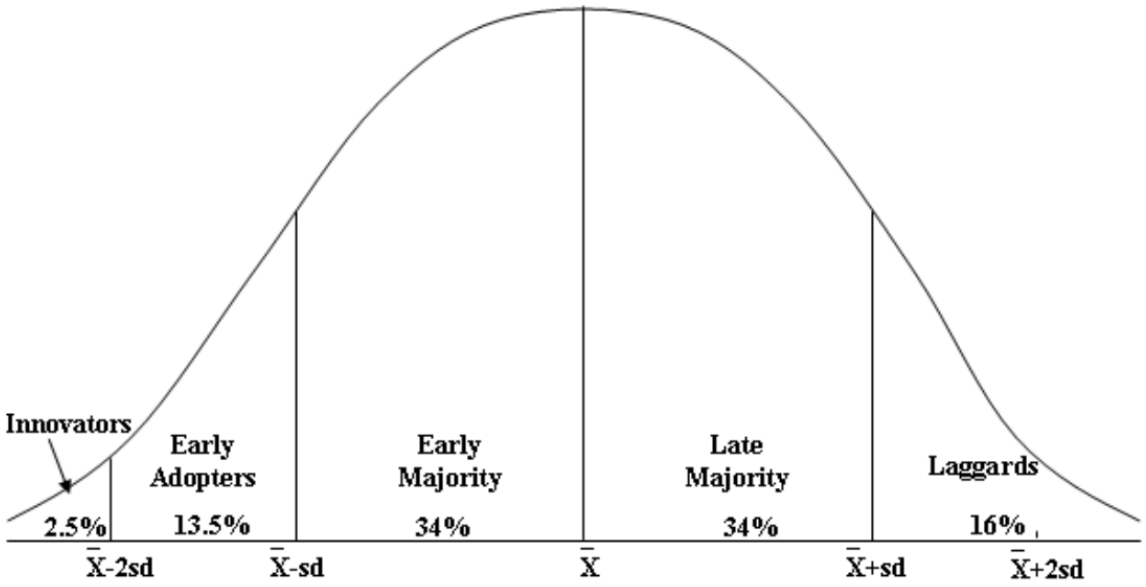


Figure 2. Adopter Categorization on the Basis of Innovativeness (Rogers, 2003: 281).

The first and smallest group of the five adopter types are the *Innovators*, they are the ones who are willing to take the risk of adopting a new innovation. Due to this risk and uncertainty they may face setbacks but their interest plays an important part within the diffusion process (Rogers, 2003: 283).

Even though the *Early Adopter* group has the second smallest total percentage, the highest amount of opinion leaders out of the five adopter groups are found here. Others look at them as role models to whether this new innovation is worth adopting and seek to gain information and advice from the *Early Adopters*. The *Early Adopters* play an important role in communicating messages to their peers and can do this whether or not they adopt a new idea (Rogers, 2003: 283).

The *Early Majority* are the ones who will adopt the new idea just before the average person within society. Taking up the joint top percentage of adopters, they are important within the diffusion process as they are interlinked to many networks and can spread the message to many. They tend to wait a little longer than the first two adopters before adopting the new idea but still have a desire to adopt before others (Rogers, 2003: 284).

The next adopters that also make up 34% are the *Late Majority* and typically are more sceptic and cautious when it comes to new ideas, as they need to feel safe. They will only start to adopt an idea once a large majority of others have and are influenced by pressure from others around them in society (Rogers, 2003: 284).

The last of the five adopters are the *Laggards*. They spend longer time during their innovation decision process, as they are more suspicious and will typically have traditional past values. The *Laggards* also need to see a certainty of success in the new idea before they feel that they can adopt it (Rogers, 2003: 284).

In other words, Rogers believes that the Diffusion of Innovation explains during the adoption of a new idea or product, there are a small percentage of people who jump in first and get on board. These adopters who were first to embrace it, will start to talk about it to others who in turn will become more willing to join in before spreading to the main bulk of society. Over a period of time, the innovation will have diffused across the population until it has reached its peak saturation point where the adoption rate will slow down and inevitably stop (Kaminski, 2011).

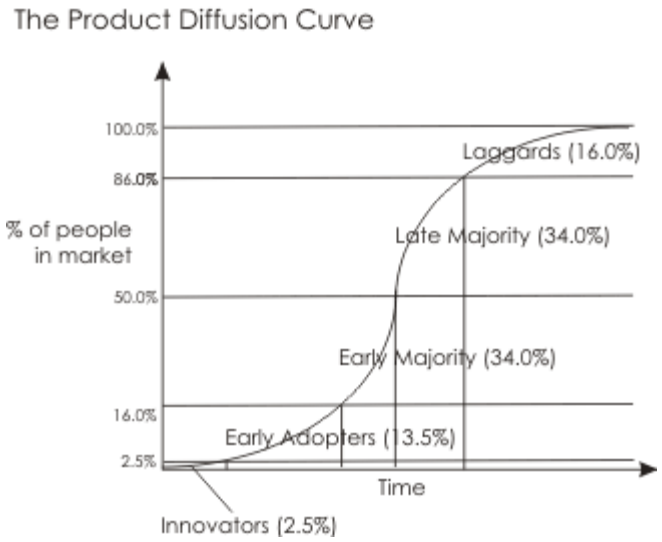


Figure 3. The Product Diffusion Curve (Mindtools, 2017).

The aim of the Diffusion of Innovation theory is not to try and move adopters between one or more of the adoption categories but to find a way to work efficiently with all five adopters. Then over time they will all adopt the new innovation as shown in figure 3, so the innovation captures 100% of the market share, or try to capture as much as possible (Kaminski, 2011).

For the purpose of this thesis, Diffusion of Innovation Theory can be used to describe how there are different stages of adapting to new innovations and technology like this of LED Vertical Farming. We believe that this theory can create insight to how the different actors may influence or play a role in the adoption rate of LED Vertical Farming.

3.2 Path Dependency and Path Creation

The events of the past, whether it be positive or negative, play a role when explaining why organizations and companies make strategic choices or decide that one way is a better choice over another (Sydow, Schreyögg & Koch, 2009).

Path dependence outlook suggests that people return to the way that things have typically been done and keep on doing it the same way. By doing this in such a way, that chosen path that everyone heads down tends to become entrenched as more people decide to go in the same direction (Cowan & Gunby, 1996: 512). Path dependence takes a viewpoint to what has happened in the past will play an important role within the current and future decisions as well as what actions will be taken in the future (Sydow, Schreyögg & Koch, 2009). People may choose to take the path that has already been created, walked upon and explored, as they know the outcome from previous experiences, which could be what they seek to achieve (Cowan & Gunby, 1996: 512).

Vergne and Durand (2010) give their own definition of path dependence as being:

"property of a stochastic process which obtains under two conditions (contingency and self-reinforcement) and causes lock-in in the absence of exogenous shock" (Vergne & Durand, 2010: 737).

With this definition, Vergne and Durand mention that from the view of path dependence, once someone has been locked in, it is very hard for them to break out unless an external shock occurs (Garud, Kumaraswamy & Karnøe, 2010).
Although others may suggest history or past events play a role, the reason(s) why someone may head down a path dependant route is still unclear. However, Vergne and Durand explain that it could be due to: "*initial conditions are followed by a series of contingent (or chance) events whose influence on the path taken is larger than that of the initial conditions themselves*" (Vergne & Durand, 2010: 741).

While other researchers are trying to explain and expand the definitions for path dependence, Garud & Karnøe (2012) have created a definition to view the paths taken by people in a new light. This new definition is called path creation:

"Path creation does not understand agencies to be constrained by the past actions nor is path creation a rejection of the past. It is constituted by the sociotechnical arrangements that shape temporal dynamics of projects as actors frame issues about the future, coordinate their actions in

the present and make sense of what may have transpired in the past" (Karnøe & Garud, 2012: 735).

Also, Garud & Karnøe go on to explain how: "*entrepreneurs meaningfully navigate a flow of events even as they constitute them*" (Garud & Karnøe, 2000: 2), meaning entrepreneurs head down a path that is not entrenched as traditional methods and one could say take things as they come when met with something that they did not expect.
Entrepreneurs differ from those taking the established path by using their own knowledge to reflect and act in a way they feel suits their route rather than obeying to existing social rules (Garud & Karnøe, 2000: 2).
For new paths to be created and move forward the entrepreneurs need to look to do things that may be alternated but could return greater potentials. This creation and activation is a crucial part of path creation (Garud & Karnøe 2000: 7).

One of the drawbacks of trying to create new paths, such as when you are creating something different, you need to not replicate from what is happening within the present-day situation. This can be hard for people to overcome as they are living in the present, not the future (Garud & Karnøe, 2000: 10).

Path creation provides possibilities to those who decide to step away from the traditional route. It allows for actors, such as entrepreneurs, to explore and develop new ideas and allows for these to be developed for future goals and rearranged to suit the future (Karnøe & Garud, 2012). Being able to see whether to carry on or change throughout the different stages is an integral part of taking the path creation route (Garud & Karnøe, 2000: 17-18).

We find the Theory of Path Dependency and Path Creation relevant to use within our thesis, as it relates to breaking free from the norm and creates an understanding to why some may stick to an entrenched route. Nonetheless, it highlights why others can reflect on current states to create new paths such as seen with bringing LED Vertical Farming to the city of Copenhagen. This theory acknowledges the fact that the past plays an important role for the future but how new creations may entail not obeying to social rules.

3.3 Technological Determinism

The information typically provided for us through media avenues has implications on our everyday practices, relationships with society as well as our identity (Livingstone, 2003).

Advances within technology provides the ability to communicate messages and information while at the same time allowing the opportunity to reach a large amount of people from all corners of the world. Also, modern society shows that technology not only helps people on a daily basis but at the same time technology reshapes and affects the meaning and way these daily tasks are considered (Winner, 1989).

Technology, in various different forms, becomes a part of our everyday life and takes a habitual role with routines playing a role by using it without really considering our actions. But wonder if one day people woke up and found that a certain technology had been removed from their grips, it would be difficult to understand how they could have lived without it *(*Winner, 1989).

The term technological determinism was said to have been created by Thorstein Veblen (1857-1929) an American sociologist and economist (Chandler, 1995). The technological determinism theory sees that certain changes within technical development, media or technology itself are the sole or one of the main causes for societal change (Chandler, 1995).

Since then technological determinism has been investigated by many different researchers each adding their own perspectives. Winner (1989) in his book; *The Whale and the Reactor: A Search for Limits in an Age of High Technology*, suggests that Technological Determinism is;

*"the idea that technological innovation is the basic cause of changes in society and that human beings have little choice other than to sit back and watch this ineluctable process unfold" (*Winner, 1989: 9 & 10).

Marshall McLuhan's research investigated how communication media had an influence on individuals and society. He was also a technological determinist as he believed that one of the main causes of social changes within society was due to technology. That technology is forcing people to reconsider and revaluate everyday actions that people used to take for granted (McLuhan & Fiore, 2001).

In the book, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought*, Winner (1978) provides two hypotheses on the term, technological determinism:

- *"That the technical base of society is the fundamental condition affecting all patterns of social existence" and*
- *"That changes in technology are the single most important source of change in society"*

(Winner, 1978: 76).

Some critics felt that the definition needed to be split into either, 'hard' or 'soft' technological determinism to allow more ability for human control as well as cultural variation for the definition. Hard technological determinism means that certain technology takes control and can be seen as the main cause for social development and organization and that consequences are going to happen or are highly likely to happen. On the other hand, soft technological determinism is that with technology being available it allows people the chance to choose or opens up new options but it is up to that person who may or may not decide to do so (Chandler, 1995).

With technological development and advances there is a recognition that once a new technology has been released, people will already have started to change their activity and human institutions. It is seen with these new technologies being introduced, that people's behaviour and outlook will have to change to suit, or it will simply not work *(*Winner, 1989: 11).

The Technological Determinism theory will be used as a way to delve into how introducing LED Vertical Farming within the city of Copenhagen could shape society and how people look at the way their food is produced. Exploring how this form of agricultural technology shapes or could support the needs of the urban population and how this technology could control certain aspects related to the actors involved.

3.4 Location Theory

Johann Heinrich von Thünen, born on 24th June 1783 and later landowner and farmer in the province of Mecklenburg, Germany. He began the notions of his theory while studying at the agricultural college in a suburb city to Hamburg and soon noticed the influence a larger city like Hamburg had on the agriculture in the surrounding area. Later, he came to understand the importance of mathematics in the theoretical study of agriculture, which would create the grounds for his theory (von Thünen, 1966: xii-xliv).

Before addressing von Thünen's location theory any further we must touch upon his hypotheses, which creates the groundwork for further understanding: "*the isolated state*" or "*the central town*" (von Thünen, 1966: 7-11). When von Thünen created the idea of the isolated state he created an imaginary state called, *"The Central Town"*, and in this central town the market for selling produce and where people spent their money was located. It is important to note that in order for the theory to work, this central town must be thought of as being self-sufficient and thereby not influenced by any outside factors, but is rather a lone state surrounded by unoccupied wilderness, that cuts the

area off from the outside world. Also, physical characteristics such as the soil's capability of cultivation and fertility is consistent (von Thünen, 1966: 7-11).
Once again, this is a simplification of the reality and von Thünen also understands this. However, he finds it important to create the imaginary assumptions in order to correspond to conditions in reality.
Assuming this homogeneity of the land surface surrounding the central town, he speaks of the concentric rings that encapsulate the city.

The first ring around the city, called *"free cultivation",* is meant for vegetable and dairy farming due to being highly perishable products or for produce that has short life expectancy. Also with this first ring's location being close to the city the cost of rent is high, which means the product must be able to be grown intensely to create profit. The farmer or producer must compare the expensive transportation cost to the value of the product they wish to produce (Ponsard, 1983: 13-18). Next, is the *"forestry ring"*. In von Thünen's time timber and firewood were important and very heavy to transport so it was better to have it within the second ring closer to the central town. However, he did touch upon difficulties of wood's low capability of quick adaption to change and demand. On the outer edge of this ring as well as the next three rings is the production of cereals, however the further out the farm is, the more important it is that the product can pay back the high expenses occurring during the production. Being this far away from the market, the product must be more resistant, especially in regards to transportation. The last and sixth ring is occupied by livestock. This is because firstly you need a lot of land to keep livestock. Also, back in those days transportation cost would be low as the livestock could walk itself into the city to the slaughterhouse before being sold. Anything past this ring will be wilderness and cannot be profitable as the long distance from farm to market is too high to be profitable (Ponsard, 1983:13-18, von Thünen, 1966: xii-xliv; 7-11). The figure 4 below provides a visual demonstration of the concentric rings.

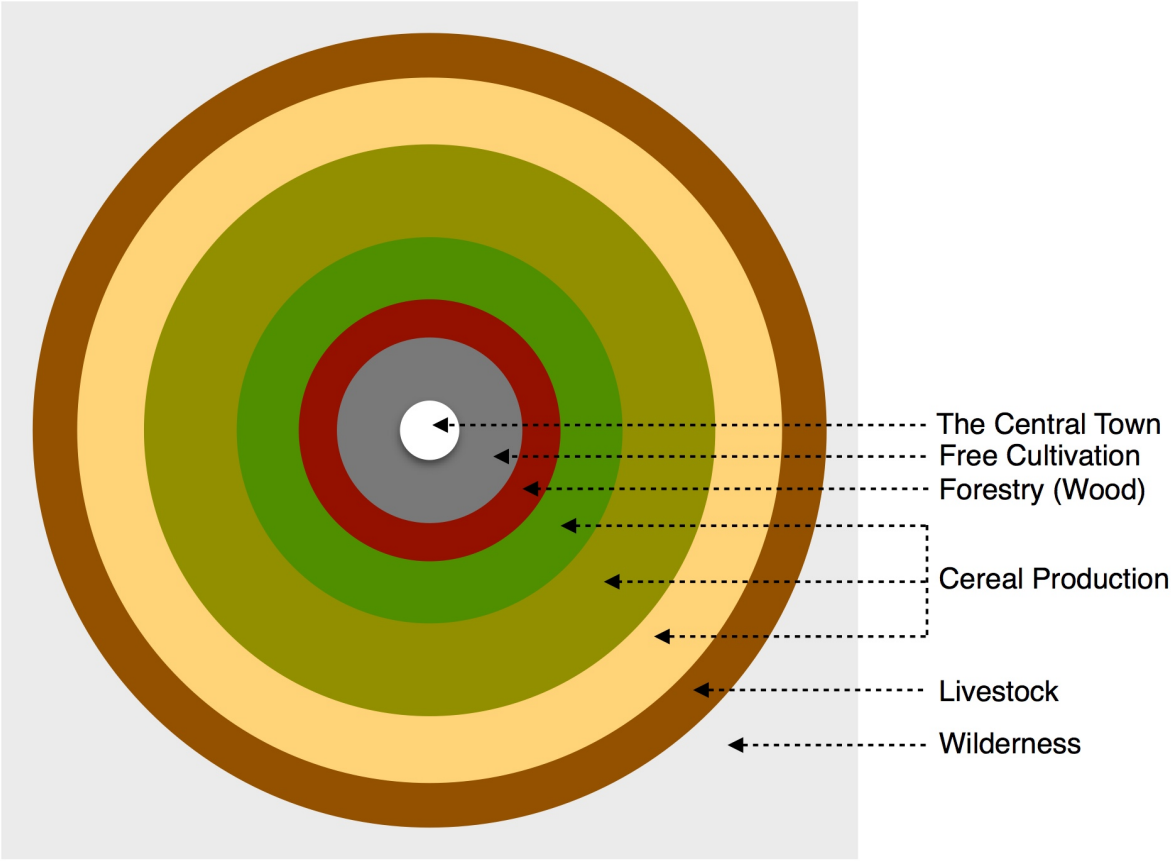


Figure 4. Own visualisation based on von Thünen Location Theory (Ponsard, 1983: 13-18, von Thünen, 1966: xii-xliv; 7-11).

Thus, he turns to the question of how the surrounding areas will be affected by their distance to the market in the central town, or as he later calls it "*The Town*".
Von Thünen made a marginal price theory saying that the price of the product "*must be high enough to pay the highest cost of growing and delivery from the farm, the cultivation which is still indispensable for the satisfaction of demand without the land rent becoming negative*" (Ponsard, 1983: 15). Ponsard also put forth in the, *History of Spatial Economic Theory*: "*Land rent becomes an indicator of the opportunities involved in various available methods of cultivation and in the choice of various products*" (Ponsard, 1983: 14).

There have been critiques of the theory, in that the likelihood of a city to be enclosed and not near other cities is small. Von Thünen also acknowledges this himself in that a city, which would have a navigable river coming into the city could provide it with the opportunity of having goods transported from elsewhere, further away from the city. This in turn goes against the concentric rings that von Thünen puts forth within his location theory (Clark, 1967). Also, some of the general aspects of the theory may be outdated such as the difference in demand for crops in the

contemporary world. One example is firewood, which back in the 1800's when von Thünen lived, this commodity was in high demand and therefore also necessary to place close to the city in the second concentric ring. With historical developments, most houses no longer are predominantly heated by firewood ovens, so in turn the demand for this product has decreased (Frambach, 2012). However, von Thünen's theory still provides aspects that are relevant even in the modern world, in that profitability is a precondition for a business to succeed. To summarize, "*close to the city, crops will be grown, which are very expensive to transport, which are highly perishable or – taking the high price of land near the town into account – which can be cultivated very intensively, that is, cost saving*." (Frambach, 2012: 306).

The Location Theory by von Thünen, will be used as a way to explore reasons why agriculture has moved out of the city. With this we can explore whether this Location Theory can still be used to explore and discuss the option of the agricultural technology of LED Vertical Farming related to how in the contemporary world there is an increasing focus on sustainability and CO_2 emissions. So rather than looking at the expenses of transportation then looking at it from the perspective of what it does to the environment to transport these highly perishable products further distances.

3.5 Actor Network Theory

"The actors identified in ANT are actants, things made to act"

(Sismondo, 2010: 82).

The fundamentals of the Actor Network Theory are that all actors, whether being human or non-human actors, serve equal importance and all contribute to building networks. But one must understand all constituents; the already existing networks and competitors, as well as the technology one is working with, to see the entire picture and to build the new networks. This also means that no actor has a higher role than the other, which gives us the opportunity to keep an open mind as well as opening up for all types of data. Perhaps this could lead to difficulties and very complex combinations of actor networks. However, by taking all factors into consideration, we will be able to see more aspects of the contemporary world (Sismondo, 2010).

Science and technology in ANT allows the modern world to pull things apart into its individual elements creating a better understanding of it and to then allow for creating new connections between the given human and non-human actors. This in turn expands the social world (Sismondo, 2010). By doing so one can try to reshape the contemporary world because the non-human actants can be pulled apart and understood better. But when identifying actors one must see what

relevance, power or interest the given actor has, to understand whether alliances can be built or not (Sismondo, 2010).
At the same time, all of these actors need to be managed to understand the interest of all and translating the interest if agreement should be formed. It is also important to bring the actors together. By doing so they must act together, which refers to the whole essence behind actors being "*actants*, things *made to act*" (Sismondo, 2010: 82).

Difficulties could occur as *"objects are defined by their places in networks, and their properties appear in the contexts of tests, not in isolation"* and *"social interests are not fixed and internal to actors, but are changeable external objects"* (Sismondo, 2010: 86). ANT is built on relations and everything working together in a society. This also means that actors may have one idea to begin with but if one element changes, such as an opinion of another actor or new technology appears, then an actor may start seeing new possibilities in something they did not previously think would be possible. Mindsets will change in societies as the society and the people living within it are constantly affected by each other. However, this also shows the importance of keeping an overview of the involved actors and their interests as these may change over time (Sismondo, 2010).

Looking at ecological thinking within ANT *"scientific and technological work is performed in complex ecological circumstances; to be successful, that work must fit into or reshape its environment"* (Sismondo, 2010: 86). So, if you want to create something new it either has to fit into the already existing environment or reshape it. But nonetheless you must be aware of the current state of environment and you must understand the circumstances in order to be able to reshape it.
It can prove difficult to generalize whether a given idea is good or a bad or whether it will be a success or a failure as this network of working towards a goal is built from many components that must work together.

A critique on of this theory is that the ANT says human and non-human actors are the same. It is instead argued that non-human actors do not have intentionality and thereby do not have a mental state, such as having beliefs or desires; *"To treat humans and non-humans symmetrically, ANT has to deny that intentionality is necessary for action, and thus deny that the differences between humans and non-humans are important for the theory overall*" (Sismondo, 2010: 90).

The ANT will allow us to identify the key actors within this thesis, whether they are human or non-human, as a means to explore the area of LED Vertical Farming. As this area is new to both of us as researchers this theory will help to understand the roles of the individual actors and how they could influence one another as a way to understand this area in more depth. Since the ANT helps to pull the information apart as well as provides the ability for a wider viewpoint, this can be helpful when

the subject area of LED Vertical Farming consists of many interpretable human and non-human aspects.

Having introduced the five theories that will be used within this thesis, we now proceed to the following section where the methods that will be used within this thesis will be introduced and explained.

4

Methodology

Prior to approaching the analytical process, we will, as part of this methodology section explain our research design and what perspective we take when gathering empirical data. Following this, we will explain the methods that we intend to use, primarily as pre-analytical tools to better understand the aspects of LED Vertical Farming. Lastly, we will introduce the experts that we have deemed relevant to interview to explore the field of LED Vertical Farming.

4.1 Research Design

Our thesis takes point of departure in a qualitative research design as this allows us as researchers to investigate in a context-specific setting, which in this case is LED Vertical Farming within the city of Copenhagen. Within the qualitative method we take the stance of a constructivist, also called interpretive, research paradigm. This means that we have the belief that reality is created in the individual and to bring this reality to the surface is through "*the interaction between the investigator and the object of investigation*" (Ponterotto, 2005: 129). This we will do through interviews. At the same time, we must also reflect on the ontology within this research paradigm, which "*concerns the nature of reality and being*" (Ponterotto, 2005: 130), where we with the constructivist approach see the world as being constructed by multiple realities. This also means that an individual and its reality will constantly be affected by its social environment. For us, this means that while one interviewee may have one standpoint at the time of our interview then shortly after this could be changed for example if political rulings were to change, which in turn could affect their business. Therefore, with this research design we understand that the world is constantly changing (Ponterotto, 2005).

4.1.1 Role of Researchers

When writing an academic paper, it is important to acknowledge our roles as researchers and where we position ourselves within the research. Although throughout the thesis there is an active attempt to keep an objective viewpoint, we as researchers from a constructivist approach acknowledge the influences that come from our surroundings, previous knowledge and experience. This means that what we present in this thesis is a version of how we understand the social reality instead of a definite (Ezzy, 2002).

Both of us as researchers have an international background and a bachelor's degree within Nutrition and Health. Throughout the current master's in Integrated Food Studies we have acquired knowledge and viewpoints on the world that combined with our previous education provides us with an understanding on sustainability, food production, nutritional value of a given food product as well as many other relatable aspects.
However, prior to this writing process we have had no connection or experience within LED, vertical farming, farming technology methods or the like aside from a personal interest. With this in mind we cannot completely come with an unbiased mindset, but by using an explorative and analytical perspective we aim to not simply jump to conclusions but to take a critical standpoint to the subject matter.

4.1.2 Exploratory and Analytical Study Design

Starting the qualitative research by looking at the phenomena from an explorative perspective provides us with the opportunity to clarify thoughts and opinions in regards to our area of interest. Utilizing this type of research is evident, when investigating a topic that has not previously been widely researched upon and considering the fact that this area is new to us (Nargundkar, 2003). The method that will be used to explore the field are expert interviews with actors that are involved within aspects of LED Vertical Farming. Following this, we will utilize an analytical approach to critically examine the expert interviews and email interviews, coupled with the relevant theories and the literature found in state of the art to evaluate these relative to our research area.

4.1.3 Semi-structured Interviews

Qualitative interviews with participants relevant for our research area will be used in this project, as interviews work as an important tool to gain knowledge about the participant's worldview and as Kvale (2007) states; *"The research interview is an inter-view where knowledge is constructed in the interaction between the interviewer and the interviewee"* (Kvale, 2007: 2).

For the purpose of this thesis, we choose to conduct semi-structured qualitative interviews as this method provides the researcher with a framework containing a structured set of questions as well as allowing for deviance from this framework. This ensures that all needed aspects are covered but at the same time giving opportunity to ask more in depth and follow-up questions depending on in what direction the conversation goes (Kvale, 2007).
In this way, the interviews will function as a dialogue between the interviewee and the researcher in order for the researcher to better understand the phenomenon and the life world of the interviewee. However, we as researchers determine the structure and purpose of the interview (Kvale, 2007). This was done through creating an interview guide, see example in appendix 2, which was the same throughout the various interviews to provide the needed framework for the questions but prior to each interview this guide was modified to suit the specific needs (Kvale, 2007). To the extent possible, the interviews will be conducted in English.
It is important to note that although we as researchers attempt to be objective, we also acknowledge that we have pre-understandings and ways of interpreting the spoken word. In order to avoid bias, we to the extent possible will ask follow-up questions to reassure that we have understood the true context.

The format for the questions that are going to be asked during the various interviews within this thesis will follow an open question style. The open style was picked over closed for our interviews

as it allows the interviewees the option to reply how they would like to answer the question and provide their own personal point of views, insights and experiences (Bryman, 2012: 246).

With any kind of method there will also be some form of advantage and disadvantage for choosing one over another. One advantage was mentioned above by allowing the respondents to answer in their own way. By having no fixed replying option(s) this allows the chance to hear and look into their knowledge and understanding within that area in question and it can also open up other areas of interest that may have been overlooked while planning the questions for the interviews (Bryman, 2012: 247).
With advantages will also come some disadvantages that need to be considered during the process of the interviews. Having this open format for the questions allow the respondents the freedom and ability to speak for as long and in as much detail as they like and this could lead them off track from the main focal point. While at the same time some respondents may struggle to talk or actively describe their answers as they find the question being too open for them to understand what is being asked from them (Bryman, 2012: 247).

With the various interviews taking place, ethical considerations need to be taken into account for both the respondents involved as well as the organisations and businesses they are representing. Having agreed upon mutual informed consent before and during the interview process is important. Both parties will be aware on how the information and data collected will be used within the process and respecting any confidentiality requirements related to this (Brinkmann & Kvale, 2015: 91-96).

4.1.4 E-mail Correspondence

When possible during the project, prearranged interviews will take place face to face or using communication methods through phone or Skype. In the case that the ones who are to be interviewed are unable to attend or facilitate either one of these style of interviews, the use of email interview will be used.

The email interview will follow a semi structured question format and that in some cases may involve numerous email correspondences between the interviewer and interviewee over an extended period of time before all questions have been answered (Lokman, 2006).
Due to the volume and the way emails are received by companies and individuals, follow up email replies may be required for the interview to be conducted and completed. (Lokman, 2006).

There are certain limitations of conducting email interviews as opposed to face to face interviews where you have the ability to delve into the questions through seeing the interviewees reactions. There is also the chance to ask further into a response or question in real time, which provides the chance to enrich and provide more data within the interview (Lokman, 2006).

4.1.5 Interviewing Experts

The interviews will be conducted with various actors involved within an active role related to the area of interest. The actors that will be interviewed in this thesis will be known throughout as *experts* and will be noted as experts as they are involved within our area of research for the thesis at a senior or managerial position (Meuser & Nagel, 2009: 18).

By conducting interviews with experts within the field of interest is a good starting point to begin by exploring the area early on in the process, through a direct, efficient and more concentrated method of collecting data than other data collecting methods, surveys or observations. Also, working with active experts involved within the field also provide access into other areas or closer social circles that may typically have been off limits (Bogner, Littig & Menz, 2009: 2).

Before conducting the interviews with each one of the experts, research into their background work with current and previous employer and/or research will be conducted. This makes sure that the angle of the questions is suited to their area of involvement and to efficiently use the time spent with each expert so questions are not asked that are not related or that can be found freely through initial research (Meuser & Nagel, 2009: 31).

The style of the interviews with the experts will be exploratory to gather as much data as possible around each question and their area of expertise. Also, the questions will be open to adapt to how each interview develops with each expert. As each expert will be different from one another as well as nationalities playing a role, this openness is important for each interview (Bogner & Menz, 2009).

4.1.6 Analysing Interviews

All interviews conducted for this thesis, when possible, will be audio recorded using an application on an iPhone so the interviews can be transcribed and provide the ability to refer back to the collected data. Doing so allows for us as interviewers to be engaged with the interviewees, asking questions and exploring the area within the question asked without either parties being distracted

from taking notes and disturbing the flow (Kvale & Brinkmann, 2009). During the interviews, the aim is not to look at the body language of the participants but to have a focus on the questions related to the field of LED and/or vertical farming methods and technology within agriculture and their involvement within this.

The transcriptions will take place after the interviews have been conducted to convert the oral data collected into a written format so it is easier to explore and use for the analytical process (Kvale & Brinkmann, 2009). When the audio recordings are transcribed they will be done in a way that all spoken words will be written up, but emotions such as laughter, will be transcribed when felt necessary to the response given. A key for any additional characters used during the transcription process that may describe events, such as a long pause, will be placed within the transcription page as reference for the reader.

When looking at categorization of data, to begin with, when reading through the literature in the review, we did not have any fixed categories. As mentioned earlier, this is partly because the field of study from which we take point of departure in is largely unexplored (Dahler-Larsen, 2008). Instead, we had an overall subject that we took point of departure in when reading through the literature; LED Vertical Farming. As mentioned by Dahler-Larsen (2008), "*qualitative research operates with a flexible design, because the most important categories of the inquiry have not been predetermined by the researcher. On the contrary, categories are developed as a function of the actual research undertaken*" (Dahler-Larsen, 2008: 25). Thus, further on in our research, it opened up the areas to explore, from which we defined the categories or themes. Although qualitative research to a large extend is subjective, this is nonetheless a scientific method, which in turn gives way for structure and systematizing (Dahler-Larsen, 2008).

The data collected through the interviews will be analysed in an explorative way in order to delve further into the different aspects and arenas that each interviewee is a part of and to interpret the data alongside other literature and theories (Kvale & Brinkmann, 2009).

The data will be coded in a categorization approach as this provides a *"more systematic conceptualization of a statement"* (Kvale, 2007: 105) and "*to show information is also to put it in a place where people can see it easily*" (Dahler-Larsen, 2008: 29). Thus, once the data has been collected and transcribed it will then be coded to pull out the information that is related to our area of focus and to provide the reader with an understanding of the matter. The data will be looked upon within the seven categories that were also used in section 2; *Environment and Sustainability; Danish Farming, Land Use and Organic; Food Trends; Urban Agriculture; Light Emitting Diodes (LED); LED Vertical Farming; and Visions of Copenhagen.*

Even though there are seven separate categories to code within, due to the nature of this research area it is inevitable that subjects will overlap. Therefore, the data can still be used freely within either or both categories if deemed relevant. An example of the coding is shown within figure 5 below.

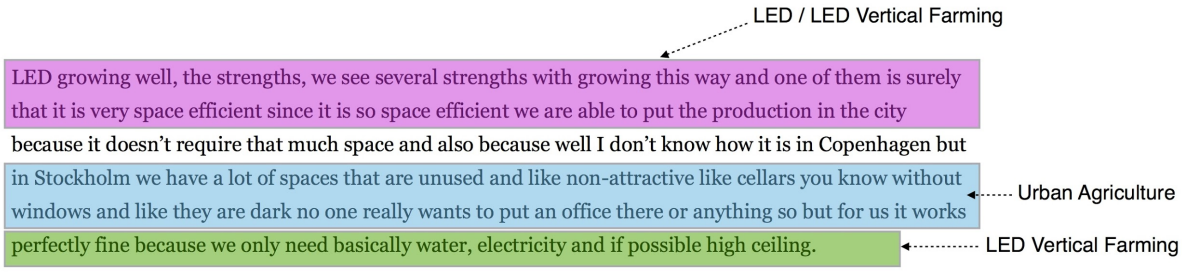


Figure 5. Colour coding example from interview.

4.2 Methods for the pre-analytical phase

4.2.1 SWOT Analysis

SWOT analysis is a method for companies, individuals and organizations to explore ideas or goals by evaluating its Strengths, Weakness, Opportunities and Threats. The SWOT analysis is broken down within two key areas, Strengths and Weakness' part of the internal analysis and the Opportunities and Threats related to the external analysis (Pahl & Richter, 2007).

By doing a SWOT analysis it provides a method to explore and discover what position within the market the chosen subject is or how it could fit within this market. Brainstorming and finding key important areas to be explored and researched upon helps for the idea or innovation to be developed (Fine, 2009).

The SWOT analysis has been used within this thesis with the subject area of LED Vertical Farming as the main focus point. As seen in the figure 6 below it has opened up key points that will be looked upon through data collected from the interviews and literature, before being used within the analysis.

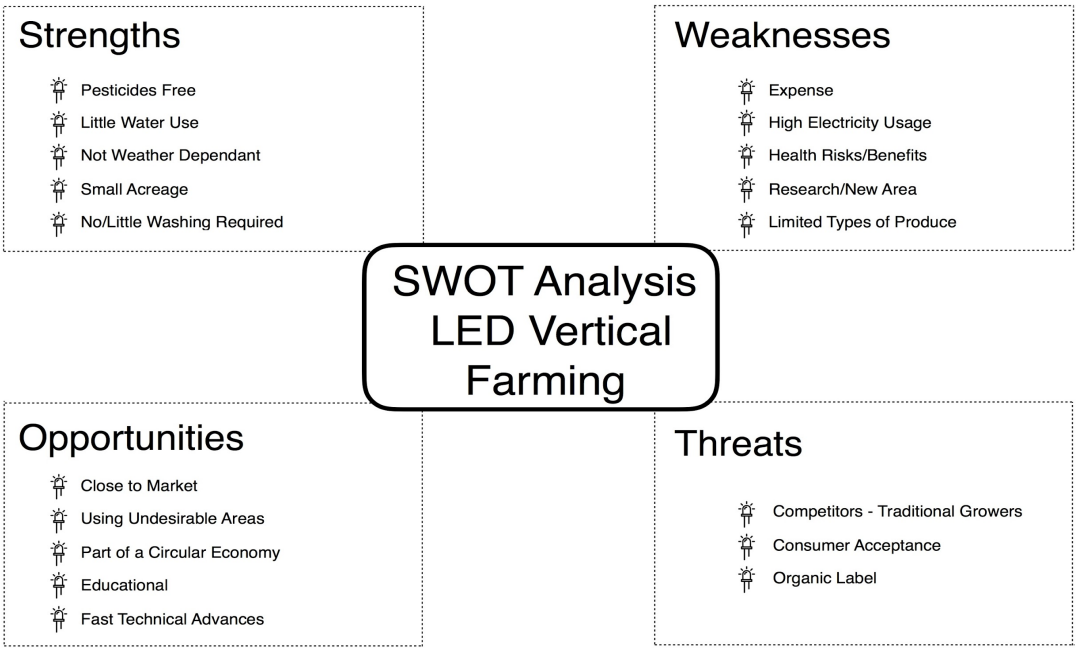


Figure 6. SWOT Analysis on LED Vertical Farming Technology Method.

4.2.2 Mapping Historical Discourses

Clarke begins chapter seven of *Mapping Historical Discourses* in the book on *Situational Analysis* by pointing out the importance of history by referring to a quote: "*We never write on a blank page, but always one that has been written on*" (Clarke, 2005: 261). Also, by having a historical dimension to a qualitative project enables us as researchers to provide a different angle to a contemporary situation. However, when exploring history, you should not solely be looking at what is blatant and right in front of you but rather focus on what lies beneath it, such as the practices behind the action of the people and not necessarily the people in itself (Clarke, 2005).

To do so Clarke puts forth a more or less systematic way of approaching the history of a research situation, where she mentions two different ways this could be done. Either by doing "*full-on*" historical research or by "*historicizing a contemporary research*" (Clarke, 2005: 265). For the purpose of this thesis, we will focus on the latter, as that approach offers a dimension to our contemporary interest to provide more in depth and hopefully give way for other explorative and analytical dimensions. Also, the intention is to avoid dwelling on the history for too long but rather to use the history to understand what has happened in the past to give a better idea of why we are where we are today and how to move from this point in time (Clarke, 2005).

To begin with, a messy map needs to be created, which involves determining the research area of interest followed by finding all the elements that we could find relevant in the case. While doing

this form of messy map it is important to avoid including unnecessary information as that may lead to confusion for the reader rather than clarification on the matter. By finding the key elements, the second stage opened up for finding materials that related to these key elements to investigate what is to be found on this subject, including searching in libraries, using online search engines, public and private document archives (Clarke, 2005).

This approach was combined with that of Jencks' diagram, which according to him has the "*value as an interpretive, historical and theory-building tool and an object/product of knowledge, as well as a generative, projective, predictive and futurological methodology*" (Jencks, 2010: 288). It is meant as a tool to investigate the history of a given area to try and predict the future. By making a diagram it allows for reflection and criticism of the subject area but to show the grand dynamics of such information in a diagram. In that way, we could pull apart the information that we found and see how the multiple dimensions could influence each other. Jencks (2010) mentions that unlike natural evolution of species, the cultural evolution is much faster and flexible as it will vary according to learning and copying traditions and skills as well as the development of technologies and social forces. So, a given diagram will be complex as it contains multiple information. This clutter of information must be simplified for others to understand but at the same time still portray the multifaceted information (Jencks, 2010).
It is important to note that soon the present we are in now will be marked as history and a diagram can therefore constantly be evolved.

Combining these approaches, a timeline was constructed in relation to our problem statement for this thesis. Before the final timeline was created as seen in figure 7, a messy version was done as a way to put down all information that could be relevant. As mentioned above this messy approach allows a large amount of data to be looked at, before key areas of interest are decided on. This information is then organised to avoid confusion not only for the reader but for us as researchers to be able to explore the area more productively (Clarke, 2005; Jencks, 2010).
The timeline figure 7, has been split into five different categories that are distinguished with colour codes: Blue - *Policies/Rules*; Purple - *LED/Vertical Farming Companies Open*; Orange - *Product to Market*; Red - *LED/Vertical Farming Research*; and Green - *Advances in LED/Vertical Farming*. Throughout the research and data collection, categories were selected as a way to explore the area further in a systematic way. This enabled us as researchers within this new area to be able to understand the different aspects that could have an influence.
Colour coding these different aspects within the timeline was done, not only to help the reader understand each event, but also for us as researchers to be able to see patterns and events that may influence or relate to one another. As mentioned earlier in this section it can help to explore not only what is right in front of you when gathering data but also what lies beneath (Clarke, 2005).

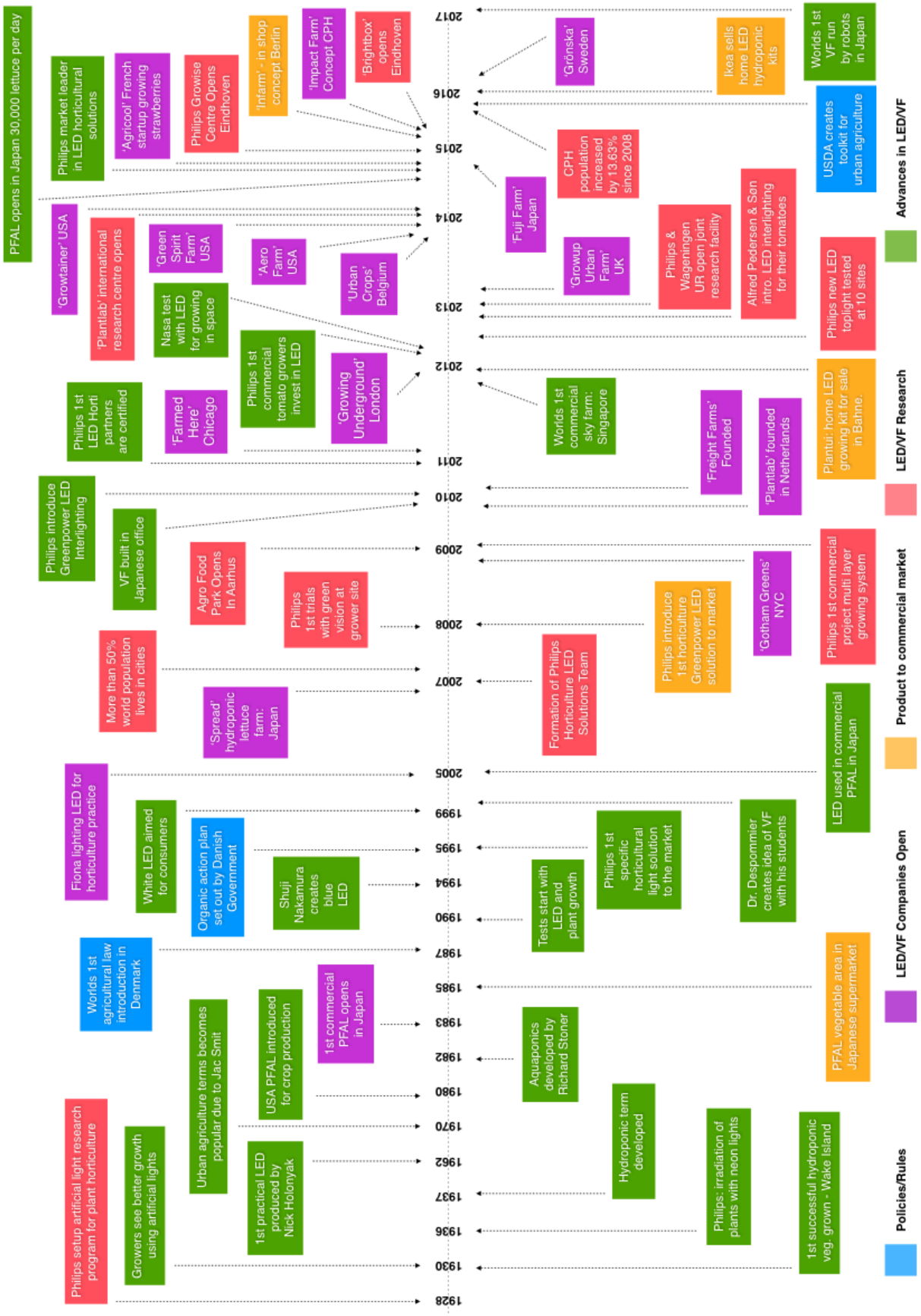


Figure 7. Mapping historical discourses of LED Vertical Farming (Appendix 14)

The timeline was a tool used as an attempt to provide our own interpretation of the research area and to aid our explorative study within the thesis. This was used as a method to look at many aspects that could have been overlooked or taken for face value without thinking of the reason why, while at the same time using the historicizing focus with the data collected, so the history is looked into and understood but not dwelled on. This will allow the data on the timeline to provide an understanding of why society currently is where it is at the given point in time related to LED and Vertical Farming, while at the same time what the next steps could be to explore further (Clarke, 2005).
As mentioned by Clarke (2005), when utilizing this type of method related to historical data usually more than one map will be constructed to explore the different historical points gathered (Clarke, 2005). The reason behind only one timeline was created to map the data found for LED Vertical Farming was to concentrate the information collected, also because the historical events were used as a base to start exploring areas within the thesis compared to having a main research focus of looking at the reason why they happened in the past.

4.2.3 Situational Analysis and Actor Mapping

In our thesis, we wish to identify actors; human actors, non-human actors, organizations and groups. Doing this will enable us to open up to the data and see things in a new light.
A way to do this is through situational analysis, which is based on Grounded Theory. Grounded theory is described in *Situational Analysis: Grounded Theory After the Postmodern Turn* (Clarke, 2005) and is a way of looking at the social world when doing research. Clarke and grounded theory position themselves in opposition to the positivistic view because the positivistic approach sees that the world fits into a theory. On the contrary, grounded theory is based on the idea that first data is obtained from observations, which then leads to creating a theory. Clarke is therefore fundamentally based in the empirical world (Clarke, 2005: 11-36; 83-125).

Clarke believes that in research the focus should not solely be placed on human actors but rather on the people, things and discourses so all come into focus (Clarke, 2005: 11-36). Also, "*researchers should use their own experiences of doing the research as data for making these maps*" (Clarke, 2005: 85). This is because Clarke acknowledges that the researcher has experience and knowledge even prior to deciding the research topic. This prior knowledge should be used and "*part of the process of making situational maps is to try and get such information, assumptions, and so on out on the table and, if appropriate, into the maps*" (Clarke, 2005: 85).

In situational analysis, there are three main types of analyses, of which we will focus on only the first; situational maps. Situational maps work as "*strategies for articulating the elements in the*

situation and examining relations among them" (Clarke, 2005: 86). This is useful for identifying actors relevant for this project as well as the networks that these actors are already in or have potential to be part of. This will be done through abstract situational map illustrated in figure 8 below.

To begin our pre-analytical phase, we first had to get an understanding of the overall situation and the human as well as non-human actors within it. This we did by asking questions such as "*Who and what are in this situation? Who and what matters in this situation? What elements 'make a difference' in this situation?*" (Clarke, 2005: 87). It is important to acknowledge the significance of identifying the non-human actors, which could include facility access, such as research papers, building, travel, as well as identifying the discourses and the understanding between the actors. One could say that a network to some extend is dependent on the non-human actors/discourses as these could be difficult to change. This could be rules or regulations, physical distances, language barriers as well as differences in discourses, all of which must be taken into consideration (Clarke, 2005: 83-109).

This process started out by writing down all actors that may play a role or have an influence related to the areas mentioned within the literature review and state of the art. They were listed with no structure in order to pull the elements apart to in turn become aware of new connections (Sismondo, 2010). The next step was then to put this into the *Messy Version* of the Abstract Situational Map. Although not all of the identified actors will continue to have equal importance in the later processes, it was still important for them to be identified here (Clarke, 2005: 83-109).

Moving from the *Messy Version* to the *Ordered Version* works, as the name implies, to categorize the data of different actors from the messy map and placing them into categories (Clarke, 2005). Here, in total nine categories were established, for the actors to be part of and even though one of the actors may be placed within one specific category does not mean that they do not play a role within another.

Clarke also recognises that this situational map will not include absolutely everything that is within the situation and also recognizes that this map is not static. It can change overtime as new data appears (Clarke, 2005: 83-109).

Our next step was to look at the relations between the actors, which is done through *Relational Analyses* of the Situational Maps (Clarke, 2005: 102). Here we took the best representative situational messy map and printed it out. The first step is to focus on one actor and draw lines to the actors where there is a relation and note down the type of relation. Once this is done, focus is put on another actor where new lines are drawn to this actor's relations. This process should continue until all relevant actors have been in focus (Clarke, 2005, 83-109). By doing this, we as researcher got an overview, as well as an idea of what connections to focus on. The subject of LED

Vertical Farming has various underlying aspects that are interconnected so inevitably actors can influence or be part of more than one category. This is shown in the figure 8 below with some examples having a dotted line running from one actor to another.

The figure 8 below provides a visual illustration to how we explored aspects within the research area relating to what actors, both human and non-human, could have an influence. Not only was it a way to draw out and identify these actors but also as a way to understand what networks they are currently part of or to unfold the potential networks that they could become part of (Corner, 1999).

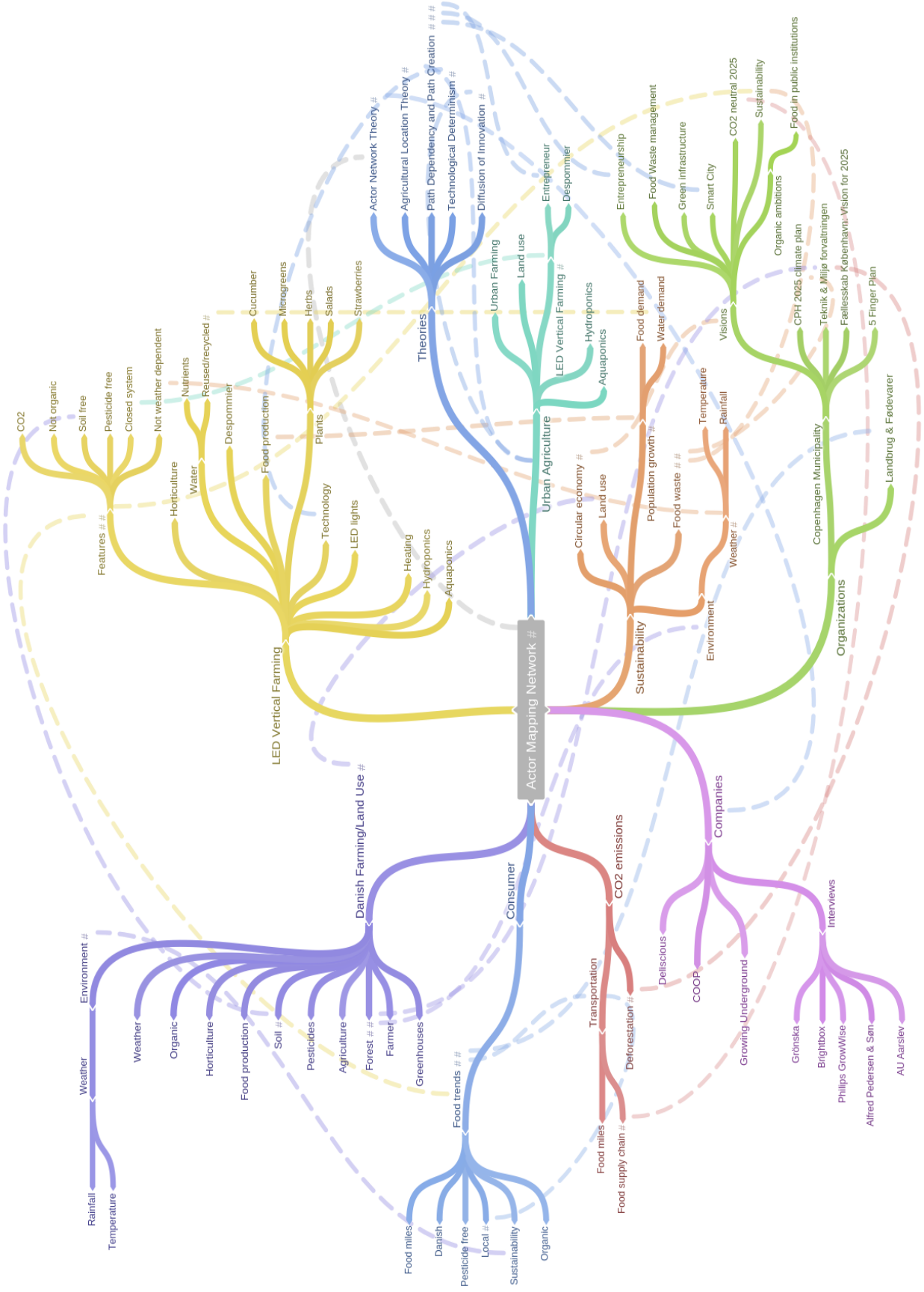


Figure 8. Mapping of actors within a network of LED Vertical Farming in Copenhagen.

This method was used as an exploratory way to work within the subject area to understand all the various actors that should be considered in the research and what role they play, so they are not overlooked throughout the whole process. Doing situational analysis and mapping the actors was also a way for us to open up our data, to see the data in a new light as well as allowing for moving in and around the data to give a better understanding (Clarke, 2005: 83-125).

4.3 Introducing Expert Interviewees

In this section, we will introduce the expert interviewees to provide an overview and reasoning behind their relevance for our research area.

Alfred Pedersen & Søn is a commercial company that grows tomatoes in greenhouses close to Odense in Denmark. The reason for contacting them were due to Philips having used them as a case study to test LED lighting related to Alfred Pedersen & Søn production of tomatoes. The company had invested in Philips interlighting LED technology to explore options of reducing energy consumption while at the same time looking to improve growth and production (Philips Cases, 2017). We were put in contact with Jan Ravensbergen whose job role at Alfred Pedersen and Søn is the Production Manager and Senior Grow Manager. Jan Ravensbergen was an expert interviewee to get a perspective from a commercial farming company who is currently using LED lighting within their production in Denmark.

AU Aarslev is part of Aarhus University, where they research into various aspects of agriculture and horticulture. The research conducted looks at all types of food with a focus on quality and sustainability through the entire chain (Aarhus University, 2017). AU Aarslev has also been conducting research in relation to the use of LED and various light combinations related to growth and attributes of certain produce. Contact was made with Katrine Heinsvig Kjær and Benita Hyldgaard who are both employed through Aarhus University and currently working at AU Aarslev facility within the Department of Food Science – Plant, Food and Climate. Speaking to professionals within Denmark who have been using LED lighting within agriculture related to their research and experiments was another area we wanted to gather data within and in order to learn more about why this type of farming technology is currently being researched within.

Grönska is a company based in Stockholm Sweden currently growing produce within an LED Vertical Farm to sell to local residents at the same time as living in symbiosis with the city. The company is jointly owned by Robin Lee, Petter Olsson and Natalie de Brun Skantz. Natalie de Brun

Skantz was contacted to conduct an expert interview, in relation to Grönska and LED Vertical Farming within an urban environment. Natalie became involved within this area due to seeing urban farming within New York in 2013 and then writing her master thesis within urban culture and discovery of vertical farms (Grönska, 2017). As currently no commercial LED Vertical Farming companies have been established in Copenhagen, Grönska was approached. Being based in Stockholm the capital of Sweden, it has some similarities to Copenhagen while at the same time could provide us with a real-life perspective from an established commercial LED Vertical Farming business.

BrightBox is based in Venlo, The Netherlands and is a purposed built research facility setup to determine *"ideal growing formula for a plant – light, air, temperature, nutrition, water and substrate – BrightBox achieve the best results for the client. A higher yield, for example. A lower cost price, faster production, better quality or more delicious flavour. BrightBox research, produce, teach, and share its knowledge. Unique in Europe. In a closed environment, BrightBox opens up the future of food"* (Bright Box, 2016). Marjolein de Bruin is the manager of the research and training facility at BrightBox. Contacting BrightBox gave the opportunity to speak to a company who are developing, exploring and researching into what options and possibilities LED Vertical Farming has for the future.

Growing Underground is based in a former air raid shelter 33 metres below the streets of Clapham in London. This commercial business grows fresh micro greens and salad leaves within hydroponic and LED Vertical Farming Technology for all year crop production in a more environmentally sustainable controlled way (Growing Underground, 2017). Chris Nelson is one of the directors of Growing Underground. Growing underground was contacted to get an international perspective from another business currently using LED Vertical Farming commercially.

Deliscious is a family run Dutch company specialising in growing lettuces. The company has recently started to collaborate with Philips to design an ideal LED lighting formula for their young lettuce plants. This is used to create a controlled and precise production process that they believe will give them a top product within quality, freshness and sustainability throughout the year (Deliscious, n.d.). Mark Delissen, one of the twin brothers who runs the business, was the contact person during the email correspondence. Deliscious was contacted to speak to a commercial business currently using LED lighting technology in a general growing perspective.

Coop is the largest retailer of consumer goods in Denmark and in total Coop has around 8000 grocery shops as well as 30 specialty shops (Coop.dk Mad, n.d.). Contact was made with Casper Lehmann Nielsen, whose job role within Coop Denmark Food is the Category Planner of

Vegetables. Coop was contacted as they are a national company that supplies both Danish and International fresh food products such as fresh salads, micro greens and herbs for their supermarkets across Denmark. In this way, we could explore how the food supply chain for distributing such products to the Danish consumer.

The City of Copenhagen was contacted to explore and investigate whether there are any rules, regulations in regards to commercial urban agriculture within Copenhagen or whether they have current or future visions related to this. Lykke Leonardsen the Head of program for Resilient and Sustainable City Solutions at the City of Copenhagen was the contact person for questions related to urban agriculture in the city of Copenhagen as Morten Kabell, the Technical and Environmental Minister, did not have time to reply to our questions.

Gasa Nord Grønt is Denmark's leading provider of Danish produced fruits and vegetables. Due to Gasa Nord Grønt dominant position within the Danish market contact was made to gather more information related to the production and distribution of fresh salad, micro greens and herbs. Anne Rohde Sangers the Direction Assistant within Gasa Nord Grønt provided correspondence through email.

Jens Nørgaard Poulsen from Global Herbs Denmark based in Lisbjerg close to Aarhus and Torben Krusborg the Business Unit Director for fresh fruit and vegetables within System Frugt A/S were both contacted through email. The reason for selecting the companies that Jens and Torben work on behalf of, was to gain more insight into the growing, production, processing, distribution and season of herbs in a Danish context.

Having addressed both our research design and methods as well as introduced our expert interviewees, we are now ready to go from the explorative perspective to analytical in order to find meaning in the gathered empirical data.

5

Analysis

The following section will bring together all of the data collected through the literature review and interviews. This data will be explored and analysed within seven categories with the use of the theories and methods brought to your attention earlier on in the thesis.

During the thesis until this point, an exploratory qualitative approach has been taken to introduce key areas related to the research questions.
Taking point of departure in the explored literature as well as keeping in mind the areas explored in the methodology, we will approach the analysis by taking a more in depth look at the information collected while at the same time analysing it in regards to the conducted interviews and relating this back to the theories. The following analytical process will in turn provide a stepping stone for the discussion.

The analysis chapter will follow the same format as found in the literature review and state of the art section 2, exploring the information through the seven categories: *Environment and Sustainability; Food Trends; Urban Agriculture; Light Emitting Diodes (LED); LED Vertical Farming; Danish Farming, Land Use and Organic;* and finally *Visions of Copenhagen*.

Each chapter will be analysed upon separately to one another, but it is inevitable that some of the data and information collected can be relevant to numerous sections and may overlap. Also, the analytical part will be relating back to the overall topic of LED Vertical Farming. Finally, the analysis will be concluded with an overall sum-up combining all of the seven sections to lead onto the discussion.

5.1 Environment and Sustainability

This section will look into the environment and sustainability effects of the growing population and the increased pressure on the agricultural sector. The main focus will be placed on the urban environment's influence, using Copenhagen as an example, and how the introduction of an LED Vertical Farm could provide supporting elements in bettering the environmental and sustainable influences the urban city has.

Globally there has been increasing concern with climate change and consequences related to the rise in greenhouse gas (GHG) emissions. Carbon dioxide (CO_2) emissions are mentioned frequently when GHG are discussed due to them being one of the main contributors to this growing environmental concern (Li, et al. 2016).

From the literature, we have learnt that sustainability is an issue the world is facing today and is a key focal point needing to be addressed to cope with the growing urban population. Current predictions will see that in 2030 nearly 70% of the whole global population will be living within cities (Eigenbrod & Gruda, 2014). Even before we reach 2030 the cities around the world are

consuming over two thirds of all the world's energy and in terms of CO_2 emissions that translates to over 70% of all global emissions (Specht, 2014: 34). Cities need to find ways to reduce their footprint that they produce, be more sustainable within the way they function and reusing or recycling as much of their waste as possible (Vásquez-Moreno & Córdova, 2013).

A report by The Danish Ministry of Food, Agriculture and Fisheries (2009) stated that: *"In Denmark, agriculture contributes 14-16% of the total emissions of greenhouse gases"*. (The Danish Ministry of Food, Agriculture and Fisheries, 2009). Within agriculture, the use of fossil fuels and how the land has been changed, such as clearing of forest, are also significant reasons for this increase in GHG (Nielsen et al., 2011: 15). The way soil is cultivated within the agricultural sector also plays a role within its carbon storage with it either releasing or storing of CO_2 into the atmosphere (The Danish Ministry of Food, Agriculture and Fisheries, 2009).

With this growing population entering the cities that are already struggling with sustainability related issues, the food infrastructure for the future population needs to be looked upon as it has the potential to become more productive and sustainable to meet the needs of everyone involved within this food supply chain (Specht et al., 2014).

The growing urban population within Copenhagen and the way the city has been developed so far has caused a sustainable issue for the city to address. The demand for water from the city's residents has started to outstrip the availability of groundwater supplies it has to offer (The City of Copenhagen, n.d.). It seems currently there is an overall demand for water, that is more than what the city can supply. Then the question that could be addressed, whether it is a good idea to bring food production, that requires additional water, into the city that could put more strain on something that is already struggling to cope with the demand?

Currently global agriculture uses nearly 70% of all of the available freshwater for irrigation (Despommier, 2010: 20). This is one of the advantages that LED Vertical Farming method could offer to help support and create a more sustainable solution in relation to the issue of water usage and demand that outstrips the current supply. As described by Despommier in his book, *The Vertical Farm, Feeding the World in the 21st Century*, LED Vertical Farms are designed to be a closed looped growing system where the water inside the system can be re-circulated numerous times for the plants to use, only having to replace the nutrients within the water and some of the water that the plants have taken up (Despommier, 2010: 142). Another suggestion put forward by Despommier to help the cities become more sustainable with their water supply would be the use of grey water such as, deposed water from sinks, showers, baths, that would typically be sent off to be treated or discarded could be used within the LED Vertical Farming system. The water will be put

through UV filtration before entering the system and the plant's natural ability to purify the water enables this growing method to use water that may have been discarded to be used in a more sustainable manner for numerous growing cycles (Despommier, 2010: 27 & 160).

Growing within a closed environment such as in an LED Vertical Farm also allows you to save water throughout the growing process. As compared to traditional methods of growing within greenhouses or the open fields, LED Vertical Farmed produce require no washing before consumption. The reason for this is due to the way LED Vertical Farms can grow produce without the need for soil or pesticides and because it is grown in a closed controlled environment free from animals or foreign substances. The water saved from not having to wash the produce after harvesting can add up when being grown on a commercial scale in LED Vertical Farms and has been stated, both for the irrigation and washing of produce, to use up to 99% less water compared to greenhouses (Kozai & Niu, 2016b).

Bringing a new sustainable food production into the city of Copenhagen, with infrastructures and surroundings already in place requires considerations at the same time, both for economic factors as well as environmental factors (Ohyama, Takagaki & Kurasaka, 2008). Would food production be more sustainable to do within the city rather than what is currently happening within the traditional growing methods as seen in greenhouses, especially in places like The Netherlands? In the interview with Jan Ravensbergen, he sees that with the way that farming is currently done within greenhouses in The Netherlands, it is hard for the farmers here to be more sustainable. The way they have developed their growing and production methods and the quantity grown, translates to minimal energy being used per unit produced (Appendix 5). It shows that with technical advances and development, greenhouses have looked to become more efficient within their growing techniques to make sure unit amount exceeds total energy used through the production process.

With this in mind, if the food production was kept within the rural areas or even in other countries, additional resources are required for this produce to be brought into the city due to the demand from its growing population, as more people require more food. To keep up with this demand the produce has to be transported to the city over longer distances before reaching the consumer, putting more CO_2 into the environment (Ohyama, Takagaki & Kurasaka, 2008). Additional CO_2 is emitted during the processing, packaging, storage, cooling and transporting of the produce, which are all areas that play a role within the agriculture's CO_2 emissions (Kozai & Niu, 2016a).

This is also something that Natalie de Brun Skantz of Grönska brought up during her interview. With Grönska being based in Stockholm, Sweden, one of the company's aims is to grow produce

that is typically imported from other countries and transported long distances to get to the consumer in Sweden. Grönska is looking at it from a sustainable point of view to bring the produce closer to the consumer because if produce has to be transported over far distances, Natalie de Brun Skantz suggests that often some form of pesticide would be used for it to survive the journey from farm to fork (Appendix 5).

Due to certain characteristics of produce with high water content, such as leafy greens that are one of the main vegetables grown within LED Vertical Farms, these are also highly perishable and they therefore require correct packaging and transportation in order to stay fresh over longer transportation distances. For the transportation, highly perishable produce requires cooling which in turn leads to excess emissions of CO_2. If transportation is not done correctly, there is a higher likelihood of the produce going to waste. If production was to move closer to consumption and thereby reducing the distances over which the product is transported, it could aid in decreasing CO_2 emissions as well as food waste. (Kozai & Niu, 2016b). This is also something Natalie de Brun Skantz is considering for the future with the way Grönska transports their produce to consumers and shops due to it being sensitive:

"So we actually transport it, because it is basil that we are selling and it is very sensitive, we actually transport it by car, but the plan is definitely as soon as the weather gets okay it [transportation] will be with a bike. And then in the future when we have more produce to transport, we want to lease an electrical car." (Appendix 5:3)

This could show that as a company, Grönska is realising the issues of emissions when transporting produce, while at the same time they want to continue their image brand of being a sustainable company with the desire to soon implement more environmentally friendly and sustainable solutions.

Food waste can occur not only in the transportation stages but also throughout various stages in the food supply chain. Within the food industry, food can be wasted within individual supermarkets as it is very difficult to predict what the consumer wants from one day to another. Food may still be perfectly good to eat but may not seem as attractive and fresh to the consumer as desired and a result of this could be a decreasing demand, which could lead to the food going to waste (The Danish Government, 2015).

As mentioned earlier on within this section, just as water can be taken from the city as a waste by-product and used efficiently and more sustainably within the LED Vertical Farming method, another waste product that could be reused or recycled is heat. If an LED Vertical Farm was built

into the city's infrastructure, it would be surrounded by numerous residential and commercial buildings all expelling excess and waste heat in some form or another. This form of energy has the opportunity to be captured and used within the LED Vertical Farm's closed loop system as a way to create energy in a more sustainable manner (Specht, 2014: 35). By using what is already occurring within the urban city environment, such as excess heat and taking advantage of this, it can be used in a more positive sustainable direction to create an overall more sustainable growing system. Natalie de Brun Skantz sees this as an instant advantage that growing within an urban city environment has over greenhouses. Typically, greenhouses are situated far away from other commercial residential buildings, they would not have the same opportunity to use waste products compared to that of an LED Vertical Farm (Appendix 5).

The current agricultural system is a large contributor to the global GHG emissions and the release of CO_2 into the environment. In Denmark 14-16% of the total GHG emissions come from within the agricultural system (The Danish Ministry of Food, Agriculture and Fisheries, 2009), so this footprint from the agricultural sector needs to assessed for the future as without change it is only going to get bigger to keep up with the demand from the growing population. The way the LED Vertical Farming system works could provide some solutions with its soilless and pesticide free growing practice requiring no washing of the produce at harvest, while with its closed loop design allows the water to be reused numerous times (Despommier, 2010). Also, this closed loop system has the ability to use a product the city may view as waste for a resource to power and run the LED Vertical Farm, providing another chance to work with the environment and sustainable factors that may not be possible with the growing practices found within greenhouses. Even though experts within the field highlight that current growing practices within greenhouses in The Netherlands are technically advanced and use little energy (Appendix 1), getting this produce to the consumer has some environmental and sustainability aspects that contribute to GHG emissions. Whether it be the distance the food travels or food waste during the food supply chain, CO_2 will be released, therefore one potential solution could be moving production closer to the mouths that need feeding within the city (Despommier, 2010). The following section, *Food Trends*, will look into the desires that these mouths within Copenhagen and Denmark are seeking from their food.

5.2 Food Trends

The following section will highlight current key food trends of the Danish consumer. These trends will then be put up against the literature and data that has been explored with a focal point aimed towards the current agricultural system and LED Vertical Farming method.

In the market analysis on consumer trends by Landbrug & Fødevarer (2016a), they state that the consumer seeks transparency in order to understand the entire story of the product from farm to fork. It is mentioned that it could be due to the consumers getting an overflow of information so as a backlash they now seek the truth (Landbrug & Fødevarer, 2016a).
In this lies the wish for transparency, which becomes evident in the increasing preference for Danish produced food as these may seem more trustworthy and of better quality (Landbrug & Fødevarer, 2016a). This wish for a less opaque food system was a future food trend that the population within the United Kingdom put forth within the *Our Food Future* report (Food Standards Agency, 2016). Similarly, to this, the *Nordic Food Survey 2015* found that the consumer is seeking to be on eye-level with the producer (EY, 2015). The consumers want to understand the producer and build trust to the product that they are buying and the quality of it (Landbrug & Fødevarer, 2016a). Looking at it from the perspective of an LED Vertical Farming method there is a possibility in living up to this trend, as the food could be brought closer to the market by having production within the city.

"*In extension of the wish for transparency we find the need for the food being 'the real deal'. 'Real food' is natural, nutritious food, which is experienced 'close to nature'*" (Landbrug & Fødevarer, 2016a: 1).

This statement from Landbrug & Fødevarer (2016a) could be viewed as both an advantage and disadvantage in relation to LED Vertical Farming. In one sense, one could argue that the produce grown within LED Vertical Farming is 'real food' and in that it still contains nutrients, taste, flavours and less processed. However, the nutrients are added to the water, in which the plant is grown and the plant will never have seen natural daylight. Does this make it become less of a 'real food'? Even though it is grown without any pesticides? At the same time the consumer takes distance from produce grown under production methods that seem complex (Landbrug & Fødevarer, 2016a). As LED Vertical Farming is a complex technology and to some people maybe incomprehensible, this could be a downside to selling produce grown under this technology. On the other hand, "*the most frequent reason for the consumers to buy organic is to avoid pesticides in their fruit and vegetables*", which is a point that speaks for produce grown under LED Vertical Farming technology as here all use of pesticides is avoided (Landbrug & Fødevarer, 2016a: 2).
Linking this to the Technological Determinism Theory with LED Vertical Farming, a new technology is created, which could change the way society views agricultural practices and potentials for change. However, in order to do so communication aspects from Theory of Innovation may be needed in order to have people in society know and understand the differences it has to offer (Chandler, 1995). One needs to communicate something to society as well as creating

something that will aid in changing the way society views things (Rogers, 2003). If this communication is successful you in turn are creating a new path (Garud & Karnøe, 2000).

A trend that is gathering momentum is the responsible consumption. The consumer wants to know under what conditions their food is grown, which also links up well to the increased demand for organic in that the consumer wants to do good to the environment (Landbrug & Fødevarer, 2016a). The trend shows that 40% of consumers either sometimes or always buy organic when shopping for groceries. This goes hand in hand with the trends of responsibility, transparency and free from pesticides, which are similar characteristics of produce grown organically (Landbrug & Fødevarer, 2016a). The *Nordic Food Survey* also pointed out that the Danish consumer looks for foods that are grown organically and without any additives (EY, 2015: 7).
There are controversial perspectives in relation to this as the consumer asks for both Danish produced food but at the same time wants organic all year round. This was also expressed by Jan Ravensbergen who stated that "*Danish people also want the organic products from Denmark in the Winter time*" (Appendix 3: 7). Issues could arise because the Danish population would like to have organic produce that at this time of year is only available by having the produce grown in greenhouses, which means the produce is grown indoors but is that good enough for the consumer's wish for produce grown 'close to nature'?

Having more aware consumers could work both for and against a new type of growing technology like LED Vertical Farming. Consumers may be intrigued by it, find it interesting and see the benefits in it, whereas others may react with suspiciousness and distance. Within the *Nordic Food Survey*, it mentions that consumers are typically more open to change and like to see new products on the market. Alongside this, the consumer would prefer that the products are more local and produced domestically rather than coming from outside of the country (EY, 2015).
As mentioned in the Diffusion of Innovation Theory, the innovators and early adopters are the key actors and communicators, who could play a role within such an area as they communicate messages to others that are interested in hearing about new innovations (Rogers, 2003). Within the *Nordic Food Survey* publication, it saw that for future key trends it will dominantly be driven by the consumers themselves (EY, 2015).
At the same time, the market analysis by Landbrug & Fødevarer (2016a) shows that the consumer is interested to be part of making a difference through their choice of consumption. However, consumers do not only place the responsibility on themselves to choose the product that will make a difference. The trend also shows that the consumer wants the producers and retailers to take responsibility (Landbrug & Fødevarer, 2016a). Also within the report by the Food Standards Agency (2016) a trend by the United Kingdom population asks for the government to be more

visual in what they are doing for the future of food so the consumers are more aware of what is being done (Food Standards Agency, 2016).

"*In continuation of the awareness of responsible consumption comes the growing awareness of aspects that contribute to sustainability*" (Landbrug & Fødevarer, 2016a: 3). Here, the consumers are concerned with packaging, food waste and renewable energy amongst others. Once again, the trend is the demand of both producer and retailer to take responsibility in minimizing the environmental impact (Landbrug & Fødevarer, 2016a).

Provided that LED Vertical Farming is growing produce under production methods that utilizes energy saving options, it could have links to this trend of minimizing the environmental impact, as long as steps are taken to utilize energy wisely. Also, LED Vertical Farming has the potential of using the technology to further adjust to the specific demands of the consumer and in that way producing only the necessary amounts (Kozai & Niu, 2016b). With the produce being grown within this farming technology, also without soil and pesticides, it is said to extend the shelf life of the produce by one to two more weeks over the current produce being sold. This is another interesting aspect and a way to address the current issue of food waste (Kozai & Niu, 2016a).
Furthermore, by bringing the production closer to the city will not only decrease food miles but also reduce the risk of perishability as well as bring the possibility of using less packaging for storage along the food supply chain; something that goes along with the current trends seen within not only the Danish population but also the population in the United Kingdom (Kozai, 2016; Landbrug & Fødevarer, 2016a; Food Standards Agency, 2016).

When speaking to Natalie de Brun Skantz from Grönska about their choice of the type of produce as well as production placement, she firstly mentioned that they chose basil "*because it is the most popular herb in Sweden*" (Appendix 5: 3). Furthermore, they "*put it in the city, which enables us [Grönska] to grow very locally and in Sweden there is a high demand for locally grown food… we [Swedish people] have high standards for both agriculture and animal keeping so I think people trust in Swedish produce*" (Appendix 5: 5). The Swedish trend also correlate with the Danish trends of wanting local as well as having high standards for their produce. This correlation was seen between the market analysis by Landbrug & Fødevarer (2016a) and The Nordic Survey (EY, 2015).

Lastly, *foodies* are also a trend that has appeared, which describes people that are less apprehensive when it comes to trying out new types of food products (Landbrug & Fødevarer, 2016a). This trend relates to Diffusion of Innovation Theory as it emphasizes the types of innovators, who are venturesome and willing to take the risk of adopting new innovations (Rogers,

2003). Connecting this to what Natalie de Brun Skantz stated in her interview about product placement: "*Because we [Grönska] want to be commercial we want to be seen in the normal grocery stores but we start with this one [Paradiset Matmarknad] to find the niche customers first*" … "*also then bear in mind we [Grönska] have been selling our product in a store where people are very aware regarding food so in general people think our product is innovative and cool*" (Appendix 5: 2, 6). Through this she shows how it makes sense for Grönska as a company growing produce through LED Vertical Farming to start out by targeting the niche customers in a shop where these consumers typically buy their food.

This increasing trend of *foodies* could be advantageous for the sales of produce grown within LED Vertical Farming as it shows that there are consumers that would be likely to explore new options open to them on the market such as this one.

The Omni-channel, as mentioned in section 2, is the way consumers shop for food, where it seems there is a consensus on technological aspects. It is seen that *"technology is an important driving force that reshapes the way we live, work and interact, which consequently means that consumers expect increased digitalization of the way we shop for food"* (EY, 2015: 6). Although this is in regards to food shopping it is interesting that the consumers, that could be classed as *foodies,* are aware of the digitalization and how technology is a big part of our daily lives. This interaction with technology could allow them to be more open to the technological advances also happening within agriculture and the production of their food. While at the same time in the *Nordic Food Survey* there is a slight conflict with the trends from the consumers and the aspects that LED Vertical Farming could provide. In the EY publication it mentions that alongside the omni-channel, consumer trends also see the consumers wanting the back-to-basics related to food quality, how and where it is produced as well as environmental impacts and the type of natural raw ingredients (EY, 2015: 6). Now here it creates a paradox because back-to-basics could be seen as an anti-pole to the omni-channel. That with technological advances and digitalization within society the consumer is seeking some form of direct connection with food hands on, rather than through technology.

In the end, it is the consumer that has the last say in whether a production method catches on or not. At least it is according to Jan Ravensbergen: "*The public opinion is really important for our company so if the public opinion turns to the LED light then we just go with it but not regardless of cost… we provide the food and society in the end decides how it will be produced. They decide by buying, it is simple*" (Appendix 3: 7).

The above-mentioned trends could be summarized by Specht et al. (2014): "*The emerging food movement is committed to reintroducing food systems into urban space. Particularly in developed countries, the understanding of 'food system' or 'food system planning' is associated*

with more than just food security. It increasingly encompasses individual and societal needs (E.g. trust and transparency, fairness, resilience) …Consumers ask for fresh, local food with low carbon footprint, more transparency, and closer involvement in the food production chain" (Specht, 2014: 44).

To sum up, LED Vertical Farming could live up to the trends of the Danish consumers, which include the use of no pesticides, being locally grown, as well as consumers being concerned with sustainability, curiosity for new products and being aware and responsible consumers. However, certain trends counteract this type of production as with LED Vertical Farming it adds nutrients to the water, which may make it less real, consumers seem to take distance from complex production methods as well as the fact that this production method does not live up to the requirements of being able to class the produce as organic (Landbrug & Fødevarer, 2016a; Appendix 6; EY, 2015; Kozai & Niu, 2016b).
This analytical section touched upon how the LED Vertical Farming technology has potentials to be changing the viewpoints in society by looking at the Technological Determinism and that Theory of Innovation creates an aspect to how communication could be needed to explain this technology better (Chandler, 1995; Rogers, 2003). Also, how this new agricultural production method could be a new path creation (Garud & Karnøe, 2000).
Creating new paths of commercial urban agriculture and what it may entail will be looked into in the next section of *Urban Agriculture*.

5.3 Urban Agriculture

Within the following section, the term Urban Agriculture will be examined from a commercial standpoint. Exploring how the urban agricultural practices have been conducted before and what opportunities it may bring by the introduction of an LED Vertical Farming method to the city of Copenhagen.

Food production within and close to the urban environment is not a new phenomenon, within history the city has always required food production for its residents (Friedmann, 1976). With new advances and developments within society the role of urban agriculture and food production systems has started to gain momentum (Hirsch et al. 2016: 342).

When the term urban agriculture is discussed, many variation and forms of the practice can be mentioned. Whether it is on a social or commercial level, within schools, local communities, inside or outside, urban agriculture can have many different meanings (Specht et al. 2014). Figure 9,

which is inspired by Thomaier et al. (2014: 47), provides an overview of the different qualities and directions urban agriculture can follow. As mentioned within the urban agriculture section 2.4, in the state of the art/literature review, an urban agriculture initiative that Miljø- og Fødevareministeriet created within Kongens Have in Copenhagen would be seen within the figure as being more of a social and educational form of urban agriculture. On the other hand, Østergro, which is also situated situated within the Østerbro area of Copenhagen, could be classed as more relatable to something in between the *image orientated* and *commercial urban agriculture* placement within this figure. Even though both are situated within Copenhagen and can be classed as a form of urban agriculture, with the help of this figure 9, it highlights the diversity of different forms of urban agriculture.

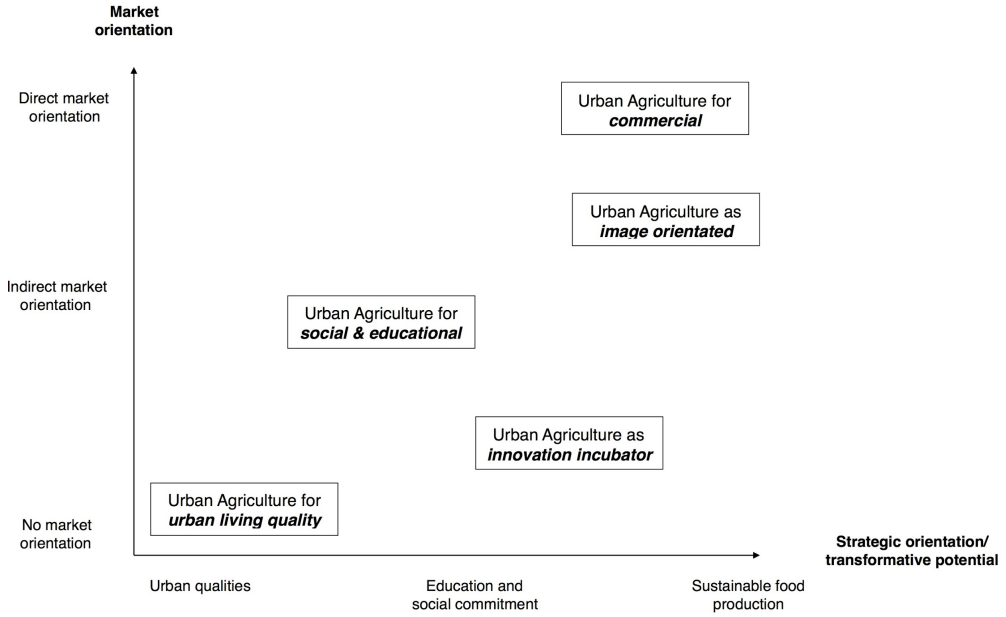


Figure 9. Urban Agriculture placement within market and strategic orientation adapted from (Thomaier et al. 2014: 47).

Previously, individuals or entrepreneurs may have been put off from considering taking part in commercial agriculture within an urban environment due to the price of land generally being high within the city (Kozai & Niu, 2016b). With urban agriculture, it has the ability to increase food production locally and nationally by exploiting areas within the city and urban environment, but prices, pollution and land availability could be factors restricting this development (Eigenbrod & Gruda, 2015). With technological research and developments within the agricultural sector, growing within the city is something that is being realised. Even though land is limited and expensive within the city, LED Vertical Farming only needs 1% of land area to grow the same amount of produce compared to open fields and 10% when comparing it to greenhouses. It can be the same produce that is grown but it will take up less land space (Kozai & Niu, 2016b). With

limited space and price of land in the city, having this technological method of growing produce and the ability to use a smaller acreage compared to traditional methods starts to open up new opportunities of growing within the urban environment.

Another important environmental and restrictive factor that also has some influence when growing within the city of Copenhagen is soil contamination. A standard law has been created, *Soil Contamination Act*, that due to soil within the city being contaminated, individuals who are wanting to grow within this soil have to add 50 cm of new soil on top of the pre-existing. Another aspect to this law, a protective layer must be placed around the area being used to grow to stop any of the contaminated soil coming in contact with the general public (Halloran & Magid, 2013). Alongside this, growing within an open urban environment has other risk factors that could play a role within the health risks related to the produce (Antisari et al., 2015), mainly due to the higher concentration of air pollution found within cities compared to rural locations (Bell et al. 2011).

With the development of new agricultural growing technologies of LED Vertical Farming, the factors that have previously held back individuals and entrepreneurs who have considered conducting agriculture within the city can now be realised, while providing the ability to do it within a more sustainable practice (Eigenbrod & Gruda, 2015: 487). Related to the *Soil Contamination Act* within Copenhagen and the soil within rural agricultural areas becoming less fertile and over worked, the rising interest and trend of using soilless techniques could be an interesting sustainable future solution, which could especially be suited to the urban city environment (Eigenbrod & Gruda, 2015: 488).

Copenhagen sees that one of the largest challenges that it faces in the future is waste. The city has used waste in the past by collecting the energy from incinerating it and using it within the city's district heating system to make this area more environmentally friendly and sustainable. This has been effective so far but for the city's future vision of becoming carbon neutral requires a new focus upon more sustainable environmental friendly energy. The residents of Copenhagen then will have to look to; "*generate less waste, increase direct reuse, recycle more and incinerate less"* (City of Copenhagen, 2014: 6). As mentioned in the environment and sustainability analysis section 5.1, recycling and reusing what the city provides and connecting it up with an urban agriculture practice like LED Vertical Farming, could be a good direction to head in, to help become and make the city of Copenhagen more sustainable. Also, by bringing the production of food into the urban environment through the practice of urban agriculture you are moving the produce closer to the consumers. With the produce being closer to the consumer, its travel distance is reduced resulting in less need of packaging for the processing and transportation section of the journey. Less packaging for the produce or to protect the produce means less waste products in the end (Specht,

2014: 40). Also, by bringing the food production into the city, in turn could provide the city and public with additional benefits and commodities while at the same time bringing the city an additional source of capital through this form of commercial urban agriculture (Specht, 2014: 46).

An environmental benefit of bringing urban agricultural food production into a city like Copenhagen could be a reduction in CO_2 emissions. However, situating production within closer range of the consumer and in turn shortening the food supply chain the produce does not have to travel that far to the consumer and it can also provide an opportunity for the consumer to buy straight from the source. This reduction in transportation of the produce will reduce the amount of CO_2 emissions emitted through the various stages, which in turn could make it more of an environmentally friendly food supply chain (Kozai & Niu, 2016b). This is because produce such as salads and herbs mainly consist of water and is therefore also more perishable. So in order to make the plant last the journey it also needs a specific cooling environment for the transportation, which in turn releases more CO_2 (Kozai & Niu, 2016b).

Correlating to this, Sonnino (2009) also writes about the *rural-urban divide* and how the fact that viewing these two as divided parts is the reason for policy makers not understanding it as a whole. Neglecting that the city is where there are the most mouths to feed but also interestingly the place, "*where the demand is greatest for alternative food products*" (Sonnino, 2009: 428). Also, rather than looking at distribution of food into the city as a means for the problem they have until now looked at the failure coming from the farm. During email correspondence with the company Growing Underground, which is based in London, they mentioned that in the future the urban farmer will become an important figure within agriculture as a whole (Appendix 7). This may be relevant for the future of food production within the city environment as Jan Ravensbergen does not believe that people from the rural areas that are currently farming would like to move to the city to produce the food within an urban environment (Appendix 2).
This could be where the new entrepreneurs and the future urban farmers use the path creation mindset. The way farming and agriculture is done today will typically follow a path dependant route due to a group of pre-existing events that group together to form the direction that farming heads in. Others may carry on accepting this way of doing farming as this is what has happened in the past and how the dependant path has been selected and stuck to (Garud, Kumaraswamy & Karnøe, 2010).

For a change to happen, entrepreneurs, who could possibly be classed as the future urban farmers, will look towards new technology and methods to figure out how to do food production within an urban environment the most efficient, environmentally and sustainable way (Garud & Karnøe, 2000: 7). As Marjolein mentioned during her interview,

"...it could be that the farmers currently are stuck in a certain way of thinking and that is where newcomers who are interested within this type of new technology are starting to come into farming and agriculture." (Appendix 6: 1).

This could show that some farmers are currently stuck doing the same farming methods, so here they are doing and thinking the same certain way, which places them within this path dependant route. On the other hand, new urban farmers are starting to become interested as new technology developed to make it possible to do farming and agriculture in different ways.

When planning and developing for agricultural practices within an urban environment many people have a view that the city has to create something brand new for it to be more productive and better for the long term sustainable future. But could it not be better, more sustainable and less destructive by using something already there within the city? What is required is the ability of using the environment and structures that are already within the city. Being more creative and forward thinking about the space available that is left untouched or vacant are interesting options to consider (Thomaier et al., 2014).

Through email correspondence, Lykke Leonardsen mentioned that currently there are no rules in place for specifically doing commercial urban agriculture within the city of Copenhagen. The only issue related to doing agriculture in the city of Copenhagen would be the soil contamination law mentioned earlier on in this section (Appendix 9). A reason for currently no rules or regulations being set out towards urban agriculture within Copenhagen could be due to urban agriculture still being seen as niche within urban environments and food supply chains (Hirsch et al. 2016). When placing what Lykke Leonardsen currently sees the way Copenhagen Municipality looks at urban agriculture within figure 9 shown earlier within this section, it would be placed towards the bottom left hand side. Copenhagen municipality sees urban agriculture as having more of a social or pedagogical focus to create new experiences within green areas of the city rather than the top right of figure 9 where there is a commercial focus of producing food within the urban environment (Appendix 9). Natalie de Brun Skantz mentions that currently she finds that regulations set out related to urban agriculture are not keeping up with the pace of development within this area (Appendix 5), she is stating this from a viewpoint of how it currently is in Stockholm, Sweden. This could link back to society still seeing urban agriculture as being a niche form of agriculture.

Food and the city have been linked together throughout history (Friedmann, 1976), but with higher land prices and limited land to use within the urban environment, the city may have been overlooked for its potential within food production (Ponsard, 1983). Exploiting the city could be an

option that LED Vertical Farming may now provide with the way the system runs. With land in high demand in the city, LED Vertical Farming can take up considerably less space than greenhouses, and grow the same amount when comparing to traditional methods. Bringing food production into the city closer to the end consumer could help limit the amount of waste produced, additional packaging as an example, with this issue of waste being something The City of Copenhagen wants to address for the future. While the term urban agriculture can have many meanings, this thesis uses the focus on the commercial angle with LED Vertical Farming. With these numerous meanings, this could be a reason why The City of Copenhagen has no set practices or future focus for growing commercially in Copenhagen, but they have not ruled it out either. With entrepreneurs looking for new ways to do old practices of growing produce, could certain technology be the answer? This leads onto introducing the next section of the lighting technology of *LED's*.

5.4 Light Emitting Diodes

The lighting technology of LED will be explored within the following section. To start off LED's will be introduced in a broader term before moving onto a focus within the agricultural sector. Finally, leading onto exploring how certain attributes and actors could play an influence for LED's within agricultural practices of the future.

Since the first practical version of the LED that was created in 1962 by Nick Holonyak, Jr there have been numerous technical advances and developments within LED technology. In the 1980's due to the rapid growth of people using and developing this technology it was made possible to improve its efficiency and introduce certain colours; red, orange, yellow and green. The biggest breakthrough came in 1993 when Shuji Nakamura from Japan developed the blue LED (Figure 7). This was important as blue alongside red and green are the primary colours and combining all of these together produce a white colour. This was also important as white LED's then could be used in many more products, such as TV's, mobile phones and cars (Yeh & Chung, 2009). Within the last decade one of the highest energy efficiency gains has been within the LED lighting industry (Specht, 2014: 42). Compared to fluorescent lights that are typically used within greenhouses, these on average have a lifespan of around 8000 hours, whereas LED's have a longer lifespan with it being on average 100,000 hours (Yeh & Chung, 2009).

When comparing LED lighting over the existing traditional lighting used within agriculture there are other benefits apart from the increased life efficiency. The way LED's can be built and designed allow them to be smaller in size and they typically will produce little or no excess heat. This allows

for the light to be closer to the plant grown under LED's in comparison to the lights in greenhouses, which must be placed a larger distance away from the plant due to the heat that it extracts. Apart from these advantages, LED's provide the opportunity to allow growers to select certain light spectrums that suit the ultimate growing conditions and requirements for their produce (Eigenbrod & Gruda, 2015: 491).

Katrine Heinsvig Kjær from AU Aarslev during the interview explained that through some experiments she was involved within, saw how certain light combinations allowed a specific produce to be grown to provide them with a better keeping quality or taste. She believes that figuring out the ideal light combination to get the perfect product to fit and suit certain requirements has potential on many levels (Appendix 4). This ability to choose certain attributes to what the produce will acquire through light choice, allows LED's to provide additional growing and production benefits that currently traditional growing lights within greenhouses cannot.

While this development within the LED and light spectrums allow these possibilities it also can provide some issues. Natalie de Brun Skantz sees this area of LED's as a new, young developing market that is still being explored in trying to understanding exactly what is the best way to approach crops and their most efficient or required light spectrums (Appendix 5). This is a part of the Diffusion of Innovation Theory where new technologies are developed or introduced they are needing to be learned and adjusted to fit into routines and working practices that may already exist (Geels, 2004: 902). With these new technologies and advances within already established areas of the market this has the possibility to affect individuals' view and adoption within this area (Rogers, 2003: 6).

Katrine Heinsvig Kjær mentions that as LED's are still being developed and classed as a new technology, some growers are finding it hard to adopt and invest in these over conventional lighting systems as there is a level of uncertainty on how long they will last and whether the payback time is sufficient (Appendix 4). This kind of thought process through individuals being sceptical and stepping back when new technologies or developments come to market is relatable to what Rogers (2003) call the Early and Late Majority. The Early and the Late Majority are the ones who will see how things play out within the market before getting involved and helping with the initial movement of new technologies such as that of LED's within the agricultural system. This is because they typically are more sceptic and cautious when it comes to new ideas as they need to feel safe (Rogers, 2003: 281).

Earlier on in the thesis within section 2.5, figure 1 displayed the evolution of red LED's over more than three decades that was created by Haitz (2000). This diagram demonstrates that due to

technological developments within the LED technology, the efficiency of these lights will improve by around 30% while prices will decrease by around 10% each year (Haitz, 2000). In the research paper by Sabzalian et al. (2014) they highlight that there has been a decrease in the price of blue and red LED lights and an increase in brightness of the lights, which makes them more suitable for indoor plant growth and production (Sabzalian et al., 2014).

Even with these improvements within the technology and decreases in prices, the initial cost of purchasing LED's aimed towards agriculture may still be putting people off. Jan Ravensbergen mentioned during his interview that when directly comparing initial costs and returns on LED lights, it will typically be around 10 to 15 years, which is two to three times longer than traditional lights. With this additional return time and linking this up with the Haitz Law a lot of progression can happen within this time frame that could play a role in whether one lighting options is preferred over another (Appendix 3; Haitz, 2000). Natalie de Brun Skantz also mentions that she believes people may be put off by the initial costs but she has seen over the last four to five years that the cost of LED's has reduced by nearly 50% (Appendix 5), which relates to that of the Haitz Law as mentioned above.

While *Growing Underground*, who are based within London and use LED lighting technology within their vertical farm, believe that LED's will become cheaper than they are today, while at the same time they believe that LED's will become more important within the growing and agricultural industry (Appendix 7). As *Growing Underground* are an already established business involved within the area of LED Vertical Farming method they could be classed as one of the Early Adopters within the Diffusion of Innovation Theory. This is because they are communicating their personal views and opinions on how they believe that LED's are important for the growing and agricultural industry trying to reach others involved or interested in this technology, which are characteristics of an Early Adopter (Rogers, 2003: 281).

In the research paper by Sabzalian et al. (2014), they test and compare growth of plants under LED incubator and greenhouses with the results showing the produce grown under LED's grew as healthy or even better than those in a greenhouse (Sabzalian et al., 2014). Marjolein de Bruin from BrightBox research facility has also seen positive results within the produce being grown under LED's by having the ability to increase antioxidant levels and shelf life compared to conventional growing methods. She believes that this is something that Philips, as well as researchers within BrightBox research facility, are working on as another advantage of using LED's within agriculture (Appendix 6).

Natalie de Brun Skantz from Grönska also brought this up during her interview, highlighting how the LED lighting industry is developing all the time, with Philips releasing and bringing out new additions to the market every couple of years (Appendix 5). For that reason, they have chosen to create their own lights not only to make it easier for them to repair in case a bulb breaks but also in order for them to fully understand the 'layers' behind the production and understanding the plant further beyond (Appendix 5).
The problematic of the lights was also mentioned by Jan Ravensbergen, who mentioned a difficulty with the LED lights from Philips as it consists of one long panel of small bulbs. Jan Ravensbergen said it is unknown how the durability is with the LED lights and if one little bulb breaks then you have to change the whole panel of lights compared to the traditional greenhouse lights, where you should simply change the broken or damaged bulb (Appendix 3).
With Philips and other LED companies bringing new advances and developments to the market, aiming it towards new and existing actors within agriculture, these companies are trying to communicate that they are looking towards the future for this technology. Comparing this with the Technological Determinism Theory these types of companies are trying to shape society, or in this case the agricultural sector, by providing new technology to fit trends or what they believe society would have preference for (Chandler, 1995). This could be seen when Natalie de Brun Skantz mentions that a core value of Grönska is to be more sustainable and grow in a sustainable manner, which is something that LED's give the opportunity for (Appendix 5).

Even though through communicating these developments, the Technological Determinism Theory believes that technology is forcing people to reconsider and revaluate everyday actions that people used to take for granted (McLuhan & Fiore, 2001: 9), where in this case it could be the type of light source used to grow the produce. This could be true due to the numerous advantages that were discussed earlier on in this section, when comparing LED to other conventional lighting methods, making them a potential ideal choice when looking at growing produce within a controlled environment (Yeh & Chung, 2009). At the same time taking a viewpoint from the Diffusion of Innovation Theory and how the different actors play a role within the take up of a new technology, if they decide to be more cautious with their choices then it does not matter how hard companies try with communication, the willingness of the individuals will always be a strong factor for decision making (Rogers, 2003).

The lighting technology of LED's are not new to the market but with research and development it has created the chance to use the lights within new agricultural practices. The design of LED's being compact, giving off less heat and the ability to provide a varied light spectrum gives them an advantage over conventional lights used in current agricultural practices. The research within light spectrums of LED's is still ongoing and this could be a reason why some farmers and growers have

not decided to use them within their growing practices. Even though the light efficiency of LED's is higher compared to conventional lights, the uncertainty of the technology and high initial cost has made certain actors more cautious and in turn creating a slower adoption of the lighting technology. For future developments with the experts mentioning that price decrease should occur and actors should become more familiar with the benefits of switching over to LED's, actors will play an important role in LED's bright future.

The following section within the analysis will continue to address LED's but within the whole growing technology of an *LED Vertical Farming* system.

5.5 LED Vertical Farming

This section will explore the LED Vertical Farming system further within all aspects related to this method of urban food production. Also, it will address how both human and non-human actors play a role within this growing system and what influence LED Vertical Farming has on the environment.

As mentioned previously in section 1.3, LED Vertical Farming is a vertical soilless growing method using LED lighting technology within a controlled closed environment that allows the most efficient growing conditions to be produced around the crop.
This controlled closed system method of growing allows crops to grow without any influence or change from the environment otherwise found in traditional ways of growing and in turn eliminates any loss of crops to return higher yields each growing cycle (Mok et al. 2014: 26).

With the population of Denmark and especially Copenhagen currently increasing more than the global yearly average, more space is needed not only for the residents to live but also additional areas for food production to support this growing population. Currently, 1.75% of Denmark's acreage is taken up by cities, streets and other infrastructural facilities, which has doubled within the last 100 years (Holmstrup et al., 2016).

Having LED Vertical Farming technology within the city allows the consumers, living in the urban areas, to know exactly where this produce is coming from and how it has been grown. This links up to the current trend where there is a growing demand for locality and transparency as well as trustworthiness and responsible consumption (Landbrug & Fødevarer, 2016a). Creating this urban, local and sustainable way of providing produce can not only help the growing urban population but

could also supplement food for others within the city such as schools, restaurants and hospitals (Despommier, 2010: 167).

Another aspect by having LED Vertical Farming within the city allows this technology in some way to shape and form how society may view aspects on how their food gets from the farm to their fork. Technological Determinism theory states that new technology in some way or another will have an influence within society, whether it is forced or not (Chandler, 1995). Either it could be that the hard technological determinism approach takes control and makes the technology the main reason for change or the soft approach where it allows the actors the chance to decide for themselves (Chandler, 1995). Having technology around the urban population in their daily lives, could also have an influence on some of the trends and desires mentioned within the previous paragraph, both for or against LED Vertical Farming.

Natalie de Brun Skantz mentioned that there are two ways that you can grow all year round at the moment; in greenhouses or using this new technology of LED Vertical Farming. The way that Grönska grow their produce using this new LED Vertical Farming technology, Natalie de Brun Skantz states that they are currently using about half the amount of energy compared to how much they would use if growing within a greenhouse environment (Appendix 5). Also, another important point to address when comparing the yield that can be produced within the same acreage, growing within a closed controlled environment like LED Vertical Farming, the yield can be over 100 times higher than growing in an open field and still ten times higher compared to conventional greenhouses (Kozai & Niu, 2016c).

Natalie de Brun Skantz has together with her two business partners, Robin Lee and Petter Olsson, started a company where they grow produce with LED's in a vertical farming method. The company is based within an urban area of Stockholm, where they currently are growing their produce in a cellar within a commercial office building. They believe that this way of growing is an important strength for them. Having the ability to grow in a very small space, it efficiently allows them to use areas and spaces within the city that others may see as being unattractive or unusable (Appendix 5). While on the contrary, Marjolein de Bruin finds that it would be hard to use this form of technology within an already built urban environment and that maybe it would be better to construct it within a new building somewhere within the suburbs or industrial area of the city (Appendix 6).

In the past, growing produce within a closed controlled environment would not have been possible, because without light the produce does not have the ability to grow. As described in section 5.4 with the evolution and development of LED's, it has opened up opportunities to create a light

spectrum similar to that of sunlight that the produce requires to grow (Sabzalian et al., 2014). During the interview with Jan Ravensbergen he mentioned that plants need light, and LED's can provide the same light spectrum. Just as with the sun or other light sources, this light spectrum is turned into energy for the plants. But with the way LED Vertical Farming is constructed there is the ability to control many factors and knowing exactly how much light and energy each plant and growing cycle is receiving (Appendix 3).

In chapter two of Kozai & Niu (2016b) it provides an understanding of what type of produce would be suited to grow in an LED Vertical Farm. Here, some of the characteristics that are put forth for the plant, which is grown, are that it should be short in height so that there can be more cultivation layers stacked on top of each other, the plant should be fast growing to provide faster harvest, the product should have high-value sales and about 85% of the fresh produce should be able to be sold (Kozai & Niu, 2016b).

Natalie de Brun Skantz also brought plant choice up as an important factor when looking at LED Vertical Farming from a commercial point of view. Making sure that within an LED Vertical Farm, the right quantity and variety of produce being grown within the specific area is important to make sure that it is economically viable (Appendix 5). The choice and amount of produce has another important benefit when being grown within this kind of closed looped system. It is the ability to work with the current market demand, which is an area that was touched upon with Food Trends in the analysis section 5.2. The growing cycles and plant growth rate can easily be adjusted to suit what the general public demands at a certain time of year or adjust to environmental factors that may require additional production, LED Vertical Farming has complete control to speed up or slow down production (Kozai & Niu, 2016b).

Whether the produce is grown outside on an open field or within a greenhouse, the production is from beginning to end still largely dependent on the seasons. Agriculture has always been affected by the environment around it such as, rainfall, temperature, disease or sunlight; all factors that can affect how sustainable and how much produce can be grown. To control or overcome some of these factors expensive equipment or pesticides will typically need to be used (Banerjee & Adenaeuer, 2013). This is where growing within a closed controlled environment has its advantages because with LED Vertical Farming the produce is grown inside without soil and is not affected by the weather in any shape or form. Also, there is no need for pesticides and there is control of what enters and leaves the system (Eigenbrod & Gruda, 2015). However, when purely looking at the overall initial costs for installing and running of an LED Vertical Farming system, it can be relatively high, which can be seen as a disadvantage (Thomaier et al., 2014).

Marjolein de Bruin describes that the environment plays a role related to the growing seasons for production in the greenhouses within The Netherlands. Typically, the greenhouses in a good season, will have on average of seven growing cycles during the whole year. But this is all

dependant on the environment at the time as this is a factor, which is uncontrollable and out of their hands. During the testing and researching within the BrightBox facility it is almost guaranteed to have eight or nine growing cycles during the year, due to the controllable closed system (Appendix 6). Growing on a commercial scale having guaranteed one or two more growing cycles each year provides a great advantage within the food supply infrastructure of the city. With this method of growing the farmer does not have to rely on the seasons in regards to amount or intensity of sunshine, temperatures, diseases or rainfall. An advantage for this way of growing is the ability to know exactly how much crop is being grown at the time and when it will be available to harvest. This gives the ability to work to the requirements of the growers and consumers (Despommier, 2010: 147), which could also be connect to the food trends discussed earlier within section 5.2, related to demand for specific produce at certain times of the year from the consumers.

As mentioned earlier on in this thesis, BBC News released a news statement at the start of 2017 highlighting that due to unseasonal and unexpected bad weather, the agricultural sector in Spain and Italy would be affected with the produce currently being grown. Given the fact that many of the Northern European countries rely on imported fruit and vegetables from these areas, consumers for a duration of time would see limited stock or increase in prices (BBC News, 2017). Due to the design and growing closed system of LED Vertical Farming it eliminates certain external and unpredictable factors as seen with growing produce in the open or even a greenhouse.

Brought up earlier within the Environment and Sustainability analysis section 5.1, when looking at this type of growing method within an urban environment it provides the LED Vertical Farming growing system with the chance to use many resources that individuals in society may deem as being waste, unusable or just even overlooked. The way that an LED Vertical Farming system works needs to be looked at from the various non-human actors that play a role in the running of such a growing system. The resource inflow and waste outflow allows potential waste products, such as heat, CO_2, wastewater and organic waste that ideally could be used as resources within the growing of the produce inside this controlled growing environment (Kozai & Niu, 2016b).

With LED Vertical Farming method growing produce within a closed controlled environment, various important factors within the system have to be created to suit the requirements that the produce can live and grow in, whether it is controlling the CO_2, water and nutrient levels or the amount and type of light used (Banerjee, & Adenaeuer, 2013). These controllable factors come at a cost, usually in the form of having to supply the system with more energy (Specht, 2014: 42). Even though as shown in the LED analysis section 5.4, the light efficiency of LED's has improved significantly over the past decade, they still contribute to high energy use within the LED Vertical Farming method, due to the technological system running and controlling the production 24/7 for

all year-round production (Kozai & Niu, 2016b). This is where the use and recycling of waste products mentioned above could help with the high energy use but if these steps are not taken within the LED Vertical Farming system then this method of growing could seem less viable for commercial use or less environmentally sustainable (Specht, 2014: 42).

Although the energy usage is an area of discussion, the LED Vertical Farming method has the ability to have the light switched on at any time during the day because it does not rely on natural sunlight. This gives the opportunity to take advantage of special electricity prices if needed. The Danish Ministry of Climate, Energy and Building in 2013 put forward a new *Smart Grid Strategy* and one of the points addressed under this is to encourage people to use electricity during off peak hours where the demand and pressure on the national grid is less. With less demand and pressure the power can be provided at a cheaper rate and availability of energy is plentiful (Danish Ministry of Climate, Energy and Building, 2013). Due to the LED Vertical Farming system being a closed built system this allows the opportunity to have the production and growing of the crops done during off peak periods, during the night, when energy tariffs are lower and more readily available, helping the city of Copenhagen being run more sustainably (Kozai & Niu, 2016b). Having the ability to work during off peak periods allows it to weigh up some of the issues mentioned earlier in this section about the system being high within its energy usage.

Marjolein de Bruin highlighted that growing with LED's in a vertical manner is still only a recent addition to the agricultural market with it being available for the last ten years. Due to it still being relatively new both for consumers, farmers and entrepreneurs, it may still not be widely known or accepted that produce can be grown within this form of high technological growing techniques (Appendix 6). It could be seen that then this type of technology is still within the early stages of the Diffusion of Innovation where only a handful of people are involved within the first two stages and it requires more social and societal influences for more adopters to accept and be involved (Rogers, 2003). Marjolein sees BrightBox as being one of these early adopters who are researching and developing this technology for the future adopters (Appendix 6), while at the same time some form of change is required from consumers within society to accept that this technology is a positive addition to the market place. It could be classed as a soft technological determinism approach where the technology is there for people to be involved in some way or another and open new possibilities and options but, in the end, it is the individual who will ultimately decide what will be done (Chandler, 1995).

As analysed earlier on in this section, the choice of crop and produce grown within the LED Vertical Farming setup is an important economical factor for a commercial business. The overall end cost of the produce is an important aspect to consider. Using important communication

methods and key actors within and related to LED Vertical Farming is vital to create knowledge and understanding of this new product and idea so more are willing to adopt and accept, which plays an important part of the Diffusion of Innovation Theory (Melkote, 2006). Marjolein de Bruin believes the end cost will be a factor to whether people are willing enough to buy the product. Creating and communicating the message that this way of growing provides many sustainable benefits not only for the end consumer but through the production system could be one way to stand out from the other products on the market (Appendix 6).

An increased demand for new niche technology could also prove beneficial not only for the companies but also the consumer. By creating a learning experience and feedback opportunities between the companies and consumers enables everyone to learn from one another, which in turn can help future developments as well as lower costs (Slocum, 2005: 32). The digitalization of companies links up to the *omni-channel* consumer aspect mentioned in EY (2015) in that consumers are expecting and looking for technological solutions to their grocery shopping (EY, 2015: 6).

This is seen within the Diffusion of Innovation Theory when more adopters accept and get on board with an idea, societal changes can happen and people are more open to new ideas for the market place. With more people using the technology and in the case of LED Vertical Farming, overall costs for all aspects of the system from start to end could improve and prices could start to fall at the same time (Rogers, 2003), as seen with the Haitz's Law in the previous LED chapter with the efficiency and cost of LED's (Haitz, 2010). Also, looking at all of the actors both human and non-human involved within the system have a certain cost connected to them and have to be considered rather than just looking at one in particular.
Natalie de Brun Skantz mentioned that even though that there are many costs involved in running a commercial LED Vertical Farm there are other areas due to this technology and way of growing that saves time and money compared to traditional methods. An example Natalie gave was due to it being a soilless way of growing and no pesticide use, the produce requires no washing when harvesting for sale and also being close to the consumer has the advantage of saving time and money as well (Appendix 5). Looking at the bigger picture and all aspects of the system is important in order to see what LED Vertical Farming has to offer not only within the sustainability and environmental factors but also from a commercial point of view regarding time and money.

During this section LED Vertical Farming technology has been approached as being a new technology. Taking a look at the historical timeline in figure 7, section 4.2.2 that was created as an exploratory tool to look into the area and history around and before the creation of LED Vertical Farming, one could say it is not so new after all. As in 2005, PFAL in Japan started to use LED

within their growing systems, then in 2007 Philips formed a horticultural LED solution team and in 2010 there was an increase in companies and businesses coming to the market using LED and Vertical Farming techniques to grow produce (Figure 7, Appendix 14). Even though this has happened in the past, LED Vertical Farming can still be seen as a new form of technology as mentioned in the Diffusion of Innovation Theory earlier on in the thesis. This is because LED Vertical Farming on a commercial basis is currently not found within Copenhagen and is only starting to gain momentum within Europe, which means that it is still new to many individuals and could be classified as a new innovation (Sahin, 2006). This is why we are mentioning it as a new technology within the context of this thesis.

Described in the previous analysis of LED in section 5.4, the advantages that this form of lighting technology has over traditional lighting options, make it a potential ideal solution to be used as a plant production system that has the ability to grow produce all year round (Sabzalian et al., 2014). Combined with the other factors discussed in this analysis section 5.4; adopters of new technology, closed controlled environment, sustainable and environmental options when running the system and the ability to use locations within the city all can contribute to the future outlook for LED Vertical Farming within an urban environment like Copenhagen.

With the introduction of LED Vertical Farming technology, it allows actors the chance of growing indoors in areas that have not been considered before. The LED Vertical Farming method being within a completely closed and controlled environment allows it to perform year-round reliable production without being influenced by external factors such as the environment. This control allows production to be conducted to suit current demands while at the same time providing the end consumer with transparency to where their food is coming from and how it was produced. With this growing system relying on technology and being a closed controlled system the running costs can be higher than traditional methods. Looking at the bigger picture, certain aspects of the system can provide options to use other resources to create a circular economy and in turn reduce some of these costs. With LED Vertical Farming being introduced as a way to do future agriculture the next section on *Danish Farming, Land Use and Organic*, will explore current agricultural practices.

5.6 Danish Farming, Land Use and Organic

The following section will start off by introducing the farming sector in Denmark before being divided up into smaller subsections, *Greenhouses, Organic and Danish Production versus Import*.

Each one of these subsections when possible will have a focus on Danish perspective while analysing these practices comparing to LED Vertical Farming method.

As mentioned earlier within this thesis, Denmark is, together with Bangladesh, the most intensively farmed country in the world (Holmstrup et al., 2016). In Denmark, 51% of the country's area is rural of which 66% is occupied by agricultural land and 14% by forests (European Commission, 2014).
Although Denmark relies on its agriculture for both economic and employment reasons, this could have environmental consequences, which is mentioned in the Denmark Country section of the *Environmental Performance of Agriculture in OECD Countries Since 1990* document (Landbrug & Fødevarer, 2016b; OECD, 2008). In this publication, it states that the reasons for water, soil and air pollution are, amongst others, due to the utilization of inorganic fertilizers and pesticides in agriculture (OECD, 2008). This has been seen to have a negative impact as "*the cost of reducing agricultural nutrient pollution has been considerable and led to a sharp increase in the price of water for household users*" (OECD, 2008: 273). As mentioned in section 5.1, the capital, Copenhagen, is already having sustainability related issues due to the growing demand for water alongside increased prices of water due to agricultural problems. This shows that having agricultural nutrient pollution does not come without a cost. In the end, these pollutants must be removed again in order for it to not harm anyone. However, Denmark is already doing positive actions in reducing pesticides as "*there was a nearly 40% reduction of agricultural pesticide use from 1990-92 to 2001-03*" (OECD, 2008: 273). It shows that Denmark has an awareness regarding the situation and are doing positive actions to change the situation. Maybe this could mean that incorporating a technology supporting this direction would be valuable? Even though water consumption within Danish agriculture has been declining, there is still an issue in regards to the water that is required for irrigation as it has been taking away from the groundwater supplies (OECD, 2008). Similarly seen with the groundwater supplies in the city of Copenhagen, where the supply and demand of groundwater is still a problem (City of Copenhagen, n.d.).
Looking at LED Vertical Farming, which is a method that grows produce within a closed system could avoid such problems as once the water is put within the growing system it can be recycled and reused numerous times due to its closed circular efficient system (Despommier, 2010).

What could also be seen as an issue within the Danish agriculture sector is that greenhouse gas (GHG) emissions stemming from the intensive crop and livestock production in the agricultural sector, currently are above the EU average. This means that the Danish farmers must start thinking differently in order to live up to the demands that come with the "*Green conversion and green jobs*" objective that the Rural Development Program for Denmark have put forth (European Commission, 2014). At the same time, "*Denmark aims to improve biodiversity, water and soil*

management with environmentally friendly management practices, by land use change to more climate-friendly practices, for example by doubling the area of organic farming to 12%" (European Commission, 2014). To do so, there is a need for entrepreneurs to think differently and ensure progress. This progressive and green thinking is needed in the agricultural sector; however, it is seen that there is a lack of well-educated work force in the rural areas (Ministry of Environment Denmark, 2006; European Commission, 2014). If a well-educated work force in the rural areas is what is needed, would it not then be a problem if more production is brought into the city and thereby taking away jobs from the rural areas? This seems to be a problematic concern within the agricultural sector and an area that should not be overlooked.

In regards to the demands placed on spatial planning, the Ministry of the Environment in Denmark states that it "*must preserve Denmark's special qualities and nature and also create a favourable framework that attracts"* (Ministry of the Environment Denmark, 2006: 8). This to some extent shows that Denmark wants to keep what it is known for as the beauty outside of the city, so making conversions of agriculture into woodland could potentially aid to this.
Denmark understands that the world is changing and the character of the Danish land will change. This idea of change and development introduces the entrepreneurial mindset that people need to think more innovatively to create solutions that can suit many. This could in turn fit with Theory of Path Creation, because Denmark understands that new innovations and ideas must be built to go forward. Entrepreneurs know that when creating new paths and direction, they are going against what some may see as being normal or the way it has been done in the past, but in doing this in present time they are looking forward to creating a potentially better future with these new innovations and ideas (Garud & Karnøe, 2000: 6).

Slightly controversially the Ministry of the Environment of Denmark state that "*no one should be in doubt as to where the town ends and the countryside begins*" meaning that the urban areas are for densely built areas opposite to rural areas, which should be free of development (Ministry of the Environment Denmark, 2006: 11). According to von Thünen's Location Theory it highlights the use of having the city entirely free of agriculture as the price of land is too high compared to profit per square meter (Ponsard, 1983). Challenging this could be to say that it could be viable to bring food production into the city if the crop grown has a yield, which price-wise will be profitable and will "*produce the highest ground rent by virtue of their particular location*" (Frambach, 2012: 306). So, if this is the precondition, as long as the crop is profitable, it should be feasible.
Although the theory was set out many years ago before the technological development that we see today, the point that was put across is how one must utilize the land in the best way possible in regards to placement and profits.

Having this forward-thinking perspective should maybe not just be kept for the city. The rural areas, as mentioned previously, also require this development and forward-thinking for the future. Nonetheless, this could provide arguments against bringing the agriculture into the city as that would mean bringing a rural quality into the urbanity of the city. On the other hand, LED Vertical Farming could aid to this view as it could make the density of the built city more intense.

5.6.1 Greenhouses

As mentioned in section 2.2, while the total number of greenhouse holdings that are growing vegetables in Denmark have decreased, the acreage of the holdings has increased, showing that the industry has moved from many smaller holdings to few but larger holdings (Dansk Gartneri, 2012). In the book *Plant Factory – An Indoor Vertical Farming System for Efficient Quality Food Production*, Kozai & Nui (2016) mention several disadvantages of utilizing greenhouses for food production. One of the disadvantages is that "*the greenhouse production is not energy efficient because incident light is not regulated*" (Kozai & Niu, 2016a: 3-4). Also, the irregularity of the sunlight makes it difficult to fully depend on it to have an optimal environment for the production. When the light is too intense, the temperature and humidity increase and to regulate this they have ventilation, which in turn makes the plants more exposed to insects and diseases (Kozai & Nui, 2016a).

These issues with greenhouses and energy expenditure to control the environment is also mentioned in the interview with Benita Hyldgaard and Katrine Heinsvig Kjær from AU Aarslev (Appendix 4). Benita Hyldgaard mentions that a regular problem with greenhouses is that the plants transpire, which creates a high humidity inside the greenhouse and an environment desirable for diseases. Windows are then opened to let the hot air out, which inevitably leads to that the greenhouse must be heated up once again (Appendix 4). This was also mentioned by Jan Ravensbergen: "*So the problem [with traditional greenhouse farming methods] in The Netherlands is that they have to shade the light away with the screens and that creates a climate problem in the greenhouses when the lights are on and the screen has to be closed.*" (Appendix 3: 4). This problematic area could be avoided with the use of LED Vertical Farming technology as it due to the closed controlled environment there is no need to have windows and the environment for the plant can therefore be specifically regulated. It must be noted however, that this type of LED Vertical Farming technology is a specifically tailored machine and if it is not perfectly regulated, problems such as high humidity and risk of infections could still occur.

Kozai & Nui (2016a) state that another disadvantage of greenhouses is that fossil fuels are typically needed for heating and that these "*are a non-renewable energy and excessive use results not only*

in depletion of resources but also in excessive emissions of environmental pollutants including CO_2" (Kozai & Nui, 2016a: 3-4). However, the severity of this depends on the type of energy used for the greenhouses and looking at the facts of Danish greenhouses it states that the use of district heating has increased while oil and coal have decreased (Dansk Gartneri, 2016). This may indicate that the production method is going in a more sustainable and environmentally friendly direction with the use of other energy sources that are available to these greenhouses within Denmark (Dansk Gartneri, 2016).

In the interview with Katrine Heinsvig Kjær and Benita Hyldgaard as well as with Marjolein de Bruin, what was mentioned in both interviews were the physiological advantages and disadvantages of a plant grown within a closed environment compared to one grown outside. Although, this is still an area that has not been researched much within, Katrine Heinsvig Kjær says that a plant grown outside will have a structure that naturally grows to withstand outside conditions. When a crop that has been grown indoors is taken from its natural and enclosed habitat there is a risk of it not being able to withstand the outdoor conditions (Appendix 4). Alongside this Marjolein de Bruin says that "*the plants that have been grown out in the open in the field will always have a different bio content as they are open to the natural environment and elements so each one will vary between seasons*" (Appendix 6: 1). With produce being grown outside it will be influenced and affected by the elements that are uncontrollable, such as temperature, rainfall and nutrient content within the soil, which could bring advantages as well as disadvantages for the plant's attributes.

In the interview with Marjolein de Bruin, she was asked why she thought LED Vertical Farming had not yet gathered more momentum on the Dutch commercial production: "*It is very cheap to grow in The Netherlands, it is so efficient and cheap. There has been a lot of high investments put into the system for greenhouses and so much competition between all of the greenhouses that it would not be worth while trying to compete with them currently*" (Appendix 6: 1). Especially in regards to cost she mentioned it would be difficult to compete.
Worldwide it is seen that the Dutch greenhouses have a recognised high level of technology. While this is a positive point for the Dutch greenhouse growers, at the same time keeping to this high level of technology global recognition requires continuous innovation (Wijnands, 2003: 83).
She also mentioned that "*the farmers currently are stuck in a certain way of thinking and that is where newcomers who are interested within this type of new technology are starting to come into farming and agriculture*" (Appendix 6: 1). This can be linked up to the Theory of Path Dependency and Path Creation in that there is a divide between those who are producing the traditional way with the mentality of a path dependant route because the preferred choice to take or implement is due to it being done before. At the same time, they know others will be more willing to accept and

try new (Garud, & Karnøe, 2000: 44). These are up against the path creation route of entrepreneurs, who think outside the box and try to see new ways of doing things (Garud, Kumaraswamy & Karnøe, 2010).
Furthermore, it could have links to the Diffusion of Innovation Theory as Marjolein mentions the *newcomers*, who could be projected as the *Innovators* and *Early Adopters* (Rogers, 2003). This is because these are the ones that are coming into the agriculture industry and are creating new paths for the industry.

5.6.2 Organic

Within the Danish organic sector there have been fluctuations in the demand for organic produce since the 1990's. Organic farming practices peaked in 2002, where after a decrease was seen in organic farming due to lower market prices and changes in agricultural financial support (OECD, 2008). However, OECD (2008) was written almost ten years ago and since then an increase has been seen in the demand for organic products, as seen in the analysis section 5.2 on food trends by Landbrug og Fødevarer (2016a). As mentioned in section 5.2, it is stated how organic, during recent years has seen a strong growth, in that 40% of Danish consumers often or always buy organic (Landbrug & Fødevarer, 2016a). Also, the organic sector has not only seen an increase within the purchasing of organic produce, but within the past ten years the export of organic produce from Denmark has also increased sevenfold (Landbrug & Fødevarer, 2016b).

Although LED Vertical Farming does not utilize any pesticides and to a large extend ticks many of the boxes that are a prerequisite to meet the organic requirements. Related to the European Union Law on organic production, labelling and control, one reason why LED Vertical Farming produce cannot be classed as organic is related to the growing technique:

"Organic plant production is based on nourishing the plants primarily through the soil ecosystem. Therefore, hydroponic cultivation, where plants grow with their roots in an inert medium feed with soluble minerals and nutrients, should not be allowed" (EC 889/2008. § 4).

This was brought up by Natalie de Brun Skantz from Grönska (Appendix 5). She indicated that this could give difficulties in linking LED Vertical Farming up to the demand for organic, however, there are other parts of the technology that could be linked positively to organic, such as not utilizing pesticides. At the same time Natalie de Brun Skantz mentioned that a way to approach this could be by creating a new label, which could be a Path Creation-way of looking at the problematic. This is because sometimes it could be useful to look in new directions when something is not fitting in to Path Dependency and how things are currently done (Appendix 5; Garud, Kumaraswamy &

Karnøe, 2010). A label such as the red organic label (Ø-mærket) has been created for everybody to understand and fit production methods into a box. But maybe new initiatives need to be created for those that do not fit into this box. Adding to this Natalie de Brun Skantz said, they might work with another company to "*see if we [Grönska] can take another labelling like called 'city farmed' that will be adapted to all new kinds of growers*" (Appendix 5: 7).

5.6.3 Danish Production vs. Import

During one of the expert interviews Mark Delissen from *Deliscious* was asked why he thought LED Vertical Farming had not gathered much momentum yet, where after he stated it is because "*we in Europe have a mild climate. Therefore, it is possible to grow cheap and safe food year-round*" (Appendix 8: 1). This quote links up to various areas found within this analysis. Firstly, it touches upon the production in Europe, hence why we have put this quote in this section. It shows how Europe as a whole has various climates that provides a variety of food all year round. At the same time, it also touches upon the locality, which was mentioned in section 2.3. As there are different ways of viewing local, questions such as the following could arise: Is local only from a producer within your own country? Is it from a producer within a certain radius? Should the food product only have traveled a certain distance? Or is Europe an adequate size to claim it being local? The opinions are many and there currently is still not one universally accepted definition of *local food* (Eriksen, 2013).

Looking at the current Danish production and provision of food, we found it interesting to look into where the salads and herbs that are sold in Denmark come from and if possible how the transportation along the food supply chain from farm to fork. Also, as mentioned earlier in section 2.2 one reason for choosing this type of produce was due to lettuce being among the five largest vegetable produce imported into Denmark (Chamber Trade Sweden, 2009).
For that reason, we contacted Coop, where Casper Lehmann Nielsen, the category planner of vegetables, explained that Coop has three terminals or warehouses; one in Jutland (Hasselager), one on Zealand (Brøndby) and an intermediate warehouse on Bornholm (Rønne) (Appendix 10: 1).
Coop's fresh herb assortment is mainly bought from Danish suppliers, where Rosborg (Gloriamundi) is their main supplier, who packs and delivers to Coop's terminals depending on the requested amounts. When seasons allow it Coop get the organic herbs from outdoor growing but these are usually in very limited amounts (Appendix 10).
In 2016, they had two suppliers; one that grows, packs and delivers to Brøndby terminal and one that grows and has the produce packaged at Coop's central in Harndrup (Fyn). In the last months of 2016, Coop used organic outdoor grown cut herbs from Israel. These were grown in Israel, flown

to The Netherlands, driven to a wholesale supplier, where Kryddergrønt packed Coop's order and delivered to one of their three terminals (Appendix 10).
In times of high demand, Coop gets conventional herbs from the same supplier, where the herbs can be from Kenya and Israel. Simultaneously, in times of high demand, Coop gets herbs that are delivered to the packaging station in Harndrup and transported from there to the terminals (Appendix 10: 1).
It is mainly the same for salads as with herbs. In the Danish season Coop gets the salads from Denmark, where the producers grow, pack and deliver to Coop. In the off-season Coop get conventional as well as organic produce from Germany, The Netherlands, Italy, Spain and Portugal but this depends on the individual produce. These produce do not get delivered to The Netherlands unless they are being packaged there, which then depends on the individual supplier (Appendix 10: 1).

In connection with the production and provisioning of fresh salads and herbs, additional contact was made to other growers and suppliers within Denmark.
In an email reply from Gasa Nord Grønt, they wrote that Gasa Nord Grønt occupies around 65% of the market for Danish produced fruits and vegetables. The season for the individual produce vary but during the off-season they get the produce from import and all their salads as well as parsley are grown outdoor, whereas their production of herbs are grown within greenhouses (Appendix 11: 1).

Global Herbs wrote that they grow and sell approximately 12 different types of herbs. The herbs are grown organically all year round in greenhouses with light and heating. The produce is then packaged by themselves before being sent off to warehouse terminals (Appendix 12: 1).

In the reply from System Frugt A/S they state that they do not provide fresh salads, however, they work with cut off herbs from Israel, Spain and Italy, which according to System Frugt A/S is mainly due to the wish of the customers. At the same time, they also believe that the taste of herbs grown outdoors abroad have more taste than products grown in greenhouses in Denmark, so because herbs are not grown outdoors in Denmark, they made the choice of importing produce. On the other hand, System Frugt A/S only get herbs grown in pots from Denmark but it could occur that they supplement with pots from The Netherlands or Belgium in the rare case of shortage (Appendix 13: 1).
It is interesting how System Frugt A/S bring in the wish of the consumer and that the reason why they chose to import herbs are to cater for their customers. Also, touching upon the taste of the product by comparing outdoor growing to greenhouses could be put alongside with Marjolein de

Bruin's perspective on how the produce must be different from outdoor versus indoor (Appendix 6).

Wiskerke & Viljoen (2012) bring up an interesting problematic that is embedded in a historical perspective on, what in time, has said to be rural versus urban challenges. In doing so, food and agriculture have been classed as a rural challenge and thus has not been incorporated in urban research and policies. As an example, current issues in regards to food reaching the city, are seen as problems in the production and thereby rural problems. Subsequently, food supply chains neglect to see the potentials of using urban agriculture as a means to solve these problems (Wiskerke & Viljoen, 2012).

Although we are aware that a food supply chain is far more complex than portrayed below, in figure 10, 11, and 12, then getting an insight into and an overview of the supply chain of Danish as well as imported produce sold in Coop gave way to elaborate further on how a supply chain could look in comparing the current food supply chain to one of food production within the urban city environment.

The first (figure 10) illustrates a simplified farm to fork food supply chain of European imports of fresh salads and herbs to Denmark for Coop supermarkets (Appendix 10). It shows how the produce is harvested by the farmer, gone through packaging, processing and delivery to a terminal, transported to another terminal, where the produce is then loaded on a truck to be delivered to the supermarkets where the consumer buys the produce.

On the second (figure 11), it shows the simplified version of farm to fork food supply chain of Danish fresh salads and herbs to Coop supermarkets (Appendix 10). Similar to figure 10, the farmer harvests the produce, brings it through the packaging, processing and delivery to a terminal before being loaded on a truck and brought out to the supermarkets where the produce is bought by the consumer.

As mentioned by Hirsch et al. (2016), the longer the food supply chains are, the higher likelihood there is of the food supply chain being prone to shocks and changes that can have a global effect on the actors involved along the chain (Hirsch et al. 2016: 343)

The third (Figure 12), illustrates how a possible farm to fork food supply chain for LED Vertical Farming could look. This was inspired by Grönska, who currently have their production facility within an industrial area of the urban city. Natalie de Brun Skantz states how their vision for the future is to have electrical powered transportation to have the food supply chain be as environmentally friendly as possible (Appendix 5).

Figure 10. Farm to fork food supply chain of European imports to Denmark.

Figure 11. Farm to fork food supply chain of Danish produce.

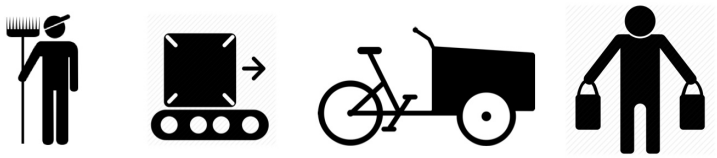


Figure 12. Possible farm to fork food supply chain for LED Vertical Farming Technology Method.

This analytical section presents some of the negative impacts the current agriculture has on the environment in the high uses of water, which there is a growing demand for, and that the GHG emissions are above the EU average. However, the literature shows how Denmark expresses awareness regarding the wish to make changes for climate-friendly practices in bettering conditions of biodiversity, water and soil management (OECD, 2008; City of Copenhagen, n.d.; European Commission, 2014). In order to do so they also acknowledge the need for progressive and green thinking, which shows a noteworthy link to the Theory of Path Creation (Ministry of Environment Denmark, 2006; Garud & Karnøe, 2000).

Also regarding the greenhouses, it states the development of larger but fewer greenhouses in Denmark and poses the disadvantages of it being affected by the weather changes and the difficulty of regulating the heat, light, temperature and humidity within them (Dansk Gartneri, 2016; Kozai & Niu, 2016a; Appendix 4).

It notes that the demand for organic has increased over recent years but because LED Vertical Farming is not officially able to be classed as organic this could create problems in that the consumers trust the red organic label (Landbrug & Fødevarer, 2016a; Appendix 5). The locality of production is also brought up and poses controversies in that the term local has not been universally defined (Eriksen, 2013). The division between the rural and urban is brought up in regards to who should take responsibility of provisioning food to the growing urban population and lastly, simplified figures of the food supply chain both for European, Danish and LED Vertical Farming were made (Wiskerke & Viljoen, 2012; Appendix 10; Figure 10, 11, 12).

From here we move to the *Visions of Copenhagen* to analyse the visions of the Danish capital city and to what extend LED Vertical Farming may or may not fit into these.

5.7 Visions of Copenhagen

During the next section, various future visions and goals will be addressed that The City of Copenhagen have set out through various different publications. The practice of urban agriculture through LED Vertical Farming will be brought into question to whether this method can support these visions that have been put forward for Copenhagen's more sustainable, greener and smarter future.

Copenhagen is already known around the world for their climate and environmental efforts as well as being a cycling city and "*today, the City of Copenhagen and the Capital Region are front-runners in the green Danish economy*" (Københavns Kommune, 2015b; The City of Copenhagen, 2012: 11). The city of Copenhagen acknowledges the already high living standards but at the same time the city should have moved towards and hopefully have reached the visions and goals for the future once reaching 2025. Comparing themselves with other cities and acknowledging Copenhagen is growing in population and thereby increased demands to resource management, Copenhagen understands that change is needed. *Københavns Fællesskab* explains that Copenhagen City wants to show leadership in being innovative, edgy and contrasted without being divided (Københavns Kommune, 2015b). "*To secure the best possible conditions for growth, Copenhagen must continue to establish an attractive knowledge environment capable of attracting and retaining research and businesses*" (The City of Copenhagen, 2012: 10). This visionary point of view could be put in relation to Diffusion of Innovation Theory where Copenhagen City currently in some aspects may be more towards the Early Majority stage in that they do take initiative but that they want to be more towards the innovators or early adopters. In doing so they understand that they need to be new-thinking and give way for innovative approaches rather than following the norm (Rogers, 2003).

"*The core of The City of Copenhagen's Local Agenda 21 Plan a greener and better everyday life is a series of activities which, taken together, create new opportunities for city dwellers, users and businesses where environmental and climate considerations are part of everyday life in a natural way.*" (The City of Copenhagen, 2012: 12).
For the City of Copenhagen to reach its goal by 2025 of becoming carbon neutral as well as becoming a greener city with more green growth, they have come up with five specific themed areas to focus upon: *Energy Consumption, Energy Production, Green Mobility, City Administration and New Initiatives*. These are illustrated in figure 13.

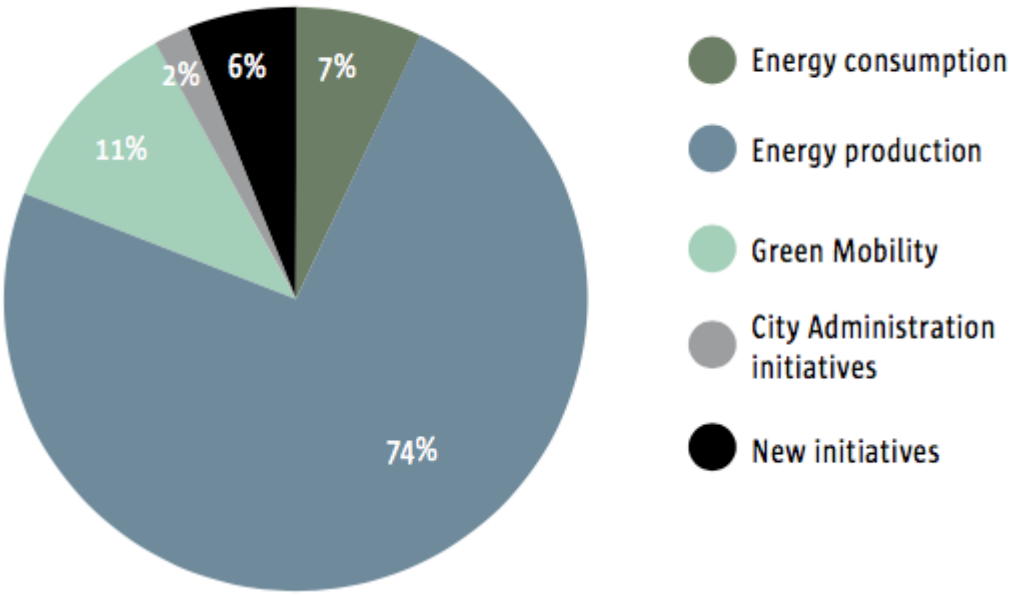


Figure 13. Distribution of total CO_2 reductions in 2025 resulting from initiatives contained in the five themes (The City of Copenhagen, 2012: 13).

The city of Copenhagen also states that new investments and visions for each of the themes are necessary to reach the goal of carbon neutrality (The City of Copenhagen, 2012: 13-14). The area of interest for this thesis would be the theme of *new initiatives* that could help and contribute to the future visions of Copenhagen. It is also mentioned that the initiatives need to be worked towards both on a national level as well as together with Copenhagen. Here, everyone plays an important role for the future not only the city but individuals and businesses together (The City of Copenhagen, 2012: 14).

Reaching the goals that Copenhagen envisions requires innovative thinking and planning. In *Fællesskab København* (Københavns Kommune, 2015b) it indicates that new ways of thinking should be encouraged to allow for creativity and development of the city. This aligns well with Path Dependency and Path Creation Theory as currently Copenhagen is following the path they have previously explored and looking to break free from but realizing that what is needed now is to look at new ways of doing things. Following the usual path will not make Copenhagen an innovative and new-thinking city to make way for experimenting projects (Københavns Kommune, 2015b). Copenhagen wants to encourage uniqueness to the different areas as well as between the old and the new without creating division between them. With this they see the Copenhagener contributing to this in that the originality should come from the ones that have the willpower, creativity and visions (Københavns Kommune, 2015b).

Responsibility is an aspect that is also emphasized greatly. Again, Copenhagen Municipality sees that its citizens should put a level of responsibility upon their own shoulders. The same is expected from the businesses and municipalities. This responsibility is to go towards certain aspects; becoming the first CO_2 neutral capital city in the world as well as having no waste of resources (Københavns Kommune, 2015b).
Examining LED Vertical Farming technology in relation to Copenhagen becoming the first CO_2 neutral capital in the world, then firstly, this type of technology could contribute by creating more green jobs (Københavns Kommune, 2015b).
Secondly, aiming for decreasing waste of resources and becoming leaders within circular economy, this technology provides to this in that it can make use of waste products from buildings such as heat (Københavns Kommune, 2015b). For the whole economy, not just the commercial business of an LED Vertical Farm but also the city itself, waste can provide not only financial benefits from utilizing it but also being able to run, grow and develop in a more sustainable manner without relying more on other resources. (Rutqvist, & Lacym, 2015: XVII).
Thirdly, they want to be climate proofing with more values by creating a robust city securing itself against the climate in doing green initiatives (Københavns Kommune, 2015b).

These three aspects of responsibility go together with what is mentioned by Specht et al. (2014) as "*sustainable solutions for food, water, energy, and transport of food or waste are needed as integrated components of a city's climate change adaption*" (Specht et al., 2014: 34).

The City of Copenhagen acknowledges that food is another contributor of waste that needs to be addressed. When food has been produced for the consumers but ends up not being consumed it has environmental impacts, not only for the city but the whole country, due to the CO_2 emissions that have followed throughout the entire farm to fork (City of Copenhagen, 2014: 17). This was touched upon in section 5.1 and an area Natalie de Brun Skantz is looking at with her company is to shorten the food supply chain by bringing the food closer to the end consumer (Appendix 5). In that way, the chances of food being wasted in various aspects is reduced and in turn the overall CO_2 emissions from the growing, producing, packaging and transporting can also be reduced (Kozai & Niu, 2016b). Also, another aspect mentioned within the Food Trends analysis section 5.2, is that produce grown within the LED Vertical Farming technology method on average lasts one to two weeks more than conventionally grown produce, which can aid the fight to decrease food waste within society (Kozai & Niu, 2016a). Furthermore, by bringing produce that usually comes from abroad closer to the city can in turn cut down on transportation and be part of moving the city towards becoming more self-sufficient (Københavns Kommune, 2015b).

Ambitions of Copenhagen city is to exploit going carbon neutral by creating new jobs, attracting new investment to Copenhagen but by doing so acting smarter, greener and also being more open to new opportunities that could support this (The City of Copenhagen, 2012: 8). As mentioned above, the city of Copenhagen knows that it cannot do it alone and in its publication, *CPH 2025 Climate Plan, A Green Smart and Carbon Neutral City*, it highlights that they are wanting to listen and work with others to create new solutions, technologies and suggestions as an important part to develop new green solutions (The City of Copenhagen, 2012: 10).
This correlates with Gallo et al. (2016), who state how it is necessary to involve the public administrations, citizens and professionals when wanting to grow food in an urban space; "*The recovered role of growing food in urban space is actually rapidly spreading, and it makes thus necessary the involvement of public administrations, citizens and professionals, in addition to a diffusion of specific knowledge about design and technical consultation or assistance for the various activities interested"* (Gallo et al., 2016: 108). This involves an understanding of the Actor Network Theory, knowing who plays a role, influences or gets influenced by an action is important to understand the environment at the moment for what and whom it is created for as well as who is involved.

In the research paper by Voigt (2011), they state that there are positive aspects of LED Vertical Farming when looking at it in regards to pollution. Even though Copenhagen may not be the most polluted city this can still be of concern, which was also mentioned by Lykke Leonardsen from Teknik og Miljøforvaltningen (Appendix 9). She wrote that all soil in Copenhagen can be polluted, which could create problems in doing urban gardening as there are requirements that outdoor produce must be grown in raised beds (Appendix 9). This problem is avoided within LED Vertical Farming, as the produce is grown within a closed system, which in turn eliminates the risk of pollution on plants. On the other hand, Voigt (2011), states that indoor farming does not contribute to freshen air, which he sees as a negative of indoor farming (Voigt, 2011).
On the other hand, "*ZFarming practices are not in and of themselves sustainable and need to be managed properly*" (Specht, 2014: 33). This statement is controversial and important for this thesis because the idea of this thesis is to be targeting the city of Copenhagen and aid in becoming more CO_2 neutral but by bringing this technology into the city it technically will not reduce CO_2 emissions. However, this technology could aid the decrease of CO_2 emissions in other ways such as reduce food miles by reducing import, as well as creating grounds for forestry. Also, "*Copenhagen is unique. Copenhagen is a metropolis large enough for its climate solutions to be interesting in an international context, but also small and manageable enough to test out new, smart solutions*" (The City of Copenhagen, 2012: 9).

The City of Copenhagen and Municipality have set out numerous visions through their publications so that by 2025 the city will be carbon neutral. The realisation that change is required for Copenhagen to move forward into the future, to grow and become a better place for everyone to live and do business in. Attracting new businesses is key but at the same time it should be in a way to create a greener and smarter city. New initiatives should be setup to achieve this and done with actors working together, both individuals and businesses to think more creatively, innovatively and be forward thinking. This thought process will allow the various actors to take some form of responsibility for the city of Copenhagen and to understand what needs to be done for the future. Creating a circular economy within the city to combat concerns of waste is required with the issue of food waste being addressed as one. The future visions to become a greener, smarter, carbon neutral city is something that The City of Copenhagen feels it can be accomplished by the use of new solutions and new technology together with the partnerships of actors working together.

Through the analysis the idea of LED Vertical Farming has been explored and analysed through use of literature, methodology, theory and data collected through the interviews with experts from within the field.

This leads us to the next section, where we will be discussing our findings and address our research questions.

6

Discussion

In order to address the main research question as well as the sub questions, we have divided the discussion section into sub categories. To reiterate how we came around forming the themes for the analysis, which happened through developing categories "*as a function of the actual research undertaken*" (Dahler-Larsen, 2008: 25), now after finishing the analytical process, we have gone through the same procedure prior to the discussion. Here, we have pulled apart the findings, which opened up to areas that have reoccurred throughout and all stem from the findings in the analysis. This allows us to view our data from a different perspective in trying to dig deeper into addressing our research question as well as sub-questions and in turn, pose more questions that may be left unanswered but nonetheless provide talking points to take into consideration.

6.1 Addressing the Research Questions

In the following discussion sections, five new categories will be introduced; *Grey Spaces, Rural-Urban Divide, An Evolving Technology - New but Old, Food Supply Chain* and *The Level of Control.* These will be followed by the *Methodological* and *Theoretical Considerations* as well as *Expert Interviews* sections.

This thesis addresses the following question:

"How could a new commercial agricultural technology of LED Vertical Farming provide sustainable possibilities for Copenhagen in relation to the city's growing urban population, as well as contribute to Copenhagen's visions for the future?".

To make way for addressing this in more depth, three sub-questions were formed.

The first of these is "*Why could the city of Copenhagen be the place to utilize the technology of LED Vertical Farming or why not?*", which will be addressed within *Grey Spaces.*

The second sub-question; *"The growing urban population of Copenhagen may entail more mouths to feed, but who should take the role of feeding these?*" will be addressed in *Rural-Urban Divide.*

Lastly, the third sub question *"How could LED Vertical Farming be utilized to address the current food supply chain, as well as environmental and sustainability issues within the city of Copenhagen?* will be addressed throughout *An Evolving Technology - New but Old, Food Supply Chain* and *The Level of Control.*

As mentioned previously in this thesis, the subject area of LED Vertical Farming is complex and the areas inevitably will overlap, thus questions may be addressed several times throughout the discussion as they can be relevant for more than one of the sections.

6.1.1 Grey Spaces

In order to discuss whether LED Vertical Farming is a viable solution for the city of Copenhagen, then an aspect that should be considered is where the growing of produce should be place within the city?

As mentioned by Specht et al. (2014), for many cities open space is scarce and since Copenhagen has an average yearly population increase of 1.95% (Statistics Denmark, 2016), land in the city will become increasingly scarce in the future. So, the question arises on why agriculture, which is currently being conducted outside of the city, should be moved into the city where there is competition for space? And if so, how is this best done? The first question we already attempt to answer and analyse throughout this thesis, however the latter will now be discussed a little further.

Due to climate change, population pressure and soil degradation, agricultural land will decrease at the same time as food demand will continue to increase (Thomaier et al., 2014). This in turn puts pressure on agricultural land and could call for new ways of looking at the problem to create a future that is sustainable for the growing population. Throughout this thesis, the new way of looking at this problematic has been to see whether LED Vertical Farming could be a viable and sustainable solution.
The general idea of vertical farming is that this type of farming method does not intend to take up more land but rather utilize the space that is already there more efficiently (Thomaier et al., 2014). In the research paper by Thomaier et al. (2014) as well as Eigenbrod & Gruda (2015), they emphasize the opportunities that lie within utilizing vacant buildings or rooftops and integrating the production site innovatively into the empty spaces that may otherwise be seen as undesirable (Thomaier et al., 2014; Eigenbrod & Gruda, 2015). In doing so, the production site is also placed closer to the consumer, which in turn could be "*an innovative way to address the issues of land scarcity and food security*" (Thomaier et al., 2014: 8). In some research papers, the authors have mentioned the use of vacant buildings or plots for the purpose of urban agriculture (Thomaier et al., 2014; Eigenbrod & Gruda, 2015).

Throughout our exploratory research, we did not find a generic recognised term to describe the use of areas within an urban environment that are viewed to be undesirable or unused due to practical reasons. Due to this, for the purpose of this thesis the term, *grey spaces*, will be used to define these types of spaces within the urban environment. Although grey spaces have previously been used to describe the grey concrete spaces in the city in how to make the grey concrete green (James et al., 2009), the term *grey spaces* will be used with a different perspective towards conducting commercial agriculture within the city.

Due to the fact that LED Vertical Farming is a technology that does not use outdoor sunlight, it provides the opportunity to utilize spaces in the city that could otherwise be unsuitable to live in or to conventionally grow produce, such as underground spaces with no natural light. In that way an LED Vertical Farm has the possibility to not take up essential areas of land within the urban environment. This topic of certain spaces within the city was also mentioned in the interview by

Natalie de Brun Skantz: *"I do not know how it is in Copenhagen but in Stockholm we have a lot of spaces that are unused and non-attractive like cellars without windows and they are dark so no one really wants to put an office there or anything, but for us it works perfectly fine because we basically only need water, electricity and if possible high ceilings"* (Appendix 3: 4).

Another company that has utilized an unused grey space within the city is the company Growing Underground, who have based their production site in a former air raid shelter 33 meters below the streets of Clapham in London (Growing Underground, 2017). Here they have utilized a space in a city that was overlooked for practical reasons but now has the possibility to grow fresh produce closer to the consumer reducing food miles as well as the need to import (Growing Underground, 2017).

However, one must not neglect the fact that land rent has an impact on the type of business and where it is situated, whether it is situated on its own land or within a building also used by others. This was touched upon by Ponsard (1983), where he states that "*land rent becomes an indicator of the opportunities involved in various available methods of cultivation and in the choice of various products*" (Ponsard, 1983: 14). This can be related to von Thünen's Location Theory, where the goal is to suit the type of crop to its placement in regards to market, in order to create a profitable production. Elaborating on this, the cost of land and production should be outweighed by the price that the produce can be sold for so that it creates a profitable outcome. An example of this could be to grow fresh produce that have a high value "*such as micro greens or tomatoes that can be sold at a premium, especially in off-season*" (Specht et al., 2014: 45), so that one could produce a crop that would otherwise be imported during off-season. Also, as mentioned in section 5.4, the likelihood of profitability to be highest would be by growing a produce that has the characteristics of having short growth periods for faster harvest, being short in height providing additional cultivation layers, having 85% of the fresh produce to be sold as well as having high-value sales price (Kozai & Niu, 2016b). These should all be taken into account for a profitable production, especially for harvesting in the city to make most use of the available plot.

Where Thomaier et al. (2014) and Eigenbrod & Gruda (2015) state that grey spaces should be used, Marjolein de Bruin from BrightBox on the other hand is of a different opinion. She highlights that "*it would be easier if one started with a brand-new building or constructed a building for this type of farming within an industrial area close to the city, which is not being used or could be redeveloped as I see it as being difficult to incorporate this in the city with all of the existing buildings around*" (Appendix 6).
Due to there already being limited free and available land in the city, it could be beneficial to move the production further out of the city to the peripheral urban areas, also called peri-urban areas.

Peri-urban is the area on the urban fringe, where urban lifestyles are taken up by the rural population. This in turn is an area, where the farmers are pressured to sell their farmland due to the increase in land prices. Instead this land is converted to favour the urban development (Zasada, 2011). In the case of this thesis, the area outside of the City of Copenhagen but within the Greater Copenhagen limits will be used as the peri-urban area.
Looking at peri-urban areas was amongst others mentioned by Eigenbrod & Gruda (2015) as one could use these vacant areas while at the same time being aware of not becoming too focused on areas, with a dense population (Eigenbrod & Gruda, 2015). Also, the perspective on utilizing an unused industrial building could be a solution, which is what Grönska are currently doing. Grönska has its production facility in the South of Stockholm approximately five kilometers from the city centre in an area that Natalie de Brun Skantz regards as slightly suburban but convenient as it is close to a subway station. The production facility is placed in the basement of an old district heating station, where there are offices on the floors above (Appendix 5). This correlates well with what was mentioned by Marjolein de Bruin on moving the production further out of the city but still within an unused building. Interestingly, Grönska has also placed their production in the cellar, which once again shows the possibilities that there are, in that LED Vertical Farming does not need natural light to grow and using what others may regard as undesirable or unusable grey spaces within the city.

It could be a valid option to build a new building for this type of farming in the peri-urban area as it could be more cost-effective. However, this would create a larger distance to the consumer and thereby also more food miles. Conversely, the fact that Grönska's facility is placed further outside of the city is not regarded as an issue to Natalie de Brun Skantz as Grönska plans to have electric transportation of their goods to retailers in the future (Appendix 6). On the other hand, constructing a new building could imply added costs and further environmental issues compared to utilizing spaces within one that has already been built (Kozai, 2013).

Building on this, it is interesting to take a look at *The Finger Plan* created by the National Planning Directive (The Ministry of Environment, 2015). The purpose of this development was so the *"urban development is concentrated along city fingers linked to the railway system and radial road networks"* in order to make it easier for the population to reach the central Copenhagen from the Greater Copenhagen area and vice versa (The Ministry of Environment, 2015: 3).
As it is shown in figure 14, the palm of the hand is placed on Copenhagen city to show that it works as the primary centre for the Greater Copenhagen. The 'fingers' show the peripheral urban region, the green wedges are in between the fingers and the rest is the area of the Greater Copenhagen (The Ministry of Environment, 2015). Relating to this, figure 15 illustrates the cities as well as the transport infrastructure.

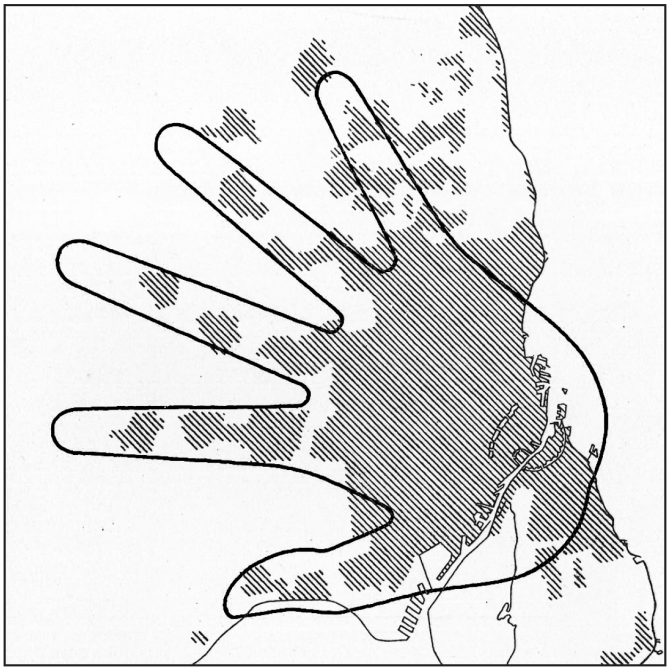


Figure 14. *Sketch from the first Finger Plan created by the Regional Planning Office in 1947* (The Ministry of Environment, 2015: 5).

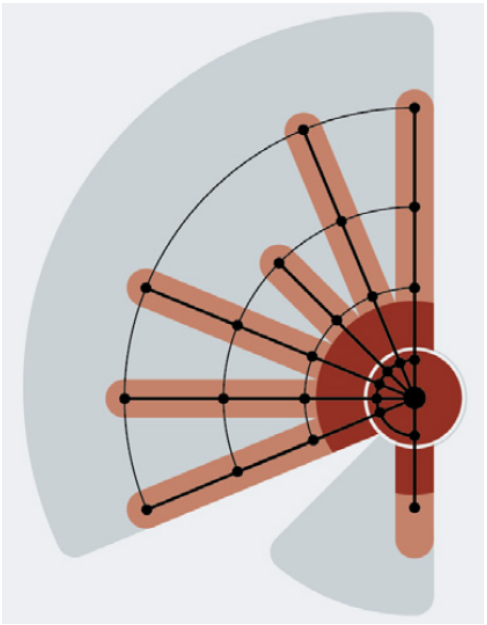


Figure 15. *The finger city structure: Cities and transport infrastructure* (The Ministry of Environment, 2015: 19)

This to some extent shows links to the version of von Thünen's Location Theory, where there is a focus on a primary centre, here central Copenhagen, to which the outer areas must cater to but also acknowledging that there are secondary centres to supplement the main centre. This is seen in that the commercial businesses are placed in central Copenhagen but that there are regulations in

regards to what types of businesses as well as the size of these are allowed to be placed outside of the primary centre (von Thünen, 1966; Clark, 1967; The Ministry of Environment, 2015).

The public transport system and the infrastructure behind The Finger Plan could be something that we could draw on in regards to the LED Vertical Farming. This infrastructure consists of *"railway services with suburban trains, regional trains, metro and light railways as well as an attached general road network"* (The Ministry of Environment, 2015: 10). By Copenhagen having a smoother traffic infrastructure making it easier to access the urban fringes and vice versa, gives the opportunity to locate a facility along these 'fingers', thus allowing for easy access into the city with produce as well as for the urban population to reach the facility if necessary. Furthermore, the National Planning Directive states that if *"shops selling specific goods which require an unusually large amount of floor space may be planned outside town centres"* (The Ministry of Environment, 2015: 8).
The Ministry of Environment (2015) addresses placing business facilities on locations near stations in the peri-urban areas as a strategy for workers to use the public transport system as well as creating balance across the regional areas and generate new urban zones that in turn can stimulate developments near stations. Moreover, they are looking at situating companies and businesses near transportation systems that can benefit both the running of the businesses as well as environmental issues in that they understand locations of businesses that either transport or distribute must be near motorways and those with many workers must be near public transport stations (The Ministry of Environment, 2015).

Linking this up to the idea of Marjolein de Bruin stating that creating a brand-new building for this type of farming within an industrial area close to the city could be a solution (Appendix 6). However, as stated by Kozai (2013), then the added costs connected to building a new structure could be a disadvantage (Kozai, 2013). On the other hand, the rent may be lower the further one moves the facility outside of the city. Following the example of Grönska then finding an unutilized basement in a large building in the peri-urban region could be beneficial. Moreover, taking advantage of the traffic system could allow for utilizing either public transport or electric vehicle for the transportation of produce (Appendix 3). Thus, aiding to the goal of the City of Copenhagen for 75% of all trips in Copenhagen to be by foot, bicycle or utilizing the public transport system (The City of Copenhagen, 2012).

Irrevocably, the placement of a facility in regards to the Finger Plan, as seen in figure 14 and 15, would have to be a balancing act and dependant on rules and regulations on where specific types of facilities are allowed to be built in combination with financial costs.

Urban agriculture can be looked at from both bottom-up and top-down perspective. Bottom up is in the sense of citizens that by own encouragement create gardens for social and pedagogical purposes (Gallo, Casazza & Sala, 2016). This type of urban agriculture has, in the past, been seen by authorities and locals as a way of bringing people together socially and introducing green spaces within the city environment (Kozai, 2016).
However, with advances in technology and entrepreneurs exploring new possibilities, urban agriculture has caught the attention as an emerging commercial business opportunity that could be incorporated within the urban environment (Kozai, 2016). This could potentially work in the perspective of a top-down process because this could be an initiative to strengthen the infrastructure of the city (Gallo, Casazza & Sala, 2016).
Currently, as mentioned by Lykke Leonardsen from Copenhagen Municipality, Copenhagen regards the potentials of urban gardening solely as a social, educational or pedagogical perspective to create experiences in green spaces. She supplements that, by stating that there is not enough communal space for commercial agriculture. However, at the same time she also states that if one was to create a commercial agriculture that could be viable in the city of Copenhagen, one should opt for solutions such as the vertical farming. However, this is not something that they have been speculating in as they have not received any specific requests regarding this (Appendix 9).

The Copenhagen Municipality has followed the same path of solely utilizing urban agriculture for pedagogical and social purposes because they have not previously been introduced to new ways of doing it. They may have had the impression that it would not be viable to create commercial agriculture in the city, because of the lack of space (Appendix 9), which is also what the original view of Location Theory would imply. However, when being introduced to a new path with the perspective of efficiently using the space by vertically stacking the cultivation layers, Lykke Leonardsen does not seem opposed. This could show how the Copenhagen Municipality has previously been following the path that it has known but that this innovative viewpoint provides new opportunities.
This shows how this type of farming is new to Copenhagen and could have potentials at the same time as this type of farming may also be met by scepticisms in regards to available space and that new innovations and entrepreneurs would be needed if this was to develop.

While looking at the opportunities of exploring the use of LED Vertical Farming technology method in a commercial setting to the city of Copenhagen in a more sustainable manner, building a new structure may not be the right direction to head. With the development and design offered by an LED Vertical Farming technology system it has the ability to utilize spaces and places that may previously have been overlooked, grey spaces, especially in regards to the urban agricultural sector.

With the urban population increasing and the availability of land reducing within the city, utilizing and taking advantage of these grey spaces already built into the city's infrastructure, that some may see as unusable or undesirable could be the option. Being situated within the city could be a controlling factor related to the land and rent prices, and this may make the peri-urban areas of Greater Copenhagen seem more attractive in an economic sense. Using the transport network that have already been established through The Finger Plan, allows access between the City of Copenhagen and the peri-urban areas that could be used for transporting of produce and/or consumers coming to the source of their food. Placing businesses within the peri-urban areas also fits in line with some of the visions set out by The Ministry of Environment (2015) and using this transport network works with what The City of Copenhagen (2012) wishes for, in that 75% of trips in the city should be taken by foot, bicycle, public transport.

Whether we take advantage of the grey spaces already found within the urban city environment or in the peri-urban areas, in the end it allows food production to come in or closer to the city. This ability to bring the food closer to the mouths that need feeding and utilizing the grey spaces provides an option to help out within sustainability and environmental factors related to the growing urban population (Eigenbrod & Gruda, 2015).

6.1.2 Rural-Urban Divide

The rural and the urban are two different environments, but at the same time they are interconnected in many aspects, with food production and consumption being one of them.

With over 60% of Denmark's land acreage being taken up by farmland (Holmstrup et al., 2016), and more people moving to the cities, such as Copenhagen, then who is going to take the responsibility to figure out how the agriculture and supply of food will benefit everyone, with a future sustainable viewpoint? Which actor(s) are going to take responsibility for the increase within the food production required to supply the need and demand from the growing urban population?

In the past, it has been debated as a rural versus urban challenge, whenever food or agriculture has been brought up due to challenges faced. Historically, the responsibility has been put towards the rural sector to figure out a solution, rather than trying to figure it out with urban research and policies (Wiskerke & Vijoen, 2012). As the food is currently grown outside of the urban environment within the rural areas, this produce grown comes through the food supply chains into the cities. Then you have to think, maybe the city has overlooked these issues by not addressing the potentials that urban agriculture could provide to solve some of these problems. Is it time for the

city to think creatively about food production in order to help out the agricultural sector, which currently is being conducted in the rural locations or would it create more issues in doing so?

The way agriculture is being conducted today, Despommier (2010) believes the land needs time to recover and heal itself. The way farming has been done before has not been a long term sustainable solution with the use of pesticides, nutrients being washed away or used up by over-farming (Despommier, 2010: 136-137). According to Despommier (2010), by bringing food production and agriculture into the city on a commercial basis could allow the urban population to continue with their daily lives without damaging or using up more agricultural land for the extra food production that could be put to more environmentally friendly and long term sustainable use (Despommier, 2010: 142). While on the other hand, would this not just be a way for the city to turn a blind eye and not consider the effects also caused by bringing food production and agriculture into the city? Or is it an option for the urban environment to show how agriculture could be conducted more sustainably, in a new setting for the end consumers, allowing the land to have some time to heal itself?

However, looking at this from a different perspective, by bringing the food production into the city, it could bring other problematic issues to the rural areas such as the loss of jobs within the agricultural sector, which was previously touched upon in the analysis section 5.6. Since the FAO (2009) highlights that the population within rural areas will continue to increase without enough available job positions, then the issue arises with which actor(s) would be the one(s) to step up and figure out the solution? This in turn brings us back to the rural-urban divide and responsibility (FAO.org, 2009: 3), which is where the need is to address all actors involved, both human and non-human, within the rural and urban sectors. Why not treat them as individuals? By bringing the actors together to understand the important issues, could be a way for the key issues to be addressed for long term solutions with an environmental and sustainability understanding towards the food production system (FAO.org, 2009: 3).
With agricultural food production having a potential to be within the city, with the introduction of LED Vertical Farming method, it can also provide jobs at the same time from those taken away from the rural areas. While this could seem like a good solution it was mentioned by Jan Ravensbergen that the rural residents may not want to move away from their current surroundings to do agriculture within an urban environment (Appendix 3). While on the other hand as Marjolein de Bruin mentioned, this could be a perfect solution for the future farmer based within the urban environment, wanting to do agriculture but with the use of new innovations, developments and technology (Appendix 6). Bringing the food production within the city could also create new green smart technological jobs for the future, something that The City of Copenhagen has put forward as one of its visions for the future (The City of Copenhagen, 2012). Then again, the rural-urban

conflict could arise with more jobs being available to those within the cities than out in the countryside. Could placing these LED Vertical Farms within the peri-urban areas of Copenhagen be a better solution for all to meet in the middle or should the city take control of its food production?

One interesting suggestion that has been brought up that could benefit actors both within the rural and urban environments is the planting of woodland. With the introduction of LED Vertical Farming technology into the city, it could take away food production from current practices within the rural areas, whether it be greenhouses or open fields. The land that then will be freed up from the current food production has the option to give back something, in the sense of both environmental gains and also jobs. To address the job suggestion first, within his book Despommier (2010) mentioned that any land that had been replaced by the LED Vertical Farming technology method, then this land could be transformed into new woodland areas. The planting of trees on this land could provide financial benefits from the land with new activities and roles related to this conversion (Despommier, 2010: 144). Another benefit from this land conversion to woodland is reduction within atmospheric CO_2 levels. With more trees being planted on land that had been used for agricultural food production, the reduction in CO_2 footprint can occur at various points including that with the trees absorbing the CO_2 naturally (Despommier, 2010). This could be a way not only to support the visions of Copenhagen with its aim of becoming the first carbon neutral city in the world but also a way to help the country as a whole with its reduction in CO_2 levels.

The planting of woodland within the rural areas could be viewed at going with or also against what the Ministry of the Environment of Denmark is aiming for. The Ministry of the Environment of Denmark would like people to be able to see where the countrysides and cities begin and end (Ministry of the Environment Denmark, 2006: 11). This aim has some connection with von Thünen's Location Theory that once you leave the central point, city, then there are separate rings of certain agricultural practices that change the further you move away from this central point (Ponsard, 1983:13-18) (von Thünen, 1966: xii-xliv; 7-11).

So would the transformation of agricultural production land, fields and greenhouses to woodland be a good visual aid to show where the rural and urban areas start and end? One could say that, to the eye, the woodlands is natural, a part of nature and maybe could benefit other actors at the same time. The introduction of these new woodland areas could also help certain animal species that are currently threatened with loss of habitat or environmental issues that have been influenced by the agricultural sector (Frostholm, Schjelde & Holmstrup, 2016).

The mindset of people could demonstrate that the view of farming should be done outside of the urban environment, within the rural areas of Denmark, relating to the rural-urban divide as mentioned earlier. However, with the advances in technology it allows the option to move across

borders, rural to urban, changing the way agricultural practices have been done in the past to how they can be done now.
Agriculture is a large part of Denmark's economy and Danish agricultural brands have gained global recognition (OECD, 2008). The next step for the agricultural sector could be to move the production of certain produce to be grown within the city of Copenhagen itself. With this, following the example of other cities around the world who have incorporated LED Vertical Farming into the city could be what Copenhagen should be looking to do in their near future. Could another option be to move the production not to the city itself but within the peri-urban areas surrounding Copenhagen? The Grey Space discussion brought in a point that could help support this proposal, which is relating to the design and development of the transport infrastructure of Copenhagen by utilizing The Finger Plan, as this provides a direct connection between the urban and the peri-urban areas.
While creating these new paths from the old to the new agricultural practices, especially within the introduction of a new technology such as LED Vertical Farming method to the city of Copenhagen, it is important to consider the actors that would be involved and influenced (Garud, & Karnøe, 2000: 10). Whether it be the farmer, land, produce, jobs, organisations, companies, residents of rural or urban areas, all the actors play a part in one way or another and have the ability to work together. Working together and taking some responsibilities could bridge this gap between the rural and the urban environment to make decisions and contribute towards a more sustainable and environmentally friendly agricultural sector, economy and use of Danish land.

It is understood by The City of Copenhagen that everyone, both within urban, peri-urban and rural areas, must work together to create *new initiatives* that could help and contribute to the future visions of not only Copenhagen but also the whole of Denmark. Here, all actors play an important role for the future not only the city but individuals and businesses together (The City of Copenhagen, 2012: 14).

6.1.3 An Evolving Technology – New but Old

"To be successful either it must fit into or reshape its environment" (Sismondo, 2010: 86).

Even though the lighting technology of LED's is not a new creation, as the first practical version was produced in 1962 and the white option was developed in 1999, shown within figure 7, the way it can be used in certain applications is still new to many. The decrease in the overall price of red and blue LED's within the market and at the same time as having increased their efficiency, shown earlier within the Haitz Law, is one of the reasons why this type of light has been regarded as more suitable and considered for use within agricultural practices such as LED Vertical Farming

(Sabzalian et al., 2014). Also, when looking at points along the explorative mapping of historical discourses in figure 7, it highlights that numerous companies, businesses and research facilities utilizing these lights, have been set up globally over the past 15 years (Appendix 14).

Then one could question if there is a technology available to be used to do something that is not currently being done, why has there not yet been any businesses, companies or entrepreneurs who have established this technology of LED Vertical Farming in Copenhagen??

On the other hand, do we need to get involved within these new advances in technology in general or could the viewpoint of Winner (1989), to simply sit back and watch the technological development unfold, be the better option? There is a drive to create new technologies, conducting research and developments but would it not just be better to look at the end consumer and educate them better. In terms of food production, educating individuals to eat what is grown locally or in season rather than importing the produce could be another solution over that of new technology. Jan Ravensbergen said the customers ultimately control what happens within the market (Appendix 3), so rather than developing a new technology to suit their demands why not control their demands from a different direction looking away from technology?

While on the contrary, the reason why the food supply chain must to be reviewed could relate to the need for addressing the old practices as well as addressing the new paths to be created in the form of new technologies. It may of course be easier to do things the way they have been done before, following the path dependant route, due to it being comfortable, knowing how it should be navigated and knowing the typical outcome (Garud & Karnøe, 2000: 44). While Schumpeter (1942) stated, *"any system designed to be efficient at a point in time will not be efficient over a point in time"* (Garud & Karnøe, 2000: 6). Even though something has been done for many years and has previously worked well, it will need to be looked at again to make sure that it is being conducted efficiently and sustainably. So why not do the same with the way our food is currently being grown and supplied?

The quote at the beginning of this section; *"To be successful either it must fit into or reshape its environment"* (Sismondo, 2010: 86), is relatable to many aspects of new technology. Entrepreneurs while developing new innovations and ideas are not trying to fit into the environment directly but are trying to create new paths, while shaping them in real time by changing social factors and shaping directions to suit the ideas that ultimately may create something new (Garud, & Karnøe, 2000: 2). Growing produce such as salads, herbs and micro greens, within a controlled environment using LED lights, on vertical platforms is a new way of growing what has typically been grown in greenhouses or out in the open environment on fields.

While the thought by entrepreneurs of creating something new is exciting due to the unknown, getting this idea accepted and taken up by the actors that are either influenced or involved is an important factor to consider and the thought behind the Diffusion of Innovation Theory. Getting these actors on board, to interact and work with one another are important steps for development and progression with the idea within the market. This overall interaction between all the actors will produce an outcome where the technological arena will start to take shape (Garud & Karnøe, 2000: 10).
Saying that, one aspect of the Diffusion of Innovation Theory that is problematic, especially voicing a new technology, is the way a message is communicated between the different actors. Everyone is different in important, unique and interesting ways. These actors come from many different walks of life, social circles and the message they collect, process and pass on will be different from one person to another (Rogers, 2003: 19). Creating this new path and introducing the new technology to Copenhagen may not be to everyone's personal acceptance or advantage. However, at the same time the Nordic Food Survey mentions that the consumers are more open to change and like to see new products on the market but with a preference towards these products to be produced locally or domestically rather than abroad (EY, 2015), which shows that there may be a level of acceptance.
Bringing LED Vertical Farming to the city, which is not the traditional way of doing agriculture and especially within an urban environment, could be seen as an opposite way to look for a solution but then being forward thinking to create new innovations, ideas and solutions for a more sustainable future is a key point within path creation (Garud & Karnøe, 2000: 6).

The uncertainty has two sides to the story. It is something that can drive people to become innovators and early adopters within the market while at the same it could make people back away until they feel comfortable in accepting what is on offer. Even though the production cost for LED lighting from what it is currently may reduce to half by 2025 (Kozai et al. 2015), the price of this technology seems to be a common trend popping up when speaking to experts within the area as well as the literature. Both Jan Ravensbergen and Growing Underground mentioned that price can play a role in whether the adoption of the LED Vertical Farming technology is taken up (Appendix 3 & 8). As traditional conventional growing lights have been used for many years, with this path dependant viewpoint, individuals know what to expect when they purchase these lights (Appendix 4). Marjolein de Bruin also in regards to economy states that end cost could be a factor to whether people are willing to buy the product (Appendix 6). Both of these look at LED's in connection with economic benefit and this could be important as it may seem that this could determine whether this technology could be viable to implement. However, one major question occurs from this, which is whether one can put a price on the environment. One cannot get everything they desire, so in some areas one must compromise. With the direction that the world is currently going in, we could

question whether the right compromises have been made so far. But should the compromises be in the actual production of food such as converting some of the agriculture to LED Vertical Farming in the city or should it be in the teaching of food, which was also mentioned earlier in this section.
While with the introduction and development of LED's within agriculture, it provides a new way produce can be grown, that may have been restricted previously with the conventional lights. Although this new novel way is exciting for some, it could bring challenges and there may be a need in doing further research to help others understand the potential benefits from switching over to this new technology (Sabzalian et al. 2014).

The LED lighting agricultural industry is still developing and like with any technology it will continue to develop as tomorrow is never the same as today, but this constant development can provide both positive and negatives within the adoption of the technology. Marjolein de Bruin from BrightBox highlighted that Philips is constantly working to make the next generation of lights better than the last. This in order to be able to offer new innovations and advantages of using this technology over others to get the best product and produce in the end (Appendix 6).
While this is good for the overall market to grow and develop, it could still cause some conflict for new adopters who are sceptical towards investing in something that may be outdated by a new better model coming to the market sooner than expected.
The uncertainty of introducing a new technology can come from many actors that are involved or influenced by it, whether it be the LED Vertical Farming system itself, local residents, the end consumer, farmers, Copenhagen Municipality, other businesses or organisations. In order for a city like Copenhagen to develop into a future smart city it could be of importance that each one of these actors put trust in the introduction of new technologies (Doody et al., 2016: 13).
One problematic area could be acceptance of this new technology due to the uncertainty of what it can provide long term weighed up against all of the other elements and components that make up the LED Vertical Farming technology system. With this area of agricultural technology currently not having any long-term studies that have been conducted within LED Vertical Farming (Specht, 2014), it could have an influence on its adoption.

With cities such as London, New York and Tokyo, already having established commercial LED Vertical Farming businesses (Appendix 14), then bringing this technology to Copenhagen would not bring the city to the forefront of innovators but it could provide a sustainable technological solution for the residents as well as for the visions for the city's future. With all forms of technology continuously developing, by Copenhagen becoming a smart city, putting their own input and a Nordic twist to the technology (Københavns Kommune, 2015b; Rogers, 2003), could potentially bring Copenhagen further towards being an innovative front runner of this old but new technology.

6.1.4 Food Supply Chain

How is our food grown, where does our food come from and how does it get to us?

Asking these questions seems to be a trend getting more popular within the Danish population. Transparency in all aspects of the food and the food supply chain seems to be the desired demand from the Danish consumer and having the ability to understand the journey and steps the produce has taken from farm to fork (EY, 2015, Landbrug & Fødevarer, 2016a).

Could a way of bringing this transparency for the consumer be by incorporating the food production into the city of Copenhagen, into the urban environment, where the consumer spends their daily lives either for residential or work purposes? By bringing the food production into the urban environment with an LED Vertical Farm, it has the ability to shorten the food supply chain and in turn allows the consumer to understand the farm to fork journey their food has taken to reach them.

Local food production within the city has typically been an activity conducted to allow people to reconnect and see how their food is being grown, providing an educational, social and sustainable aspect to the whole production system (Olsson et al., 2016). One could argue that the design and method of growing within an LED Vertical Farming system would not be able to offer the reconnection, as the produce is not being grown the traditional way, out in the open and in soil. On the other hand, one cannot simply look at one component to decide whether this new technological way of growing is either good or bad, but rather look at all the factors involved from a sustainable and environmental viewpoint to show what this technology could offer to the urban population. The LED Vertical Farming technology could also provide an educational aspect as well within a new modern agricultural sense, teaching individuals how produce can still be grown within a new highly technological closed controlled environment compared to how the agricultural practices are conducted today.

Although we acknowledge that the food supply chain is complex with vast number of actors and influences, from what has been brought to our attention by Coop, their current food supply chain of fresh salads and herbs can have on average between six to eight different touch points, shown within the simplified figure 10 and 11. These vary according to whether the produce is coming from producers within Denmark or abroad, such as southern Europe, Turkey or Israel (Appendix 10). At each stage of the current food supply chain it allows itself to be more prone to shocks and changes that can have a global effect to the various actors involved along this international food supply chain (Hirsh et al., 2016). An example of this fragility was seen within Europe's vegetable supply chain at the beginning of 2017, where environmental factors affected the production at the

beginning of the food supply chain, which in turn decreased the amount of production of produce. This shock trickled all the way down the food supply chain to the retailers and consumers, that in turn, saw an increase in price as well as a shortage of produce available on the supermarket shelves (BBC News, 2017).
This highlights how the food supply chains of today may need to become more resilient to these sorts of changes that can happen at any point in time, whether it be natural disasters, climate changes, food speculations, economics or political crisis. Shortening the food supply chain by going from a more global industrial food system to one that has less steps could be an option in becoming more sustainable (Hirsch et al., 2016).

With the development of new innovations and technology, food production within the city and urban environments, has the ability to shorten or even remove some of the stages within the food supply chain. Cooling, transporting, packaging or storing are all activities conducted within one or more of the stages in the food supply chain but are also activities that can generate CO_2 emissions that will be released into the environment. By removing some of the stages in the supply chain could in turn alter the amount of CO_2 released into the environment (Kozai & Niu 2016b: 10; Ohyama, Takagaki & Kurasaka, 2008).
Looking at the food supply chain as individual aspects, both within the steps they take and also what inputs and outputs happen within these steps, is something to consider rather than viewing it as one whole system. This highlights that the system, as mentioned above, is a whole system but interconnected with many aspects that have an influence on one another. By conducting urban agriculture on a commercial level within the city could allow the produce to be transported over a shorter distance from where it is grown to reaching the end-consumer or even being collected by the consumer in person. As the produce has to travel a shorter amount of time it has the chance to aid in reducing the amount of produce wasted, for example being damaged because "*if fresh food is not cooled and/or not carefully packaged during long-distance transportation, much of it is lost. Thus, reduction in food mileage or 'local production for local consumption' is particularly important in the case of fresh food*" (Kozai & Niu, 2016b: 10).

This ability to reduce the amount of food waste additionally helps to reduce the amount of CO_2 being emitted into the environment (Kozai & Niu, 2016b; Ohyama, Takagaki & Kurasaka, 2008). This could be an important aspect for Copenhagen and its visions for the more sustainable and carbon neutral future as food waste has been a topic of discussion within Denmark and Copenhagen, looking at new ways to combat this problem, so a shorter supply chain could be one of them (City of Copenhagen, 2014). An advantage of growing within this LED Vertical Farming was provided in section 5.2, has seen an extension in shelf life of the produce by one to two weeks more over the current produce being sold. This could either be because of the methods it has been grown

within or due to closer proximity to market through a shorter food supply chain. Either way this relates back to the issue of food waste (Kozai & Niu, 2016a).

The food supply chain cannot change without the help from various actors that play a role in this system. With the development of technology and entrepreneurs looking for new innovations and creating new paths, the urban agricultural system and growing within the city like Copenhagen has the potential to work. To create a sustainable and resilient urban food system, Hirsh et al. (2015) believes that the city's residents should be seen as being active within two roles; being the consumer as well as the citizen in that they should be actors that have an active role within this (Hirsh et al. 2015). This means various actors within the city will have to work together with one another to make this happen, whether they are working directly with it or having an influence on it (Sismondo, 2010). Copenhagen municipality also believes that this is an important role that needs to be played by the city's population and businesses to work together and use one another for a better future for all (Københavns Kommune, n.d.).

Viewing the food supply chain from a historical perspective, related to the Location Theory by von Thünen, the city has always required food to come into the city to feed its citizens. The produce was grown in a way that the location was important so that the production of a more perishable produce had to be located closer to the city so the produce was not wasted during the transportation (Parham, 2015).
With technological and urban developments, this locational thought process does not have to be the case any longer. Produce can be grown further away from the consumer and transported to them as seen within the current food supply chain from Coop, but is this going to provide us with a long term sustainable solution? Should we bring the food production back closer to the city? Agricultural technology such as LED Vertical Farming could overcome certain aspects that had to be considered before related to the food supply chain but with important sustainable aspects to it and these new technological developments within other sectors can also aid this progression.

As mentioned within the Nordic Food Survey Consumer Trends by EY (2015) they highlight two current terms within consumer food trends. The first being the *Omni-Channel* where consumers enjoy using technology within their daily lives with links to food habits. While on the other hand, consumers wish to go *back-to-basics*, where this relates to food quality, how and where it comes from and environmental issues (EY, 2015). These two terms within food trends of the consumers is an interesting subject, as usually they are used up against one another, while LED Vertical Farming method could provide the best of both worlds. This could be done by using technology to grow the produce while at the same time the end consumers can find some transparency in knowing how

and where their food was grown and under what conditions. Could LED Vertical Farming be what the consumer trends mentioned within the publication by EY (2015) are searching for?

With the ability to grow the produce closer to the mouths you need to feed within the city, other options to be used within this shorter food supply chain can come around that may have been limited beforehand. With Natalie de Brun Skantz from Grönska mentioning that the opportunity to use other delivery methods, electric cars, public transport or bicycles, is now possible, providing the chance to deliver the produce in a more sustainable and environmentally friendly manner (Appendix 5). Reducing the CO_2 emissions in relation to the actual transportation method rather than just the distance travelled within the food supply chain could be an aspect that had been overlooked and not considered. Also, packaging could be addressed in this regard as well. With the produce traveling shorter distances it provides the opportunity to control the amount and type of packaging used for the transportation; less packaging for the produce or to protect the produce means less waste products in the end (Specht, 2014: 40).

While the consumers can have the ability to control the market through selective demand, this could also work in a positive manner too. The trend of transparency within the Danish population also shows that they are looking towards a more responsible consumption. The consumer wants to know under what conditions their food is grown, which also links up well to the increased demand for organic in that the consumer wants to do good to the environment found within section 5.6, linking up to the trends of responsibility, transparency and free from pesticides (EY, 2015; Landbrug & Fødevarer, 2016a).

Using the consumer as both the end user as well as a communicator, which is seen in the Diffusion of Innovation Theory, and working together with other actors is an important factor to consider. Highlighting the message that this type of urban agricultural growing method has the ability to shorten and make the food supply chain more sustainable through the whole system is an important fact to get across to all actors involved (Appendix 6).

From another perspective, why do we have to create new technology or innovations, spending time and energy to develop ideas to solve these problems? Could going back-to-basic be an option instead? Spending more time teaching the population to eat according to the seasons and what is grown closer to home rather than importing and creating these longer food supply chains, could work as the customers control the market with their demands (Appendix 3).

The introduction of an LED Vertical Farming technology into the city of Copenhagen allows one to bring the food as well as production closer to the consumer. It opens up the ability for the end

consumer to physically come to the production site and understand the aspects of this type of produce grown in this type of technology. This could be an important aspect for the Danish population currently, as it seems these consumers have a growing trend for transparency. While at the same time this type of urban agriculture, currently, is not a solution to fulfil the food needs of an entire growing urban population, but provide sustainable elements when relating it to food and the city (Gallo et al, 2016). The introduction of an LED Vertical Farm to Copenhagen could also be an option to push the food supply chains, we currently see in society today, in re-evaluating these to become more resilient and environmentally sustainable in the long term.

6.1.5 The Level of Control

"*Every bit of today's farming in the developed world is driven by technology*" (Despommier, 2010: 99)

With advances in technology, such as LED Vertical Farming, it now provides us with the ability to fully control the growth environment for a produce. With all aspects of our daily lives there will be advantages and disadvantages with what we do. Some will like it, some will not. Some the changes will benefit, some it will not. Technology provides us with the ability to take control, but should we use this level of control with some caution?

To some extent one could say that we within agriculture have already made vast attempts at taking control of the environment. In open-land conventional agriculture, pesticides have been used to control pest attacks and to enhance certain aspects of the growth process (Mok et al., 2014). Greenhouses protect the plants from the outdoor environment by putting the plants in a closed structure to provide the right environment related to heat, light and water. However, greenhouses although they are controlled, are only controllable to a certain extend and the changes between seasons can have an effect on how the greenhouses are run. The facility needs to be cooled down or warmed up, adjusting the lights to suit the sunlight, ventilation as well as shading (Appendix 3; Appendix 4). These are some factors that have to be considered due to the environment outside of the greenhouses (Kozai & Nui, 2016a). Nonetheless, in both outdoor agriculture as well as greenhouses the environment in which the plants are grown in, are controlled to a certain extent, so why does LED Vertical Farming seem to be different?

Growing within a closed controlled environment, as with an LED Vertical Farm, means that regardless of whether the production site is in a cold or hot region, in one with varying seasons or even underground as well as at night, each growing cycle will be almost identical to the last and typically at the same expenditure of resources and produce (Kozai & Nui, 2016c). This in turn

means that "*as the production systems are not directly dependent on soil and climate factors, cultivation can take place all year round independent of weather extremes"* (Eigenbrod & Gruda, 2015: 490-491). Again, "*one of the greatest advantages is that Vertical Farming is not reliant on favourable climatic conditions*" (Eigenbrod & Gruda, 2015: 490-491).
An interesting aspect that came to light through our analytical process was that of how one could take advantage of the fluctuations in electricity price throughout one day. With LED Vertical Farming not relying on the natural sunlight the growing process with LED's can be used during the evening when demand and price for electricity is usually cheaper. This was a point brought up by The Danish Ministry of Climate, Energy and Building in 2013 with their *Smart Grid Strategy,* encouraging the use of electricity during off peak hours, helping the city of Copenhagen with their visions within sustainability as well (Danish Ministry of Climate, Energy and Building, 2013).

With LED Vertical Farming method being conducted within a closed environment, it allows the opportunity to have near perfect control over the whole growing process. With this technology, the ability to have complete knowledge related to the produce and how much water, nutrients, hours of light it has received per growing cycle is possible (Appendix 3). Growing with this method allows high level of constant quality of produce that can be supplied for each crop cycle no matter what is happening within the environment outside. This trend for quality produce is shown within the Danish population related to how they would have a preference towards their food being produced (Landbrug & Fødevarer, 2016b).
While this is the case, is this way of growing seen as being too controlled or unnatural? Within the LED Vertical Farm, the system can be monitored, changed and altered to suit what is required. Does this just show what possibilities new technology and the future of agriculture has to offer and meet the needs and demands of the consumer? Knowing exactly how the produce was grown in a physiological point of view, could be the new future transparency, a trend for knowing how the food was grown, highlighted for the Danish consumer.
However, as mentioned in section 5.2, the consumer may take distance from produce grown under production methods that seem complex. Therefore, with a technology like LED Vertical Farming with aspects that may seem complex to some, it could make people shy away from accepting this type of food production. This could link up to what kind of approach is taken when introducing this new technology to Copenhagen; whether it is the hard or soft technological determinism approach. By allowing the consumer the soft style approach they have the ability to decide whether they accept and adopt technology like LED Vertical Farming within their lives. While on the other hand, even if the hard technological determinism approach is not fully undertaken, introducing LED Vertical Farming within Copenhagen will have some influence upon society and place some control within certain actors (Chandler, 1995), for example controlling the environment and how the produce is grown within the closed growing system. Although consumers may shy away from the

idea of this new technology, society would be affected in some way and that could eventually trickle down to these original consumers, directly or indirectly.

Another way that the LED Vertical Farms can control the produce is the ability to alter the light recipes of the LED's so that the crops can produce a certain quality. Through research it has shown that by giving the produce a different type and amount of light you have the ability to alter its taste (Appendix 4). Over the conventional growing methods currently being done this is an advantage to be able to control the crop and what it can offer the consumer, but again having this control to hand could be viewed in two frames of minds. The path dependent frame of mind, by bringing up the thought that why should we change what is natural for the crop and just leave it to grow to how it has been done before. As mentioned by Marjolein de Bruin, the produce grown outside will have certain attributes that can vary between the different seasons. As these are grown outside it will be influenced by the environment around it, which is natural and uncontrollable (Appendix 6). This natural influence will bring some advantages and disadvantages, but does this create more of a natural produce and a 'real' food from the viewpoint of the consumer due to its attributes varying between each growth season?
While on the other hand the path creation could see it as a way to explore and develop further into this form of technology, being able to offer an innovation for the consumer while showing the possibilities of control in a sustainable growing system. This could be possible, but because this is a new technology it is still being researched within also regarding the level of control and power you have. This is also in relation to the light recipe and end results to develop the perfect solution as each crop requires a different recipe (Appendix 5).

On the other hand, LED Vertical Farming cannot provide a produce that has been grown out in the fresh air and is this not what the consumers demand of a product being close to nature, in that it is the nature that decides how the produce will taste? Or are these consumers not aware that agriculture is already being controlled by pesticide use or other factors, such as growing inside within a greenhouse? If so are we not then back to square one of wanting a sustainable, transparent, quality food production in a world where the population is increasing, which means more mouths to feed? Changes within climate and the environment will have a direct effect on the agricultural land and sector. While at the same time looking at the increased problematic of land scarcity due to all of the above stated changes. The world is currently seeking an agricultural system to grow more high-quality produce but in a sustainable environmentally friendly manner by using less resources and energy to produce this increase in food (Sabzalian, et al. 2014). Maybe rather than looking at whether the produce is grown outside in soil to be close to nature then instead look at it from a more abstract perspective then the benefits that an LED Vertically Farmed produce may make the produce closer to nature as it could benefit nature in many other ways.

Looking at LED Vertical Farming as a potential solution to positively aid the environmental impact agriculture has had, urban agriculture also "*has the potential, in certain contexts, to be a more environmentally damaging food source than conventional agriculture*" (Goldstein et al., 2016: 989). This viewpoint is interesting from the perspective that this type of food production demands large amounts of energy to run. If this energy is not acquired and utilized resourcefully, it could have the opposite effect of being environmentally friendly and sustainable.
This in turn could go against one of the themes, energy consumption, which was put forth by the City of Copenhagen to reach its goal of becoming carbon neutral by 2025. The City of Copenhagen wishes to put focus on the energy consumption in the city so if an LED Vertical Farming technology would not utilize the energy and control it in a sustainable manner, it could counteract to these goals and thereby not aid to the city's push towards becoming a carbon neutral city (The City of Copenhagen, 2012). In the analysis section 5.7, it was highlighted that LED Vertical Farming technology is not in itself reducing CO_2, but that this technology could aid the decrease of CO_2 emissions in other ways, such as food miles.

As mentioned by Li et al. (2016), in order to reduce the greenhouse gas emissions that comes from energy consumption in agriculture it must "*increase energy efficiency and increase the use of renewable energy sources*" (Li et al., 2016: 683). The first point in this quote, LED Vertical Farming could have the potential to live up to but the second point links to what was just mentioned about the use of energy. That with the technology of LED Vertical Farming that can be demanding through its energy consumption, then the energy used must come from renewable sources for it not to be damaging and to fulfil the visions from the city of Copenhagen in being a sustainable and environmentally friendly agricultural practice.
As a counterargument Specht et al. (2014) mentions that *"many authors logically state that reduced transport miles will save CO_2 emissions. However, the total CO_2 footprint has not yet been quantified"* (Specht et al., 2014: 43). On the other hand, if the food production is brought closer to the consumer, this could provide the opportunity to utilize electrical means of transportation. Thus, in turn, decrease the amount of CO_2, provided the fact that the electricity used comes from renewable sources. If not, we are back at the previously above-mentioned problem.

Another aspect related to the potentials of LED Vertical Farming to be a more sustainable solution over other farming production practices is the issue of food waste. Food waste is an issue that the City of Copenhagen is currently working towards solving with the help of various actors and initiatives for the future (City of Copenhagen, 2014). Is it possible for a city like Copenhagen to create less food waste and control this issue by bringing food production into the city? An idea

behind this argument, that was brought up within the Food Supply Chain discussion section 6.1.4, in that by bringing the food production closer to the city, then one provides a closer proximity to the consumers. Due to the type of produce that would be grown, salads and herbs, are highly perishable (Kozai & Niu, 2016b), the less time a produce spends in transport the less likelihood there is of perishability. This could be seen as a controlling factor that by introducing this form of new technology to the city of Copenhagen you are able to create a different way the food supply chain is conducted and this could influence other actors involved in food production and distribution.

Another design aspect of the LED Vertical Farming system that could control the amount of food waste as well as water waste, is the production method of how the produce is grown.

The aspect of water was touched upon in the analysis as the question was raised whether it could be a good idea to bring food production that requires additional water, into the city if there was already a struggle to cater for the demand of water. As mentioned within the Environment and Sustainability analysis section 5.1, Despommier (2010) highlights a key feature of the LED Vertical Farming system. This key feature is the ability to reuse water numerous times within the system, with just the need to add more nutrients for the produce, allows it to be water efficient, with it using up to 90% less water than other agricultural practices growing similar crops (Despommier, 2010). This feature of the LED Vertical Farming system provides another advantage for it to be considered as a method of growing within the city, even if Copenhagen does have an issue with water supply and demand.

Also, the features of the LED Vertical Farming system aids to some of the points that Foley et al. (2011), brought up in the beginning of the thesis within section 2.1. Here four key points were put forth that the agricultural system needs to cut GHG emissions from agriculture practices, create more biodiversity, reduce water waste and water pollution by limiting the use of pesticides (Foley et al., 2011) all points that LED Vertical Farming could address.

An LED Vertical Farm provides the ability to grow produce in a controlled closed environment without the need of soil (Kozai & Niu, 2016b). Conventional growing methods within soil means that part of the produce, typically with salads, their outer leaves will need to be removed after harvesting and before being packaged. Also, due to being in contact with the soil the produce will also have to be washed and cleaned from any external properties collected through the growing process (Appendix 6). The design of the LED Vertical Farm allows further control in relation to waste in many aspects helping to provide a sustainable influence to the whole system.

Control could be used to take advantage of a situation and put it to greater good. With global warming and climate change we are unable to predict and control the environment directly. With this control out of our hands, it can be a difficult situation when current agricultural and food

supply chain system today are relying on the environment to fulfil future needs of food. With this climate and environmental change happening and what little control we have over it, why do we not look at something we can change, that can be directly affected? Taking the opportunity of going away from the path dependent route of how our produce is grown today into a more path creation direction where we have the ability to control all aspects from beginning to end. LED Vertical Farming, growing within this closed controlled environment, has the chance to tailor produce to suit the demand, trend and wishes from the consumer. However, could this be viewed as a step too far in growing something that may not seem as natural as it should be or is this the realisation of how new technology is changing and taking control of the future food production? In the end, is it the consumer that will decide and have the overall control?

6.2 Reflections on Frameworks and Interviews

Throughout the writing of our thesis we have gathered reflections regarding our methodological and theoretical framework as well as reflections on the expert interviews. These will now be addressed in the following sections.

6.2.1 Reflections on Theoretical Framework

With the introduction of new technology, like that of LED Vertical Farming, the Diffusion of Innovation Theory highlights that within society certain actors will play a role within the adoption of this new innovation (Melkote, 2006). These actors will play a role in creating knowledge and understanding of these new products for the rest of the market. Through our research, we found companies like Philips and BrightBox Research Facility could be classed as the actors of the Innovators within the Diffusion of Innovation. This is because they are the ones who have been involved within this technology earlier on, trying to reassure and motivate others to join (Rogers, 2003). Also through the research, we see key points have appeared related to this adoption of technology within LED Vertical Farming. The uncertainty in regards to this new technology related to future investments, economics, potentials and future developments were all mentioned numerous times throughout the literature as well as from the expert interviews. Within this thesis, we found that the Diffusion of Innovation Theory helped us explore and understand the idea of bringing new technologies and innovations into a society and how actors are important players within communicating the idea further. Also, understanding that the diffusion of a new technology will inevitably have some societal change and influence (Rogers, 2003), that allowed this theory to also be used with others, such as Technical Determinism.

Technological Determinism theory was used as a way to explore how introducing technology will have an effect and change within society (Chandler, 1995). As Copenhagen currently does not have a commercial LED Vertical Farming business, then by bringing this into the city could potentially bring some change within society. This act of change does not necessarily have to be directly involved within the LED Vertical Farming method but could also be how the consumer views the current agricultural practices. Using the theory to understand that even if you push a new technology on to society or allow individuals to choose on their own behalf, some form of change within society will inevitably occur.
One problematic issue with this theory, was related to finding the original source or founder, which has proven to be difficult. Other researchers and academic professionals have added their own perspective and thought processes to the theory which has opened it up to debate. On the other hand, the Technological Determinism theory worked well alongside the Path Dependence and Path Creation to provide additional viewpoints and perspectives. Working with both theories alongside one another provided an explorative way of addressing how introducing LED Vertical Farming to Copenhagen could involve and influence numerous actors and their actions.

Path Dependence and Path Creation theory helped break apart how agricultural practices are currently being done today, which is Path Dependence, compared to how the introduction of an LED Vertical Farming method within Copenhagen, could change the way agriculture is conducted in the future, which is Path Creation (Cowan & Gunby, 1996, Garud & Karnøe, 2000). Taking a standpoint within the Path Dependence side of the theory allowed us as researchers to explore the way agriculture is currently conducted and connecting to this, various actors both within the rural and urban settings.

While looking at the other side of the theory, Path Creation, brought into context how entrepreneurs go against the stream of how certain practices are currently done within society (Garud & Karnøe, 2000). As LED Vertical Farming is an alternative and technological way of growing produce as well as having the ability to be grown within grey spaces of the urban environment, showed how this goes towards a direction of path creation. Entrepreneurs aiming to make changes within society, which is also part of the Technological Determinism, will look to create a new path and introduce an innovation to push what is currently being done and accepted to make this change. Actor acceptance within this part of the theory was aided through The Diffusion of Innovation, in regards to how actors adopt, accept and communicate messages based on their willingness of a new innovation (Melkote, 2006).
This theory helped us within the thesis to stand in the middle of both directions so they could be assessed for their strengths and weaknesses related to the research question.

The Location Theory by von Thünen allowed us to step back and look at how in the past agricultural practices and the location of these were placed in relation to the city and reasoning behind their placement (Ponsard, 1983). With this theory, it provided information that opened up areas to consider and explore related to the food supply chain, agricultural locations and the type of perishable produce that back in history had to be closer to market. The produce mentioned within this theory are also the ones that are typically those now grown within LED Vertical Farms which lead us onto the current issues of food miles and food waste. Even though this theory is from the 19th Century it has points which are relatable issues we face today.
While on the other hand taking into consideration how agricultural practices, land, society and technology, since then has changed and developed, this theory could show some weaknesses. This could be demonstrated by finding literature adapting this Location Theory within a modern context. The reason why we decided to go back to use von Thünen's earlier work and other literature that is older was to have a perspective from the original theory. Within future research using some of the new perspectives that have been brought forward could be an option to consider in relation to working with new innovations and technology for the future urban population.

The Actor Network Theory played an important role within exploring the various categories put forth related to LED Vertical Farming. Understanding how actors, both human and non-human, that can be involved as a whole group while at the same time as a part of smaller sub groups highlights how one subject can involve numerous actors (Sismondo, 2010). This was shown within our expert interviews, with ten in total that took place all involved in different areas, contexts, countries or businesses, but with all of them having some form of connection to the focus of LED Vertical Farming. Even though we started using the Actor Network Theory at the beginning of our explorative process, this theory was active throughout. More actors appeared throughout the writing process as this area is still ongoing, being developed, researched and people getting on board with this technology. While this is an exciting, explorative and ongoing process with new actors appearing, at some point we had to stop and work with what we had at that time. Using the Actor Network Theory also kept refreshing our minds that non-human actors play an important role within LED Vertical Farming, whether it is the water, the environment inside the system, the produce or the LED's themselves they are all just as important to explore as the human actors.

Utilizing this theoretical framework and keeping it in mind when exploring the literature enabled us to view the findings from various perspectives that we may not otherwise have understood in the same way. An example is how we could distinguish between the path dependency or path creation and understand the background for why things are currently done the way they are but also what it may take to change this route (Garud & Karøe, 2000). How these new path creations are made by venturesome innovators and the adoption trickles down to other adopters (Rogers, 2003). Then

addressing an agricultural innovation from the perspective of placement and economic benefit the location theory creates valuable viewpoints (von Thünen, 1966; Ponsard, 1983). In the end, who and what will affect or be affected by a change is then put into light through the Actor Network Theory (Sismondo, 2010). This in turn gives an example of how the theories in one way or another were interlinked, which made them relevant although some of the theories have been used more than others throughout the thesis.

6.2.2 Reflections on Methodological Framework

We as researchers for this thesis do not come with a background within the specific subject area of LED Vertical Farming. However, our background within food and sustainability provided us with the interest towards this subject area. Thus, the fact that we do not have a vested interest in LED Vertical Farming has allowed us to keep an open and critical viewpoint towards the subject matter.
In the preface of the study, we turned to literature that has also been used throughout this thesis, which is the book by Dr. Dick Despommier, "*The Vertical Farm feeding the World in the 21st Century*" (2010). One should always be cautious when using literature with few references and with a one-sided view due to personal interest. However, Dr. Dick Despommier is the initial founder of bringing perspectives to Vertical Farming within the city and we therefore found it inevitable to use his literature within this thesis. Also, because little research has been written on this type of technology we, through our explorative study found books, such as the one by Kozai, Nui & Takagaki (2016), that may be one-sided in favour of LED Vertical Farming. However, these were relevant references in explaining this technology as well as some of its advantages and disadvantages, as they had in fact conducted research within it.

Our thesis has the methodological approach of a qualitative study that takes point of departure in a subject area that is unexplored; LED Vertical Farming with a focal point on Copenhagen. This is also why this thesis took point of departure in being explorative. However, in order to carry out this type of study one must also put it in relation to a city in which this production could be explored in and before that, one must see whether it makes sense to even see this type of production in relation to the city. For that reason, there are steps before one could finally say whether a type of farming production technology method fits into a city so with this thesis we have attempted to take the first steps of explorative research within the field in the hopes of giving others an understanding of the field. The main purpose of writing this thesis was to write it on behalf of an entrepreneur looking to establish an LED Vertical Farming business in Copenhagen. However, through our research and empirical data collection we see that it has the opportunity to also be useful for other human actors; either ones who are already involved within this type of farming, ones who are interested in participating in it, for the municipality who could be stakeholders in this, ones within food

provisioning or ones who are working within the municipality for food related problems. Also, retail and restaurants could have an interest in learning about new ways of growing food or providing produce to their restaurants.

For the reason of this subject area being unexplored, we began our research by exploring the literature and research already conducted within this field. Here we did a mixture of structured as well as random searches.
As mentioned in section 1.3 there are and have been put forward different definitions of LED Vertical Farming so there may be words that we have overlooked that could have opened up for more relevant literature, which could be seen as a weakness of our literature search. On the other hand, this is an evolving field so new words may have appeared several times throughout as this thesis progressed, however, at some point one must stop to keep the process going.
We continued our research of literature until we began to see the same types of themes appearing in the literature. From this, categories started to form. Following this, we continued our search to find literature, which enabled us to describe the areas in depth but we kept the categories open for change throughout the analytical process of our thesis. With this we made use of the openness that qualitative research allows us to have as it operates with a flexible design (Dahler-Larsen, 2008).

It must be noted that in looking at publications and research papers, agriculture is used as a general term and we therefore acknowledge these may also have included animals within the agricultural system. Due to some of the research papers written on Danish agriculture not distinguishing between what types of agriculture they are being specific to, this thesis has had a main focus, when possible, on vegetables.

While addressing the food trends of the Danish consumer a publication by Landbrug & Fødevarer was used as reference. It must be noted that the data provided by Landbrug & Fødevarer may not be entirely scientific but at the same time provides an insight into the trends of the Danish consumers. Although this market analysis is based on quantitative and qualitative data conducted on a representative sample (Landbrug & Fødevarer, 2016a), we acknowledge that this survey does not portray the entire Danish population.

In the process of writing this discussion we went back to see if new literature had appeared on the search mentioned in Appendix 1. This, we could have looked back at earlier in the exploration and analysing of the subject matter but it can be difficult to progress with an analysis if you keep looking back. Since the initial search back in October 2016 (Appendix 1) there are now, in May 2017, six new research papers that appear within the search results. This shows not only that this is an evolving field but also that new ways of describing this type of farming methods also continue to

appear. Through this second search we found that one research paper had utilized “Building-Integrated Agriculture (BIA) in urban contexts” as a way to describe the urban agriculture within buildings (Benis, Reinhart & Ferrão, 2017). This could be relevant as it is using a new term to describe growing within an urban environment.

As previously mentioned, we generated the categories to create a directive to the data that we had collected and we kept the same framework of categories for the analysis to keep the process focused. For the discussion however, we chose to view our entire process from a different angle, which enabled us to take some steps back and view with new eyes.

This explorative and analytical way of conducting qualitative research has benefited us extensively in that this subject area, as mentioned previously, is unexplored especially in the sense of linking it up to Copenhagen, Denmark, where no research in the same way has been done before. As we touch upon the environmental impact that agriculture has today and what potentials LED Vertical Farming could bring in regards to this, then an interesting aspect would be to put up findings against each other to see to what extend LED Vertical Farming could be better or worse for the city of Copenhagen. However, in a qualitative study design it could prove difficult to put the findings up against each other as this methodology would be a quantitative approach (Ponterotto, 2005). For the purpose of this thesis, we wish to create grounds for discussing the opportunities that this technology may have within the city of Copenhagen. The various aspects are difficult to compare because you cannot put a given value on them as you can with denominators within a mathematical calculation. It could be interesting to compare the economic benefits of LED Vertical Farming but as it was also pointed out by Specht et al. (2014) there are “*not yet any long-term studies on the economic feasibility of indoor city farms*” (Specht et al., 2014: 48). Although that study is from 2014, the studies are still limited. For future studies, however, it could be interesting to head down the road of a quantitative research design that has the possibility of opening up for data that could be comparable.

We utilized three methods that we applied as pre-analytical tools; SWOT Analysis, Mapping Historical Discourses and Situational Analysis/Actor Mapping Network. These have not been discussed much throughout the thesis but were rather tools that allowed us to look at what we had already learned from the literature and interviews and to gain new aspects for our analysis that we may otherwise have overlooked.

Looking at the SWOT Analysis, it provided us with perspectives towards what could be strengths, weaknesses, opportunities or threats for the LED Vertical Farming technology. These considerations were then placed into the model, figure 6. If we were to take this research further or

make another thesis related to LED Vertical Farming, then revisiting or adding to the SWOT Analysis could be an important step to take because it could provide us with new aspects to look at the phenomenon.

When using the methodological tool of mapping historical discourses, we gave ourselves a specific timeframe in which we searched for information to explore the historical dimensions. Delving into history can provide vast information especially having this many levels within LED and Vertical Farming as it is a combination of many different aspects. However, as the history was not our focal point for the thesis but rather an exploratory point of departure we acknowledge the unfolding opportunities are unlimited. What we have chosen to include in this thesis was a choice that provided us with information that helped us go in the direction of the problem statement.

The Actor Mapping was a tool to explore the actors, both human and non-human, within the network of LED Vertical Farming in the city of Copenhagen. This provided important aspect for our pre-analytical phase as it opened our eyes to more actors that we previously would not have considered as well as connections between them that we had overlooked. At the same time, this type of map allows for change over time and it is recommended to make several versions and saving all of these to see how actors change throughout different stages of the analysis (Clarke, 2005: 83-109). This we did not do as it was merely meant for pre-analysis, however since creating the actor map, we have seen that if we were to revisit the actor network, we could have elaborated further on the subject of the current agriculture. This could be to show that much more goes beyond just the produce and the farm; there is the accountant, the people who transport the produce, the suppliers of heating, people hired to keep up the production site, suppliers of seeds etc. These would all be affected by a new way of doing agriculture. The Actor Network shows how different actors are influenced and from revisiting the actor network throughout the analysis we now see different areas that could be included for future research.

6.2.3 Reflections on Expert Interviews

Within the exploratory starting point, we decided to interview experts who are active within the field related to or connected in some way to our problem statement. Working with these experts provided us with the chance to gain access within certain areas and also connected to others that may have been hard to come by without this contact (Bogner, Littig & Menz, 2009: 2).

While doing our initial research we started to paint a picture of the type of experts that could be relevant to interview to gain more insight into this field and their professional working world (Kvale, 2007: 11), that was an unexplored new area for us as researchers. It was an ongoing

process, as by interviewing one expert opened up the thought process into considering other experts that were appropriate to interview.
For this exploratory research, a total of ten experts we had correspondence with. Three of the interviews were conducted in person; Jan Ravensbergen from Alfred Pedersen & Søn, Katrine Heinsvig Kjær and Benita Hyldgaard from AU Aarslev both based within Odense, Denmark, and Marjolein de Bruin from BrightBox in Venlo close to Eindhoven in the Netherlands.
The interview with Natalie de Brun Skantz from Grönska based in Stockholm was done over Skype, online video conferencing service. The remaining correspondence with the six experts; Growing Underground London, Deliscious Netherlands, Coop Supermarket Denmark, Lykke Leonardsen from The City of Copenhagen, Gasa Nord Grønt Denmark and Global Herbs Denmark were all conducted through email.

Working with these ten experts provided our exploratory research with data in a variety of different professional arenas from individuals directly involved within research and development of the technology, farmers incorporating LED's within their standard agricultural practices to individuals and business' running commercial LED Vertical Farms within Europe. This variety helped not only to gather data from many different professional viewpoints but also helped to open up the field to highlight that these growing practices has many elements and aspects that needed to be looked upon. Also, we gained knowledge from experts who are currently working with selling fresh herbs (Coop), producing/distributing fresh herbs (Gasa) and Lykke Leonardsen who works within Copenhagen Municipality in the department of Resilient and Sustainable City Solutions.

One of the expert interviews that was conducted in person, Marjolein de Bruin at BrightBox, was not recorded. The questions asked during our time with Marjolein de Bruin were done within two settings; the first during a large group tour of the facility that was followed by further questions within a meeting room with two other students from a local university. Even though the questions asked were not recorded and conducted in a more formal interview situation, such as with the other three interviews within this thesis, notes were written down regarding all the questions answered by Marjolein de Bruin. With the interview, not being recorded some important points may have been overlooked during the note taking as both researchers were involved and took part in asking the questions. If this interview would be conducted again we would have recorded it as this allows for us as researchers to give our full attention to the interviewee as well as collecting all the possible information. However, due to the situation at the time this was not possible.

While we were in the Netherlands conducting the interview with Marjolein de Bruin at BrightBox, we made a visit to the City Farming Philips Horticulture research facility based in Eindhoven. Our time within this research facility provided us with another chance to look at a facility conducting

research within LED Vertical Farming. This visit gave us hands on visual experience of this agricultural technology method and the opportunity to speak to a member of the Philips City Farming Horticultural team. The person we spoke to was a researcher and developer of this technology. This has not previously been mentioned within this thesis as during the visit no formal interview was conducted. We cannot say that this visit to the City Farming Philips Horticulture research facility did not have an influence in any way, but as researchers we tried to keep a professional standpoint to anything gathered during our time there. However, it gave us an important insight into how this technology is in constant development and getting a glimpse into new products they are researching within.

The reason behind our professional standpoint is because Philips and their employees have a vested interest within this technology, as they are a business selling this LED Vertical Farming technology on the market, so in this case their views and opinions may be biased. While on the other hand Marjolein de Bruin from BrightBox research facility has a more mutual standpoint as she is researching within this technology to gain new knowledge from a scientific standpoint to share with others. She mentioned through personal experience that other companies within LED Vertical Farming keep their findings to themselves as these results are used for their own business. On the other hand, the viewpoint of BrightBox believes that research and results contain knowledge that should be shared to bring the technology forward (Appendix 6).

Once the interviews had been conducted and all of the data collected, the interviews were coded. The coding practice was done through colour coding the data related to certain categories that were formed during our research of the literature, to convert larger amounts of data within smaller categories (Kvale, 2007: 105). When the coding of the data was conducted we both read through all of the interviews, and we then discussed and coded the information together. This method of working with the data together allowed it to be discussed at the same time as obtaining mutual agreement with the coding to avoid conflict or confusion later on in the writing process. However, if we had repeated the process of coding more times there is a possibility of discovering new areas.

When looking at the coding style of the interviews, placing them within categories can sometimes provide a limiting factor that must be considered. Having categories for the data to be placed within, may influence or restrict the meaning and context of the spoken word (Kvale, 2007: 106). Also, the meaning of the categories could be seen in different ways depending on what person reads it. Throughout the whole researching and coding process the categories changed as new ideas and thought processes came to light. In turn, the categories were kept open to allow for flexibility. Also, all the categories and titles were formed following a similar structure that was found within the literature and research to keep structure and direction (Meuser & Nagel, 2009: 36)

When conducting future research, going back and recoding the data with new eyes for a second time could be a good method to be sure that the data is still situated in the relevant categories. While this method could take extra time and resources, at a certain point in time the mutual agreement to stick with the decision and move on with the writing process was required.

Initially, the aim was to interview various small and large commercial LED Vertical Farming businesses currently established within Europe. Through research, numerous active commercial businesses were contacted but unfortunately only a small amount of these replied, with two not having time to participate and the remaining being included within this thesis. As contact was being made with commercial businesses, their resources and time to fulfil our request may have played a role within the ones providing no response and also our emails may have been overlooked (Lokman, 2006). For future reference, we could have nudged the companies to make sure they had read our email, but you need to be aware that this is still uncontrollable. Also, the way the email had been written could have been revisited to compress the content. As this email process was part of our exploratory research we also at some point had to decide to continue as delving on unanswered emails would restrict us moving forward. On the other hand, these may have had vital information.

Through doing these expert interviews the knowledge gathered has opened up thoughts about experts or actors who could have been approached for interviews, if this thesis and research was going to be taken further. Conducting interviews with actors within Copenhagen and some of the peri-urban towns and cities within the Greater Copenhagen area would be considered. Another actor that could be of particular interest would be Landbrug & Fødevarer as they are a company that represents the Danish farmer. We believe that they may have been able to provide us with viewpoints in relation to urban agriculture in Copenhagen. Here, there would be potential to get their perspective in whether this would have any conflict related to their stakeholders and actors they represent within the agricultural sector.

To sum up, conducting these expert interviews were an important part of the research within the thesis. The data and knowledge gathered allowed us to open up the new area being explored by us as researchers and gave interesting aspects to our research. By looking back at the process has allowed us to be critical and discuss way future research could be conducted.

7

Conclusion

While exploring the research area, it showed that the technology of LED Vertical Farming is being used in other large cities worldwide. However, no commercial LED Vertical Farm has currently been established in Copenhagen, nor have studies been conducted on this specific subject matter. For that reason, with our integrated background within food, we took the skills learned throughout the Masters of Integrated Food Studies to take on the explorative approach to understand the complexities that could go beyond integrating an LED Vertical Farm. We wanted to explore how this new commercial agricultural technology of LED Vertical Farming could provide sustainable opportunities for Copenhagen in relation to the city's growing urban population as well as contribute to Copenhagen's visions for the future.

The City of Copenhagen has the vision of becoming a smarter and greener city as well as CO_2 neutral by 2025. At the same time Copenhagen has a yearly population increase above the global average. This in turn means that the city of Copenhagen needs to find ways to reduce its carbon footprint to become more sustainable in the way they function also in regards to reusing and recycling as much of their waste as possible (Vásquez-Moreno & Córdova, 2013).

Our research showed that LED Vertical Farming could be part of fulfilling one of Copenhagen's visions of being more creative and forward thinking. This was seen in that this farming technology could utilize the city's resources in a more creative and sustainable manner also in regards to the more mouths that will need to be fed. Being able to grow produce within the city of Copenhagen not only brings the food closer to the consumer but could also provide the city with an additional source of capital through this urban agriculture. During the thesis, we point towards the rural areas currently having the responsibility placed on them for providing food to the urban population, but this LED Vertical Farming method could give new ways for the urban population to feed itself. At the same time, you have to be aware that not all types of produce can be grown sustainably within this technology. Therefore, the city cannot, by itself provide all the food needed. Here, through our research we found that at the moment highly perishable food products that usually travel over larger distances leaving carbon footprint both from traveling distance as well as various aspects related to the storage, could be more viable for placing production into the city. This is where we see that a partnership between rural and urban needs to be created so that the various actors together can take responsibility of creating a new food supply chain.

There are currently no regulations pointed towards commercial agriculture within the city of Copenhagen, which could show that their focus currently is not within or aware of this type of urban agriculture. Also, we have found no documents stating that The City of Copenhagen has a vision to bring commercial food production into the city but rather see growing food in the city as an objective for social, pedagogical and teaching reasons. For that reason, our arguments for

bringing this agricultural technology into the city is based on various information that points towards how this potentially could be fitted to the arguments in favour for or against LED Vertical Farming. This in turn creates uncertainties on whether or not this food production would fit the visions of Copenhagen. On the other hand, perspectives of the visions do provide arguments that could favour the use of LED Vertical Farming within the city of Copenhagen.

Although this could work for Copenhagen we have through our research also found arguments for why it could suit being situated outside of the city in the peri-urban areas of Greater Copenhagen due to the infrastructure, mainly around the design of The Finger Plan. If this type of farming was to be implemented in or around Copenhagen, being more creative and forward thinking in regards to the spaces available that are left untouched or are undesirable have shown to be interesting aspects to consider. With this, grey spaces were mentioned as utilizing these spaces that others may have overlooked. In turn, this could provide options for a circular economy by making use of by-products such as excess heat and waste water produced within the urban environment's infrastructure.
With the LED Vertical Farming method, it provides the ability to make way for growing food in certain environments and setting that have not been considered before as it may have not been possible with conventional growing methods. This growing technique currently cannot fulfil the food needs of an entire urban population, but introducing it to Copenhagen could provide sustainable elements related to the food production and food supply chain for the city (Gallo et al, 2016).

On the other hand, our research could give suggestions to the reason behind why this technology has not caught more momentum. This may be related to the fact that it still seen as new and is being developed and researched within. Therefore, investing in this technology over conventional lighting systems is difficult because of the uncertainty regarding payback time of investment. In connection with economic benefit it could be important as it may seem that this could determine whether this technology could be viable to implement. Thus, we raised a question concerning whether you can put a price on the environment as from what we have explored there are many positive aspects towards LED Vertical Farming aiding to sustainable solutions, however without conducting the needed quantitative research on the actual effect, it is difficult to conclude on this.

Through our research, consumer trends showed both arguments for and against aspects related to LED Vertical Farming. The arguments speaking for this consisted of preferences for local, pesticide free, transparency as well as responsible consumption. On the other hand, trends that were going against this were that consumers are showing increasing interest towards food products that are close to nature as well as organic (Landbrug & Fødevarer, 2016a; EY, 2015). Due to current organic

guidelines, the produce from LED Vertical Farming is not able to be classed as organic, which could affect the way consumers would perceive this type of farming. Whether LED Vertical Farming produce is classed as being close to nature or not could be up for discussion.
However, should we cater for the needs of the consumer by trying to integrate advanced technologies to create produce that suits the food trends? Providing the consumer with produce that is grown close to the consumer and available on the supermarket shelves all year round is contradictory as Denmark's climate changes throughout the seasons. Instead of catering for the needs of the consumers we could take a step back and with an educational perspective teach the population about seasonal produce to change buying habits.

We found that even though LED Vertical Farming could be a good innovation for the city of Copenhagen, actors will play a role in its future development whether that being the consumer, the city itself, the produce, developments within the technology or the elements that go in the closed growing production system. This showed how the LED Vertical Farming system cannot work on solely one aspect but is a combination of many where each element has to work just as efficiently as the other. With LED Vertical Farming technology having the potential to be incorporated into the city of Copenhagen the final say to its success lays in the hands of the various actors that are part of or influenced by this technology. Acceptance is key but also one of the biggest challenges.

Although it in the end maybe the consumer that has the last say in whether they buy something or not, it is also up to the innovator to translate the message in the best possible way to have the consumer understand it. One cannot assume that all will understand a complex matter easily, so the way the message is transmitted is important. It was never our intention with this thesis to look into whether the consumer will actually buy the product or not. However, through our discussion leads us to this area in one way or another. One could think that if you simply place a new product on a market then with the right marketing and communication strategy you will be able to sell the product. But with a technology such as LED Vertical Farming, we from our research see that much more goes beyond it not only the environmental problems that we are facing but the visions that a city has for itself. Simply placing a product in the crowd may work but this could also turn out to be one product out of many. Here we find an importance in creating and showing the increased value that comes from this type of production such as with the sustainability and environmental aspect. This would not just be for the consumer to get their local, pesticide free and all-year-round produce but also a way to create something valuable for the city of Copenhagen and something that fits into the type of community that this city is aiming for.

An LED Vertical Farming product could be a product that in the long run could help the circular economy, the fight against food waste, the backlash to food miles and imports from distant

countries. But would the consumer in the end catch on to that? And is this something that they should catch on to, as that could simply just imply a trend? The environmental problems that the world is facing is not a trend. It is not something that has come but may go. It takes more to solve these problems but could this type of production in the city be a step in the right direction? Or is this just a trend? It is a paradox is it not? In the end, this is a production that creates a product to sell. To sell to a customer to earn money to create economic benefit. It could be more than that, though. It could be something that helps the greater good but cutting into the bone would it simply just be a marketing strategy?

Reaching the final conclusion of this explored area of LED Vertical Farming in the city of Copenhagen only raises more questions, which in turn concludes that this interesting subject area of harvesting in the city undoubtedly needs more enlightenment and research.

Reference List

Aarhus University (2017). *DCA - Danish Centre for Food and Agriculture. AU Aarslev.* [Online] Available at: http://dca.au.dk/en/about-dca/au-aarslev/ [Accessed: 25th Apr 17]

Aero Farms (2016). *Our Technology.* [Online] Available at: http://aerofarms.com/technology/ [Accessed: 22nd Nov 16]

Antisari, L. V., Orsini, F., Marchetti, L., Vianello, G. & Gianquinto, G. (2015). Heavy Metal Accumulation in Vegetables Grown in Urban Gardens. *Agronomy for Sustainable Development, 35* (3): 1139-1147

Banerjee, C. & Adenaeuer, L. (2013). Up, Up and Away! The Economics of Vertical Farming. Macrothink Institute. *Journal of Agricultural Studies, 2* (1): 40-60

BBC News (2017). *European Vegetables: 'Perfect storm' raises prices.* [Online] Available at: http://www.bbc.co.uk/news/world-europe-38650167 [Accessed: 27th Jan 17]

Bell, J. N. B., Power, S. A., Jarraud, N., Agrawal, M. & Davies, C. (2011). The Effect of Air Pollution on Urban Ecosystems and Agriculture. *International Journal of Sustainable Development & World Ecology, 18* (3): 226-235

Benis, K., Reinhart, C. & Ferrão, P. (2017). Development of a Simulation-Based Decision Support Workflow for the Implementation of Building-Integrated Agriculture (BIA) in Urban Contexts. *Journal of Cleaner Production, 147*: 589-602

Bogner, A., Littig, B., and Menz, W. (2009). *Introduction: Expert Interviews – An Introduction to a New Methodological Debate*. In: Bogner, A., Littig, B. & Menz, W. (eds.). *Interviewing Experts*. Palgrave MacMillan

Bogner, A. & Menz, W. (2009). The Theory-Generating Expert Interview: Epistemological Interest, Forms of Knowledge, Interaction. In: Bogner, A., Littig, B. & Menz, W. (eds.). *Interviewing Experts*. Palgrave MacMillan

BrightBox (2016). *About Us.* [Online] Available at: http://www.brightbox-venlo.nl/en/about-us [Accessed: 22nd Nov 16]

Brinkmann, S. & Kvale, S. (2015). *InterViews. Learning the Craft of Qualitative Research Interviewing* (3rd ed.). SAGE Publications

Bryman, A. (2012). *Social Research Methods. Asking questions* (4th ed.). Oxford University Press

CHAFEA (2017). *Normalising Organic Choice: Growing Sales in the UK and Denmark*. [Online] Available at: https://ec.europa.eu/chafea/agri/campaigns/normalising-organic-choice-growing-sales-uk-and-denmark [Accessed: 6th Mar 17]

Chamber Trade Sweden (2009). *Market Report. Focus on the Nordic Market – Fresh Fruit and Vegetables*. [Online] Available at: http://chambertradesweden.se/wp-content/uploads/2012/12/Nordic_FruitVeg_dec2009.pdf [Accessed: 23rd Mar 17]

Chandler D. (1995). *Technological or Media Determinism.* [Online] Available at: https://www.wolearn.org/pluginfile.php/2185/mod_page/content/6/chandler2002_PDF_full.pdf [Accessed: 9th Feb 17]

City of Copenhagen (2014). *Resource and Waste Management Plan 2018*. [Online] Available at: http://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=1184 [Accessed: 5th Apr 17]

City of Copenhagen (n.d.). *Copenhagen: Solutions for Sustainable Cities*. [Online] Available at: http://www.danishwaterforum.dk/activities/Water_and_green_growth/Copenhagen_Solutions.pdf [Accessed 21st March 17]

Clark, C. (1967). Von Thünen's Isolated State. *Oxford Economic Papers, New Series, 19* (3): 370-377

Clarke, A. (2005). *Situational Analysis. Grounded Theory After the Postmodern Turn*. San Francisco: SAGE Publications

Coop.dk Mad (n.d.). Velkommen til Coop MAD. [Online] Available at: https://mad.coop.dk/kundeservice/velkommen-til-coopdkmad [Accessed: 25th Apr 17]

Corner, J. (1999). The Agency of Mapping: Speculation, Critique and Invention. In: Cosgrove, D. (ed.). *Mappings* (pp. 213-252). London: Reaktion Books

Cowan, R. & Gunby, P. (1996). Sprayed to death: Path Dependence, Lock-in and Pest Control Strategies. *The Economic Journal, 106* (436): 512-542

Dahler-Larsen, P. (2008). *Displaying Qualitative Data*. Odense: University Press of Southern Denmark

Danish Ministry of Climate, Energy and Building (2013). *Smart Grid Strategy the Intelligent Energy System of the Future*. [Online] Available at: https://ens.dk/sites/ens.dk/files/Globalcooperation/smart_grid_strategy_eng.pdf [Accessed: 19th Apr 17]

Dansk Gartneri (2012). *Tal om gartneriet 2012*. [Online] Available at: http://www.danskgartneri.dk/projekter-og-publikationer/publikationer/tal-om-gartneriet [Accessed: 6th Apr 17]

Dansk Gartneri (2016). *Fakta om dansk* gartneri. [Online] Available at: http://www.danskgartneri.dk/projekter-og-publikationer/fakta-om-dansk-gartneri [Accessed: 5th Apr 2017]

Deliscious (n.d.). *Innovation Family Business.* [Online] Available at: http://www.deliscious.eu/en/about-us [Accessed: 25th Apr 17]

Despommier, D. (2010). *The Vertical Farm Feeding the World in the 21st Century*. New York: Thomas Dunne Books

Doody, L., Walt, N., Dimireva, I. & Nørskov, A. (2016). *Growing Smart Cities in Denmark: Digital Technology for Urban Improvement and National Prosperity*. [Online] Available at: http://www.investindk.com/News-and-events/News/2016/~/media/Files/Reports/Growing_Smart_Cities_in_Denmark.ashx [Accessed: 2nd Mar 17]

Drennen, T., Haitz, R. & Tsao, J. (2001). *A Market Diffusion and Energy Impact Model for Solid-State Light*. [Online] Available at: http://www.quarkstar.com/uploads/2/3/3/4/23343356/2001_--_a_market_diffusion_and_energy_impact_model_for_ssl.pdf [Accessed: 2nd Jun 17]

EC 889/2008. § 4. Laying down detailed rules for the implementation of Council Regulations (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control. [Online] Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0889&from=EN [Accessed: 3rd Jun 17]

Eigenbrod, C. & Gruda, N. (2014) Urban vegetable for food security in cities. A Review. *Agronomy for Sustainable Development, 35* (2): 483-498

Eriksen, S. N. (2013). Defining Local Food: Constructing a New Taxonomy – Three Domains of Proximity. *Acta Agriculturae Scandinavica, Section B – Soil & Plant Science, 63* (1): 47-55

European Commission (2014). *Factsheet on 2014-2020 Rural Development Programme for Denmark*. [Online] Available at: http://ec.europa.eu/agriculture/sites/agriculture/files/rural-development-2014-2020/country-files/dk/factsheet_en.pdf [Accessed: 28th Mar 17]

EY (2015). *Nordic Food Survey: Consumer trends.* [Online] Available at: http://www.ey.dk/Publication/vwLUAssets/EY_food_Survey_2015/$FILE/EY-food-Survey-2015.pdf. [Accessed: 29th Apr 17]

Ezzy, D. (2002). *Qualitative Analysis: Practice and Innovation. Social Research Today*. London: Routledge

FAO (2001). *Urban and Periurban Agriculture: A New Challenge for the UN Food and Agriculture Organisation*. [Online] Available at: http://www.fao.org/docs/eims/upload/215253/briefing_guide.pdf [Accessed: 2nd Jun 17]

FAO (2009). *How to Feed the World in 2050*. [Online] Available at: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf [Accessed: 3rd Nov 16]

Fine, L. G. (2009). *The SWOT Analysis. Using your Strength to overcome Weaknesses, Using Opportunities to overcome Threats*. Available at: http://lawrencefine.com/downloads/SWOT%20-%20PDF.pdf [Accessed: 2nd June 17]

Foley, J., Ramankutty, N., Braunman, K., Cassidy, E., Gerber, J., Johnston, M., … Zaks, D. (2011). Solutions for a cultivated planet. *Nature, 478* (7369): 337-342

Food Standards Agency (2016). *Our Food Future*. [Online] Available at: https://www.food.gov.uk/sites/default/files/our-food-future-full-report.pdf [Accessed: 28th Apr 17]

Fookes, C. (n.d.). *UK Organic Sector backed by EU Funding*. [online] Available at: https://www.organictradeboard.co.uk/content/OTB%20EU%20Press%20Release%20Short%20Jan%2017%20final.pdf [Accessed: 6th Mar 17]

Frambach, H. (2012). Johann Heinrich von Thünen: A Founder of Modern Economics. In: Backhaus, J. G. (ed.). *Handbook of the History of Economic Thought. Insight on the Founders of Modern Economics* (pp. 299-322). Germany: Springer

Freight Farms (2016). *Products.* [Online] Available at: http://www.freightfarms.com/#leafygreenmachine [Accessed: 22nd Nov 16]

Friedmann, K. (1976). Food Marketing in Copenhagen 1250-1850. *Agricultural History, 50* (2): 400-413

Frostholm, A., Schjelde, J. & Holmstrup, G. (2016). *Sådan ligger landet - tal om naturen 2016*. [Online] Available at: http://www.fredericia.dn.dk/departments-media/11560/sll_talomnaturen_2016_web.pdf [Accessed: 21st Mar 17]

Gallo, P., Casazza, C. & Sala, M. (2016). Performances and Potential of Productive Urban Green Infrastructure. *Journal of Technology for Architecture and Environment*, *11* (2): 104-112

Garud, R. & Karnøe, P. (2000). Path Creation as a Process of Mindful Deviation. In: Garud, R. and Karnøe, P. (Eds.). *Path Dependence and Path Creation* (pp. 1–38). Mahwah, NJ: Lawrence Earlbaum

Garud, R., Kumaraswamy, A. & Karnøe, P. (2010). Path dependence or path creation? *Journal of management studies, 47* (4): 760-774

Geels, F. (2004). From Sectoral Systems of Innovation to Socio-technical Systems, Insights About Dynamics and Change from Sociology and Institutional Theory. *Research Policy, 33* (6): 897-920

Goldstein, B., Hauschild M., Fernandez, J. & Birkved, M. (2016). Testing the Environmental Performance of Urban Agriculture as a Food Supply in Northern Climates. *Journal of Cleaner Production, 135*: 984-994

Greater Copenhagen (n.d.). *About Greater Copenhagen*. [Online] Available at: http://www.greatercph.com/about [Accessed: 22nd May 17]

Growing Underground (2017). *Welcome to the Agricultural Revolution!* [Online] Available at: http://growing-underground.com/ [Accessed: 25th Apr 17]

Growtainer (2016). *Home*. [Online] Available at: http://www.growtainers.com/ [Accessed: 22nd Nov 16]

Grönska Stadsodling (2017). *Vi odlar & säljer grönsaker & örter*. [Online] Available at: http://www.xn--grnska-xxa.se/omgronskastadsodling/ [Accessed: 25th Apr 17]

Haitz, R. (2000). *Another Semiconductor Revolution: This time it's lighting!* [Online] Available at: http://www.quarkstar.com/uploads/2/3/3/4/23343356/2003_another_semiconductor_revolution_-_adv_solid_state_physics.pdf [Accessed: 22 Feb 17]

Haitz, R., Kish, F., Tsao, J. & Nelson, J. (2000). *The case for a national research program on semiconductor lighting. Sandia Report*. [Online] Available at: http://www.sandia.gov/~jytsao/hpsnl_sand_report_2000.pdf [Accessed: 2nd June 17]

Halloran, A. & Magid, J. (2013). The Role of Local Government in Promoting Sustainable Urban Agriculture in Dar es Salaam and Copenhagen. *Geografisk Tidsskrift-Danish Journal of Geography, 113* (2): 121-132

Hayashi, E. & Higgins, C. (2016). Global LED Lighting Players, Economic Analysis, and Market Creation for PFALs. In: Kozai, T., Fujiwara, K. & Runkle, E. (eds.). *LED Lighting for Urban Agriculture* (pp. 317-346). Singapore: Springer

Hirsch, D., Meyer, C. H., Klement, J., Hamer, M. & Terlau, W. (2016). Urban AgriCulture and Food Systems Dynamics in the German Bonn/Rhein-Sieg Region. *International Journal of Food System Dynamics, 7* (4): 341-359

Holmstrup, G., Schjelde, J., Lundsgaard, R., Nygaard, T., Ogstrup, L. & Damm, B. I. (2016). *Sådan ligger landet - tal om landbruget*. Available at: http://www.dn.dk/om-os/publikationer/sadan-ligger-landet/ [Accessed: 3rd March 2017]

James, P., Tzoulas, K., Adams, M.D., Barber, A., Box, J., Breuste J., …. Thompsons, C. W. (2009). Towards an integrated understanding of green space in the European built environment. *Urban Forestry & Urban Greening, 8* (2): 65–75

Jencks, C. (2010). *Architectural Evolution. The Pulsation of Time*. In: Garcia, M. (ed.). *The Diagrams of Architecture*. John Wiley and Sons Ltd. Publications

Kaminski, J. (2011). Diffusion of Innovation Theory, Theory in Nursing Informatics Column. *Canadian Journal of Nursing Informatics, 6* (2).

Karnøe, P., & Garud, R. (2012). Path Creation: Co-creation of Heterogeneous Resources in the Emergence of the Danish Wind Turbine Cluster. *European Planning Studies, 20* (5): 733-752

Kozai, T. (2013). Resource Use Efficiency of Closed Plant Production System with Artificial Light: Concept, Estimation and Application to Plant Factory. *Proceedings of the Japan Academy, Ser. B, 89* (10): 447–461

Kozai, T. (2016). Why LED Lighting for Urban Agriculture. In: Kozai, T., Fujiwara, K., & Runkle, E. (eds.). *LED Lighting for Urban Agriculture* (pp. 3-18). Singapore: Springer

Kozai, T. & Niu, G. (2016a). Introduction. In: Kozai, T., Niu, G. & Takagaki, M. (eds.). *Plant Factory – An Indoor Vertical Farming System for Efficient Quality Food Production* (pp. 3-5). USA: Elsevier

Kozai, T. & Niu, G. (2016b). Role of the Plant Factory with Artificial Lighting (PFAL) in urban areas. In: Kozai, T., Niu, G. & Takagaki, M. (eds.). *Plant Factory – An Indoor Vertical Farming System for Efficient Quality Food Production* (pp. 7-33). USA: Elsevier

Kozai, T. & Nui, G. (2016c). Challenges for the Next-Generation PFAL. In: Kozai, T., Niu, G. & Takagaki, M. (eds.). *Plant Factory – An Indoor Vertical Farming System for Efficient Quality Food Production* (pp. 387-393). USA: Elsevier

Kozai, T., Niu, G., & Takagaki, M. (2016). Light. In: Kozai, T., Niu, G. & Takagaki, M. (eds.). *Plant Factory – An Indoor Vertical Farming System for Efficient Quality Food Production* (pp. 115-128). USA: Elsevier

Kvale, S. (2007). *Doing Interviews*. London: SAGE Publications

Kvale, S. & Brinkmann, S. (2009). *Interviews Learning the Craft of Qualitative Research Interviewing* (2nd ed.). Sage Publications

Københavns Kommune (2014). *Annual Report 2014: Copenhagen Climate Projects*. [Online] Available at: http://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=1327 [Accessed: 1st Mar 17]

Københavns Kommune (2015a). *Annual Report 2015: Copenhagen Climate Projects*. [Online] Available at: http://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=1437 [Accessed: 1st Mar 17]

Københavns Kommune (2015b). *Fællesskab København: Vision for 2025*. [Online] Available at: http://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=1448 [Accessed: 1st Mar 17]

Landbrug & Fødevarer (2015). *8 vigtige fødevaretrends i 2016*. [Online] Available at: http://www.foodculture.dk/tema/samfund-og-forbrug/2016/madtendenser-2016-tema/madtendenser-2016# [Accessed: 22nd Nov 16]

Landbrug & Fødevarer (2016a). *8 forbruger- og fødevaretrends for 2017*. Available at: http://www.goderaavarer.dk/nyheder/trends-det-hitter-paa-madscenen-i-2017 [Accessed: 3rd Mar 17]

Landbrug & Fødevarer (2016b). *Fakta om erhvervet 2016*. [Online] Available at: http://www.lf.dk/aktuelt/publikationer/logf [Accessed: 19th Apr 17]

Landbrug & Fødevarer (n.d.). *Økologisk frugt og grønt*. [Online] Available at http://www.lf.dk/viden-om/oekologi/okologiske-produkter/frugt-og-groent [Accessed: 5th Apr 17]

Li, T., Baležentis, T., Makutėnienė, D., Streimikiene, D. & Kriščiukaitienė, I. (2016). Energy-related CO_2 Emission in European Union Agriculture: Driving Forces and Possibilities for Reduction. *Applied Energy, 180* (3): 682–694

Livingstone, S. (2003). *The Changing Nature of Audiences: From the Mass Audience to the Interactive Media User*. [Online] Available at: http://eprints.lse.ac.uk/archive/00000417 [Accessed: 9th Feb 17]

Lokman, I. M. (2006). E-Mail Interviewing in Qualitative Research: A Methodological Discussion. *Journal of the American society for information science and technology, 57* (10): 1284-1295

Markets and Markets (2015). *LED Grow Light Market worth $1.9 Billion by 2020.* [Online] Available at: http://www.marketsandmarkets.com/PressReleases/led-grow-light.asp [Accessed: 22nd Nov 16]

Markets and Markets (2016). *Vertical Farming Market by Functional Device (Lighting, Hydroponic Component, Climate Control, and Sensors), Growth Mechanism (Aeroponics, Hydroponics, and Others) and by Geography - Global Forecast to 2020.* [Online] Available at: http://www.marketsandmarkets.com/Market-Reports/vertical-farming-market-221795343.html [Accessed: 22nd Nov 16]

Massa, G., Kim, H., Wheeler, R., & Mitchell, C. (2008). Plant productivity in Response to LED Lighting. *HortScience, 43* (7): 1951-1956

McLuhan, M. & Fiore, Q. (2001). The Medium is the massage: An Inventory of Effects (9th ed.). California: Gingko Press

Melkote, S. (2006). Everett M. Rogers and His Contributions to the Field of Communication and Social Change in Developing Countries. *Journal of Creative Communications, 1* (1): 111-121

Merriam-Webster. (2017). '*entrepreneur*'. [online] Available at: https://www.merriam-webster.com/dictionary/entrepreneur [Accessed 19 Feb 2017]

Meuser, M. & Nagel, U. (2009). The Expert Interview and Changes in Knowledge Production. In: Bogner, A., Littig, B. & Menz, W. (eds.). *Interviewing Experts*. Palgrave MacMillan

Miljø- og Fødevareministeriet (2016). *Kongens Køkkenhave*. [Online] Available at: http://mfvm.dk/foedevarer/indsatsomraader/start-en-byhave/ [Accessed: 6th Mar 17]

Miljøstyrelsen (2003). *Rapport fra udvalget til vurdering af konsekvenserne af en nedsat pesticidanvendelse i gartneri og frugtavl – 10 Økologisk gartneri og frugtproduktion*. [Online] Available at: http://www2.mst.dk/common/Udgivramme/Frame.asp?http://www2.mst.dk/Udgiv/publikationer/2003/87-7972-761-1/html/kap08.htm$Section8.1 [Accessed: 5th Apr 17]

Mindtools (2017). *The Product Diffusion Curve*. [Image Online] Available at: https://www.mindtools.com/pages/article/newTMC_93.htm [Accessed: 7th Feb17]

Ministry of the Environment Denmark (2006). *The 2006 national planning report – in brief The new map of Denmark – spatial planning under new conditions*. [Online] Available at: http://www.sns.dk/udgivelser/2006/87-7279-728-2/pdf/87-7279-728-2.pdf [Accessed: 3rd Apr 17]

Mok, H. F., Williamson, V., Grove, J., Burry, K., Barker S. & Hamilton, A. (2014). Strawberry Fields Forever? Urban Agriculture in Developed Countries: A Review. *Agronomy for Sustainable Development, 34* (1): 21-43

Morawicki, R. (2012). *The Handbook of Sustainability for the Food Sciences*. Wiley Blackwell

Mougeot, L. (2000). Urban Agriculture: Definition, Presence, Potentials and Risks. [Online] Available at: https://pdfs.semanticscholar.org/daf8/d61c9aeba84da4c3e23c290992342357a61d.pdf [Accessed 2nd Jun 17]

Nargundkar, R. (2003). *Marketing Research Text and Cases*. New Delhi: Tata McGraw-Hill

Nielsen, O.-K., Winther, M., Nielsen, M., Mikkelsen, M. H., Albrektsen, R., Gyldenkærne, S., Plejdrup, M., Hoffmann, L., Thomsen, M., Hjelgaard, K. & Fauser, P. (2011). Projection of Greenhouse Gas Emissions 2010 to 2030. *National Environmental Research Institute, Aarhus University, Denmark. 178 pp. – NERI Technical Report no. 841.* http://www.dmu.dk/Pub/FR841

OECD (2008). *Environmental Performance of Agriculture in OECD countries since 1990: Denmark Country Section. Paris, France*. [Online] Available at: https://www.oecd.org/denmark/40762571.pdf [Accessed: 18th Apr 17]

Oestergro (n.d.). *Velkommen til Danmarks Første Tagfarm*. [Online] Available at: http://oestergro.dk/ [Accessed: 10th Mar 17]

Ohyama, K., Takagaki, M. & Kurasaka, H. (2008). Urban Horticulture: Its Significance to Environmental Conservation. *Sustainability Science, 3* (2): 241–247.

Olle, M. & Viršile, A. (2013). The Effects of Light-Emitting Diode Lighting on Greenhouse Plant Growth and Quality. *Agricultural and food science, 22* (2): 223-234

Olsson, E. G. A., Kerselaers, E., Kristensen, L. S., Primdahl, J., Rogge, E. & Wästfelt, A. (2016). Peri-Urban Food Production and Its Relation to Urban Resilience. *Sustainability, 8* (12): 1340

Pahl, N. & Richter, A. (2007). *SWOT Analysis - Idea, Methodology and a Practical Approach* (1st Ed.). Germany: GRIN Verlag

Parham, S. (2015). *Food and Urbanism, The Convivial City and a Sustainable Future*. London: Bloomsbury Academic

Philips (2016). *City Farming.* [Online] Available at: http://www.lighting.philips.com/main/products/horticulture/city-farming.html [Accessed: 22nd Nov 16]

Philips Cases (2017). *Stimulating efficient tomato growth. Alfred Pedersen & Søn ApS, Denmark.* [Online] Available at: http://www.lighting.philips.com/main/cases/cases/horticulture/pedersen [Accessed: 25th Apr 17]

Philips Products (2017). *City Farming*. [Online] Available at: http://www.lighting.philips.com/main/products/horticulture/city-farming.html [Accessed: 6th Mar 17]

Ponsard, C. (1983). *History of Spatial Economic Theory*. Berlin: Springer-Verlag

Ponterotto, J. G. (2005). Qualitative Research in Counselling Psychology: A Primer on Research Paradigms and Philosophy of Science. *Journal of Counselling Psychology, 52* (2): 126-136

Rogers, E. (2003). *Diffusion of Innovations* (5th ed.). New York: Free Press.

Rutqvist, J. & Lacym P. (2015). *Waste to Wealth: The Circular Economy Advantage*. Palgrave Macmillan.

Sabzalian, M. R., Heydarizadeh, P., Zahedi, M., Boroomand, A., Agharokh, M., Sahba, M. R. & Schoefs, B. (2014). High Performance of Vegetables, Flowers, and Medicinal Plants in Red-Blue LED Incubator for Indoor Plant Production. *Agronomy for Sustainable Development, 34*: 879-886

Sahin, I. (2006). Detailed Review of Rogers' Diffusion of Innovations Theory and Educational Technology-Related Studies Based on Rogers' Theory. *The Turkish Online Journal of Educational Technology, 5* (2): 14-23

Sismondo, S. (2010). *An Introduction to Science and Technology Studies* (2nd ed.). United Kingdom: Wiley-Blackwell

Skovpolitisk Udvalg (2011). *Fremtidens skov – anbefalinger fra Skovpolitisk Udvalg 2011*. [Online] Available at: http://naturstyrelsen.dk/media/nst/66863/fremtidens%20skov.pdf [Accessed: 21st Mar 17]

Slocum, A. (2005). A Technology Assessment of Light Emitting Diode (LED) Solid-State Lighting for General Illumination. [Online] Available at: https://www.epa.gov/sites/production/files/2014-12/documents/technology_assessment_of_light_emitting_diode.pdf [Accessed: 2nd Jun 17]

Sonnino, R. (2009). Feeding the City: Towards a New Research and Planning Agenda. *International Planning Studies, 14* (4): 425-435

Specht, K. et al. (2014) Urban Agriculture of the Future: An Overview of Sustainability Aspects of Food Production in and on Buildings. *Agriculture and human values, 31* (1): 33-51

Statistics Denmark (2016). *Population at the First Day of the Quarter by Region and Time*. [Online] Available at: http://www.statbank.dk/statbank5a/selectvarval/saveselections.asp, [Accessed: 3rd Nov 16]

Statistics Denmark (n.d.). *Agriculture, Horticulture and Forestry*. Available at: http://www.dst.dk/da/Statistik/emner/erhvervslivets-sektorer/landbrug-gartneri-og-skovbrug [Accessed: 3rd Nov 2016]

Sydow, J., Schreyögg, G. & Koch, J. (2009). Organizational Path Dependence: Opening the Black Box. *Academy of management review, 34* (4): 689-709

The City of Copenhagen (2012). *CPH 2025 Climate Plan. A Green, Smart and Carbon Neutral City*. [Online] Available at: kk.sites.itera.dk/apps/kk_pub2/pdf/983_jkP0ekKMyD.pdf [Accessed: 21st Mar 17]

The City of Copenhagen (n.d.). *Is Frederiksberg part of the City of Copenhagen?* [Online] Available at: http://international.kk.dk/artikel/frederiksberg-part-city-copenhagen [Accessed: 23rd May 17]

The Danish Government (2015). *Denmark without Waste II A Waste Prevention Strategy*. [Online] Available at: http://eng.mst.dk/topics/waste/denmark-without-waste-ii/ [Accessed: 3rd Apr 17]

The Danish Ministry of Food, Agriculture and Fisheries (2009). *Agriculture and Climate*. [Online] Available at: http://en.mfvm.dk/fileadmin/user_upload/ENGLISH_FVM.DK/Themes/climate_change_and_food/Agriculture_and_climate.pdf [Accessed: 22nd Mar 17].

The Ministry of Environment (2015). *The Finger Plan*. [Online] Available at: https://danishbusinessauthority.dk/sites/default/files/fp-eng_31_13052015.pdf [Accessed: 10th May 17].

Thomaier, S., Specht, K., Henckel, D., Dierich, A., Siebert, R., Freisinger, U. & Sawicka, M. (2014). Farming in and on Urban Buildings: Present Practice and Specific Novelties of Zero-Acreage Farming (ZFarming). *Renewable Agriculture and Food Systems, 30* (1): 43-54

Ton, M., Foster, S., Calwell, C. & Conway, K. (2003). *LED Lighting Technologies and Potential for Near-Term Applications*. [Online] Available at: http://neea.org/docs/reports/edlightingtechnologiesd8981309b83f.pdf [Accessed: 2nd Jun 17]

UN (2015). *World population projected to reach 9.7 billion by 2050*. [Online] Available at: http://www.un.org/en/development/desa/news/population/2015-report.html, [Accessed 30th Oct 16]

UN (n.d.). *Sustainable Development*. [Online] Available at: http://www.un.org/en/ga/president/65/issues/sustdev.shtml [Accessed: 3rd Mar 16]

Urban Crop (2016). *Our Technology.* [Online] Available at: https://www.urbancrops.be [Accessed: 22nd Nov 16]

Vásquez-Moreno, L. & Córdova, A. (2013). A Conceptual Framework to Assess Urban Agriculture's Potential Contributions to Urban Sustainability: An Application to San Cristobal de Las Casas, Mexico. *International Journal of Urban Sustainable Development, 5* (2): 200-224

Vergne, J. P. & Durand, R. (2010). The Missing Link Between the Theory and Empirics of Path Dependence: Conceptual Clarification, Testability Issue, and Methodological Implications. *Journal of management studies, 47* (4): 737-738

Voigt, K. (2011). Pigs in the Backyard or the Barnyard: Removing Zoning Impediment to Urban Agriculture. *Environmental Affairs, 38* (2): 537-566

von Thünen, J. H. (1966). *Von Thünen's Isolated State*. Ed. Hall, P. Oxford: Pergamon Press. First published 1826 as *Der isolierte Staat Beziehung auf Landwirtschaft und Nationalökonomie.* Hamburg: Perthes

Vorst, J. G. A. J. van der, Silva, C. A. Da & Trienekens, J. H (2007). Agro-Industrial Supply Chain Management: Concepts and Applications. *Agricultural Management, Marketing and Finance Occasional Paper, 17*. Published by FAO

Weber, C. L. & Matthews, H. S. (2008). Food-Miles and the Relative Climate Impacts of Food Choices in the United States. *Environmental Science & Technology, 42* (10): 3508-3513

WHO (2016). *Urban Population Growth.* [Online] Available at: http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/ [Accessed: 30th Oct 16]

Winner, L. (1978). *Autonomous Technology. Technics-out-of-Control as a Theme in Political Thought*. Cambridge: MIT Press

Winner, L. (1989). *The Whale and The Reactor: A Search for Limits in an Age of High Technology* (1st ed.). Chicago: University of Chicago Press

Wijnands, J. (2003) The International Competitiveness of Fresh Tomatoes, Peppers and Cucumbers. *IDEAS Working Paper Series from RePEc*

Wiskerke, J.S.C. & Viljoen, A. (2012). Sustainable Urban Food Provisioning: Challenges for Scientists, Policymakers, Planners and Designers. In: A. Viljoen & J.S.C. Wiskerke (eds.). *Sustainable Food Planning: Evolving Theory and Practice* (pp. 19-36). The Netherlands: Wageningen Academic Publishers

Yeh, N. & Chung, J. P. (2009). High-Brightness LEDs — Energy Efficient Lighting Sources and Their Potential in Indoor Plant Cultivation. *Renewable and Sustainable Energy Reviews, 13* (8): 2175-2177

Zip Farm (2016). *Zip Farm Indoor Farming.* [Online] Available at: https://brightagrotech.com/bright-agrotech/ [Accessed: 22nd Nov 16]

Zasada, I. (2011). Multifunctional Peri-Urban Agriculture – A Review of Societal Demands and the Provision of Goods and Services by Farming. *Land Use Policy, 28* (4): 639-648

Økologisk Landsforening (2015). *Strategi 2015-2020*. [Online] Available at: http://okologi.dk/om-os/organisationen/strategi [Accessed: 6th Mar 17]


Stelling : 1
Laag : 2