A SWOT ANALYSIS OF THE VERTICAL FARM

2018, June 1

BSC Thesis
Name: Sanne van Asselt
Registration number: 941120020100
Supervisor: J. H. Trienekens
Chair group: Management Studies (MST)

Abstract

The vertical farm is in its early state, leaving many questions unanswered and many open gaps in our current level of knowledge. There is at the moment not known what the opportunities and threats of a vertical farm are. To create more knowledge on vertical farms we conducted a SWOT analysis to answer the question: what are the most promising opportunities and most dangerous threats for the vertical farm? For the strengths we sought to find subjects that created a competitive advantage for the vertical farm by having a resource that greenhouse and conventional farm do not possess or any activity the vertical farm does better. For the weaknesses we looked for resources a vertical farm does not possess and activities a vertical farm is not doing well. Lastly the PESTLE analysis was used to find the opportunities and threats for the vertical farm. The high efficiency, the high quality, the innovative technology and the high costs are the most recurrent themes in the strengths, weaknesses, opportunities and threats of the vertical farm. The results of the SWOT analysis show that there are two most promising opportunities and three most dangerous threats. The first most promising opportunity is the environmental opportunity. A vertical farm can become a circular economy and also energy efficient by further enhancing their innovative technology. The second opportunity is the economic opportunity, which is the niche market and selling opportunities (both) based on the high quality and high level of food safety of the crops grown in a vertical farm. The first most dangerous threat is the technological threat, which is the nanotechnology in greenhouses. The nanotechnology gives crops of the greenhouses the same high quality as the crops of a vertical farm. The second threats are the social and economic threat. There is a possibility that there will be a social barrier towards the crops of a vertical farm, because people may think that these crops are grown in a non-natural way and thus won't buy them. The economic barrier can occur when people are not willing to pay the higher prices compared to greenhouses and traditional farms, due to vertical farms higher costs. When the social and economic barrier occur, the vertical farm cannot be profitable. The third and last threat is the political threat, which is the urban development planning. In urban development plans vertical farms are not specifically mentioned. If the government does not allow vertical farms to be developed or put constraints on future growth this will have negative consequences. Overall, vertical farms should use strengths to explore their most promising opportunities and at the same time diminishing their most dangerous threats.

Key words: Vertical Farm, SWOT analysis, Competitive advantage, Resource based view, PESTLE.

Table of content

1. Introduction

1.1 Problem background

The Westland is a sub region in the province of South Holland the Netherlands and has a long history of agricultural activities. In the 1850s the farmers of the Westland started building glass houses around their crops to protect their harvest. They were looking for better Farming methods, this was due to the high level of competition between the farmers (Erfgoedhuis-ZH, 2017). In the beginning, the grape was the main crop that was produced in glass houses in the Westland. Only 30 years later in 1960 vegetables started to dominate in the agricultural glass house sector. Through the years more farmers in the Westland started to shift from conventional farming to farming in glass houses, this was the start of what we now call the glass city (Vijverberg, 1996).

Through technical developments these glass houses started to become greenhouses. In a greenhouse you can control the humidity, light, moisture and temperature. So, with these technical developments a greenhouse offers many advantages over traditional soil-based agriculture. In the Netherlands, there are also greenhouses build that are climate-controlled and monitored for performance (Green, 2009). In these greenhouses no soil is used. According to Despommier (2013) “the final step in the evolution of urban agriculture is to stack high-tech greenhouses on top of one another, creating vertical farms”. Dickson Despommier is a professor of Columbia university, who developed the concept of vertical farming with his students in a time period of five years beginning in 2002 (Platt, 2007).

1.2 Problem statement

According to some, the vertical farm is the next big thing in the agricultural sector. Vertical farming is quite new and so there has been not that much research done on the sustainability and the profitability of the vertical farm. What is already known is that the vertical farm is a lot more expensive than a conventional farm, this is due to the technology that is used in the vertical farm. A part which makes the vertical farm expensive is the artificial lighting, because a vertical farm does not use daylight you need to provide artificial light (Specht et al., 2013). Not only is the vertical farm very expensive, but according to Al-Chalabi (2015) there will be many people that will perceive the crops grown in the vertical farms as ‘food made from chemicals’ and ‘not natural’. These are two examples that are problems for the vertical farm.

For a vertical farm the artificial lighting is unavoidable, and so research has been done to investigate if a vertical farm could be self-sufficient. In the USA some vertical farms are reducing their carbon footprint by using solar panels, which create enough energy for the whole vertical farm (Foodable Network, 2016). In this way the vertical farm can reduce greenhouse gas emissions in several sectors.

1.3 Research question

In this paper, the research question is “What are the most promising opportunities and most dangerous threats for the vertical farm?” This question will be investigated on the basis of a SWOT analysis.

To be able to answer the research question, a few sub- questions need to be answered first.

Sub questions:

By conducting a SWOT analysis there are a number of questions that will be answered in this research.

1. **Strength**: What are the most important resources that will give the vertical farm a competitive advantage?
2. **Weakness**: Which resources could be improved to expand the competitive advantage of the vertical farm?
3. **Opportunities**: What are the technical and market opportunities for a vertical farm?
4. **Threats**: Are there potential competitors who can create competition in the future for the vertical farm?

1.4 Research relevance

In 2017 Despommier said to Tegenlicht, who were making a documentary about the vertical farm, that by 2040 the world population will be grown to 9 billion people and the majority will be living in the cities. Despommier is asking himself if all these people will have access to fresh food and if these will be grown in a sustainable way (VPRO-Tegenlicht, 2017)? The growing world population and the drastic change in climate strains Earth's resources, in particular the food supply chain. According to Al-Chalabi (2015) a good option to overcome these problems is the vertical farm of Despommier. These vertical farms can be placed in the city and thereby feed the people in the cities in a sustainable way and reduce greenhouse gas emissions. Despommier (2013) is thinking the same thing, he said that vertical farming will be the answer in the future. A lot of research is needed on vertical farming which can help the development and uptake of vertical farms all over the world.

1.5 Overview of the rest of the chapters

In this research, there will be first explained what a SWOT analysis is and why it will be used. After that there will be a chapter on what a vertical farm is and there will be given two examples of real vertical farms. Before conducting the SWOT analysis there will be explained what is meant with a strength, weakness, opportunities and threat in this research. Then the SWOT analyse will be carried out, the findings will be shown in 4 separate chapters all explaining one of the elements of the SWOT analysis. These findings will be summarized in the conclusion and the research questions will be answered. After the conclusion the limitations of this research will be discussed in the discussion.

2. Method

This research will be a literature study, existing literature, case studies and examples will be used and discussed to come to conclusions. As mentioned before, this research will focus on what will be the most promising opportunities and what will be the most dangerous threats for the vertical farm. This will be investigated on the basis of a SWOT analysis. According to Yüksel and Dagˇdeviren (2007) a SWOT analysis can be a supporting tool for decision-making and is also used to analyse an organization's internal and external environment.

When identifying the strength and weaknesses of a company, an analysis of the internal environment will be carried out in relation to greenhouses and conventional farms. When looking for Strengths and weaknesses of a vertical farm, the competitive advantages the vertical farm will or will not have over a conventional farm or greenhouse will be investigated through the resource-based view of Barney (1991). Bernroider (2002) identified competitive advantage as factors a company does better than the other in these areas: "superior efficiency, superior quality, superior innovation, and superior customer responsiveness". The resource-based view of Bareny (1991) looks for valuable resources a company has that will gain them superior performance. According to Barney and Arikan (2001) "Resources are the tangible and intangible assets firms use to conceive of and implement their strategies". So, for the vertical farm there should be looked at if there are any valuable resources that are used to create a strategy with that will lead to a superior performance.
When identifying the opportunities and threats an analysis of the external environment of the company will be carried out. Hussey (2001) explains in his paper on creative strategic thinking, that when identifying the opportunities and threats, you should look at the market situation and the industry. A PESTLE (Political, Economic, Social, Technological, Legal and Environmental) analysis will be carried out which is a good supporting tool for a SWOT analysis. (Fozer et al., 2017). With a PESTLE analysis, there will be looked at 6 specific subjects that frequently have a form of impact on the company's projects and activities (Mullerbeck, 2015).

Pickton (1998) states that it is required that strategically the future pattern of actions to be taken should match the strengths with the opportunities, ward off threats, and seek to overcome weaknesses. So, when looking at a new and innovative company it will be of great importance to know the outcome of the SWOT analysis then this can be used to make strategic decisions so that the company can develop and grow.

3. Vertical Farming

3.1. What is a vertical farm?

Dr William Gericke and colleagues perfected an alternative strategy to soil-based farming in 1930, where crops are grown in the absence of soil which is called hydroponic. Instead of normal soil Dr Gericke and colleagues created an aqueous solution, a solution where the solvent is water, which is used to provide the crops with the right amount of nutrients to grow (Despommier, 2013).

In 2007 Despommier finalized his concept of the vertical farm. He combined the strategy of Dr Gericke (1930), the innovative technology with growing crops on vertical stacked racks to create a vertical farm. In these vertical farms Led lights and computer assisted control systems are used to create the perfect crop. The computer assisted control systems assure that the crops get the right amount of nutrients and light (Despommier,2013). This strategy of farming is now used all over the world in greenhouses. Indoor farming is also referred to as CEA, Controlled Environmental Agriculture. "CEA has rapidly evolved into a commercially viable approach for the large-scale production of a wide variety of crops in close proximity to, or even within, urban centres (Despommier, 2013)."

3.2. Examples of vertical farms

Over the years several vertical farms have been built all over the world. From vertical farms using sunlight mixed with artificial light to urban vertical farms that only use artificial lighting (Despommier, 2013). The technology changed a lot since Despommier finalized his concept. For instance, some vertical farms have switched from hydroponics to using aeroponics. In this chapter, two examples of vertical farms will be shown to give a better explanation on what a vertical farm is. Staay Food Group and AeroFarms will be introduced, because their information on vertical farming will be used more often in this research.

Dronten (Netherlands)

In July 2017 Staay Food Group planned to start building their first vertical farm in Europe to be located in Dronten, but because of internal reasons the building date has been postponed to the summer of 2018. "Staay Food Group is the fresh food company in which centralized policy, marketing and sourcing control is supplemented by local expertise in growing and sales (Staay Food Group, 2018)". The main goals of the Staay Food Group is to create, transport and deliver the best product with the best quality and high sustainability. Staay Food Group is at his moment still purchasing lettuce from Southern-Europe when the crops in the Netherlands are lost by bad weather. The import of lettuce from Southern-Europe is not good for the environment. The crops are shipped by plane, boat or truck and this ensures that the emission of greenhouse gases will be high. The transport distance can also create problems, the crops will be less fresh and there is also the chance to lose a part of the harvest during transport. When the vertical farm in Dronten is up and running Staay Food Group does not need to purchase their lettuce from the Southern-Europe anymore. Their lettuce from the vertical farm will be fresher, pesticide free and have a high quality (Staay Food Group, 2018).

The vertical farm is going to be 9 stories high and will be able to grow an annual amount of 300,000 kilo grams of luxury lettuce, like Rucola and Frisee. This lettuce will be grown in the large racks inside coconut plugs using a hydroponic system to provide water and nutrients and underneath LED-light (Staay Food Group, 2018). These luxury lettuces will be processed and used for ready to eat meal salads.

Newark (USA)

AeroFarms is an agricultural company that took a new course in 2004 towards a new standard for totally-controlled agriculture (AeroFarms, 2018). At this moment AeroFarms is owning, building and operating several vertical farms that grow healthy, highly nutritious and safe food. These crops are grown in a socially responsible and sustainable way. (AeroFarms, 2018).

In August 2015 AeroFarm built their ninth farm in Newark, NJ. The vertical farm was built in a former paintball and laser tag arena, which shows that every space could be rebuilt to a vertical farm and boasts around 3000 square meters of growing space. AeroFarms grows their crops without sunlight and soil in a fully controlled indoor environment. They use smart aeroponics to give the plants the nutrient, water and oxygen that they need to create a high-quality product. Smart aeroponics is a way of growing crops without soil in an air or mist controlled environment (Buckseth et al., 2016), as shown in figure 1 the roots of the crops hang in a mist controlled environment. The products that come from this farm are now sold in grocery stores in Newark. In 2016 AeroFarms moved their headquarters to Newark and started building on the largest vertical farm in the world. This vertical farm has over 6500 square meters of growing space and has a harvest of up to 2 million pounds per year.

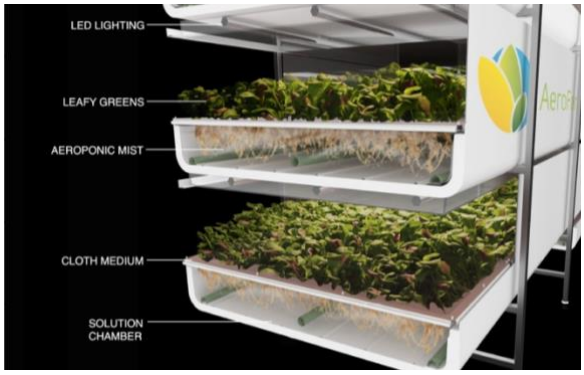

Figure 1, Smart aeroponics. (AeroFarm, 2018)

4. SWOT analysis in detail

In this chapter, there will be an explanation on what will be understood as a strength, weakness, opportunities and threat for this research. The four factors are divided in internal environment and external environment. For all the factors, there will be given a definition and an example.

4.1. Internal environment

According to Robbins et al. (2015, p. 150) a strength is "any activity the organization does well or any unique resource the company has". This means that when a company is good in something and thus has an advantage over another company, the company has a unique resource or activity which can be seen as a strength. Weihrich (1982) stated that you should look why customers would buy your products and not the products of the competitors. An example of a strength is for instance, that a company as coca cola has a great marketing and advertisement strategy. Coca cola tries to win people's heart with their commercials, by targeting people from all ages with the use of for example a song that is catchy or celebs in their commercials.

According to Robbins et al. (2015, p. 150) weaknesses are "Activities the organization doesn't do well or resources it needs but doesn't possess". So, when a company is missing resources or is not doing an activity that well and cannot create a competitive advantage, this can be seen as a weakness. Weihrich (1982) stated that to determine an organization's weaknesses you should not only look for what the company can do better, but also why the competitors are doing better. So, when the company knows why the competitor is selling more product, they know what the competitors are doing better and thus what your company is lacking. An example of a weakness is for instance the lack of product diversity. When looking at Arla and Friesland campina, Friesland campina has a much greater product diversity than Arla has. So, the product diversity can be seen as a weakness of Arla in their market.

4.2. External Environment

The definition of an opportunity is any Positive trend in the external environment of a company (Robbins et al., 2015, p. 150). So, when there is a positive change in the external environment for the company to grow, you can say this is an opportunity. This is also stated in the article of Weihrich, (1982) according to him an opportunity is a major factor to determine how your organization can continue to grow within the marketplace. An opportunity can come from anywhere for instance, from a change in government policy. An example of an opportunity is for instance, when a company starts using new technology that has just entered the market and the competitors are slow to adapt. Then you will have a big advantage towards your competitors on the basis of quality or efficiency or any other factor which is created by the new technology.

When there is a negative trend in the external environment of the company we talk about a threat (Robbins et al., 2015, p. 150). According to Weihrich, (1982) treats are external factors that are out of the companies control and will have a negative effect. So, when there is a trend that influences your company in a negative way, for instance when the government introduces extra tax or unforeseen trends like an economic depression, this can be seen as a threat. An example of a threat is for instance when the government creates a new law or policy whereby it will be harder for a company to create their product or ship their product.

4.3. TOWS Matrix

The TOWS (threats, opportunities, weaknesses and strengths) matrix, which is shown in table 1, is a complementary tool of the SWOT analysis in order to deploy a strategy. The TOWS matrix combines the external and internal factors of a company and in this way the company can choose a strategy that will fit their strength, weakness, opportunities or threats. (Aslan et al., 2012

TOWS matrix	**External Opportunities (O)** 1. 2. 3.	**External Threats (T)** 1. 2. 3.
Internal Strengths (S) 1. 2. 3.	SO Strategies that use strengths to maximize opportunities	ST Strategies that use strengths to minimize threats
Internal Weaknesses (W) 1. 2. 3.	WO Strategies that minimize weaknesses by taking advantage of opportunities.	WT Strategies that minimize weaknesses and avoid threats

Table 1. TOWS matrix (Weihrich,1982)

5. Strengths

5.1. Competitive advantage and resource-based view

When looking for a competitive advantage of the vertical farm there should be looked for “superior efficiency, superior quality, superior innovation, and superior customer responsiveness" (Bernroider, 2002). When using the resource-based view (Barney 1991) in search for strengths, there should be looked for any valuable resource that gives the vertical farm a superior performance in any way. A resource can in its own way also ensure a competitive advantage and can thus be a strength.

Efficiency

According to the Oxford dictionaries (2017), a company is efficient when achieving maximum productivity with minimum wasted effort or expenses. So, when a company strives to be efficient it minimizes its waste of resources such as physical materials energy and time, but at the same time gets maximum output. In an article of Barney (1991) about the resource-based view, he stated that firm resources are all “assets, capabilities, organizational processes, firm attributes, information, knowledge, etc.” that are controlled by a firm which enable the firm to create and implement strategies that can improve the efficiency of the firm. Bravo-Ureta and Evenson (1994) looked at the Efficiency in agricultural production and stated that efficiency is crucial when a farm wants to increase their agricultural output. When you want to increase your output, you should look for ways to produce more products. In the research of Moreau et al. (2012) they looked at “the efficiency of farming systems in vulnerable areas”. In their research, they evaluated the economic efficiency in net value added and net agricultural income. When looking to increase the output there could be looked at the growing time of a crop. When looking at the agricultural income, the use of resources as water could be evaluated and the income lost by losing crops can be evaluated.

The efficiency will be analysed on the basis of 3 major resources. The first resource will be water usage. The Association for vertical farming (2015) stated that 70% of the fresh water that is available for human use is used to grow food and raise animals. When growing crops in a vertical farm the water use will be lower than used in conventional farming or in a greenhouse, which means that there will be more water available for the human use. The second resources will be the growing time of the crops. Freight Farms (2017) has a network of famers all over the world and they found that the annual marketable yields of lettuce in a vertical farm is more than two times as high than the marketable yields for a conventional farm. This is for a big part due to the short growing time of a the crops from a vertical farm. The last resource will be lost yield. According to the association for vertical farming (2015) 50% of the crops planted are not harvested with traditional farming opposite to 10% with vertical farming. Another point is that according to Pretty et al. (2005) the highest cost on a farm are the pesticides, a vertical farm does not use pesticides and thus has lower costs. To determine efficiency of the vertical farm the analysis will look at the differences between an outdoor conventional farm, a greenhouse and a vertical farm.

First there will be looked at the water usage of a vertical farm in comparison with a conventional farm and a greenhouse. In 2007 Molden stated that the water usages of a vertical farm would be 70% less than used in a conventional farm. In 2013 Despommier supported this by saying that the water usage would be 70-80% less than used in a conventional farm. Over the years the water uses of a vertical farm even went down, due to better techniques and new growing methods, to 95% less then used at a conventional farm (AeroFarms, 2018). A reason for this is that vertical farms use growing methods like hydroponic and aeroponics systems which deliver water with nutrients directly to the roots of the crops. Conventional farms do not use these systems, which ensures that a lot of the water will dissolves in the soil (Freight Farms, 2017). There are two different types of hydroponic systems, open and closed. A closed hydroponic system also called a closed loop system, is a system in which the water with nutrients gets recycled. The closed

loop ensures that the water that is not absorbed by the plans will go back into the reservoir to be used again. This does not mean that there is a 100% water efficiency, because there will always be water loss. According to AlShrouf (2017) a closed hydroponic system uses on average 5 to 20 times less water than soil-based agriculture. In an open hydroponic system also called a non-closed loop system, the water that is not absorbed by the plans is not used again. This ensures that in a non-closed loop system new water is needed for every irrigation cycle (AlShrouf, 2017). Greenhouses that use open system use around 80% less water and for a closed system this is even 85% less water than a conventional farm (AlShrouf, 2017). AeroFarms (2018) is using a aeroponics systems to grow their crops, according to AeroFarms this ensure that their vertical farm is even using 40% less water than a hydroponic system. According to AlShrouf (2017) a aeroponics system uses 98% less water than a conventional farm. In the Netherlands, about 90% of the greenhouses uses hydroponic systems (Pardossi, 2011) and a lot of these greenhouses use closed loop systems (Breukers et al., 2008). To compare the water use of a vertical farm with that of a greenhouse, the information given by AeroFarms and the scientific researches will be used to form estimates. When comparing the water use of vertical farms and greenhouses both using hydroponic systems, the water use of a greenhouse will probably be 10% higher. For a vertical farms useing a aeroponics system the water use will differ around 40% with that of a greenhouse using a hydroponic system. When looking at other countries in Europe, around 20% of the greenhouses use hydroponic systems, which means that in these cases the water use will be higher and the difference with a vertical farm will be bigger (Martinez, 2018).

Secondly the growing time of the crops in the vertical farms are proven to be much shorter than for a conventional farm or greenhouse. AeroFarms states that they are on average growing their crops in sixteen days what otherwise takes thirty days on a conventional farm. AeroFarms stated in the speciality food magazine (Chang, 2017) that their productivity per square foot is 130 times higher than a conventional farm and 10 times higher than a greenhouse. The short growing time is also reported by Staay Food Group, they are growing their lettuce in four weeks in contrast to ten to fourteen weeks in the fields. Touliatos et al. (2016) conducted a research where they compared the lettuce yield per unit area of a vertical farm against a conventional horizontal hydroponics, a greenhouse. Artificial lighting was used for both the greenhouse with a hydroponic system and the vertical farm, the crops were all provided with the same nutrient solution and daily quantity of water. The result of this research show that a vertical farm produces 13.8 times more crops on the same growing space than a greenhouse using a hydroponic system (Touliatos et al., 2016).

At last there will be looked at lost yield. Mendelsohn (2007) found that 59% of crop failure is due to temperature, precipitation, and soils. Temperature is for 39% accountable for crop failure. A farmer has no influence on temperature, so when it turns out badly it causes crop failures. Think of extreme cold in the winter or extreme heat in the summer. Precipitation is for 20% accountable for the crop failure. When there is enough of precipitation during the whole growing season this reduces the crop failure rate, but when there are whole seasons without precipitation or with too much the crop failure rate is high. Naichia and Chung (2009) state that when crops are grown in a closed environment where there is total control of temperature and water use, this will eliminate the weather-related crop failures. Soil is for 5% accountable for crop failure. In a vertical farm the crops are grown without soil, so this type of crop failure will also be eliminated.
These three factors, temperature, precipitation, and soils, that cause crop failure will probably not occur in a greenhouse in the Netherlands. In most of the greenhouses in the Netherlands the farmers can regulate the temperature due to closed or semi-closed greenhouses (Agri Holland, 2018), regulate the water usages and the crops are also grown without soil. For other countries where greenhouses do use soil and are falling behind with good water system technologies and heating and cooling devices this could differ.

Not only the weather and soil can have an influence on outdoor conventional farming, according to Showler (1995) crops from an outdoor farm are subjected to various levels of attacks from a viruses, bacteria and plant pests, which often results into high yield losses due to crop failure. The chance of crop failure due to bacteria, pests and viruses will be very small when growing crops in a vertical farm. Looking at a conventional farm one of the highest cost are the pesticide (Pretty et al., 2005), when the crops are grown in a vertical farm there are no pesticides (AeroFarms, 2018). This means that there is also no lost income anymore due to the use of pesticides. At the moment greenhouses do use pesticide, so they are losing income (Breukers et al., 2008).
Another issue is that, from harvested crops around 30% is lost during storage and transport when looking at conventional farms and greenhouses. When growing crops in a vertical farm most of the crop failure that will occur during storage and transport will be eliminated. The transport distance is much shorter, because vertical farms will be placed in cities. This ensures that crops will not be in a truck for long which will reduce the chance of crop failure during transport. The chance of crop failure during storage will also be reduced, because the crops of a vertical farm will be sold almost immediately so there is no to little storage (Despommier, 2009).
To conclude, the efficiency of the vertical farm is very high due to low water usages, a short growing time, and there is no to little lost yield when growing crops in a vertical farm.

Water usage	With aeroponics systems the water use of the vertical farm will be 95% less than used on a conventional farm. (AeroFarms, 2018) Greenhouses that use open system use around 80% less water and for a closed system this is even 85% less water than a conventional farm (AlShrouf, 2017) The water use of greenhouses using hydroponic systems will probably be 10% higher than vertical farms using hydroponic systems. For vertical farms using aeroponics this will differ around 40% (AeroFarms, 2018).
Growing time	AeroFarms (2018) states that they grow their crops in 16 days instead of 30 days. The productivity level of AeroFarms (2018) is 130 times higher than a conventional farm. Aearofarms (2017) states that their productivity level is 10 times higher as a greenhouse. The result of the research of Touliatos et al. show that a vertical farm produces 13.8 times more crops on the same growing space than a greenhouse using a hydroponic system (2016).
Lost yield	According to the association for vertical farming (2015) 50% of the crops planted are not harvest with traditional farming opposite to 10% with vertical farming. A vertical farm uses no pesticides unlike a greenhouse and conventional farming which are losing income due to the costs of pesticides. A vertical farm will reduce the chance of crop failure during transport and storage.

Table 2. Overview of numbers of the Efficiency per subject.

Quality

The quality will be analysed by the factor product quality, so in this case this will be the quality of the crops. The quality of the crops from a vertical farm will be compared with crops from a conventional farm and greenhouses, in this way the difference in quality will be determined.
According to David Rosenberg, chief executive and co-founder of AeroFarms (2018) they are using “less fertilizers, zero pesticides, herbicides, fungicides” to grow their crops. This is supported by Despommier (2011) he stated in his article that a vertical farm does not use pesticides or herbicides. When looking at greenhouses, they still use pesticides which means that vertical farm grows their crops in a more durable

way (Breukers et al., 2008). The crops from a vertical farm have a high level of food safety, because no pesticides are used. This does not mean that the crops from greenhouses are not safe, because according to the European Food Safety Authority the risk of using pesticides on crops to consumers is low (Carvalho, 2017). However, this does mean that the crops from a vertical farm have a higher level of food safety than other crops from farms that use pesticides.
In the documentary of VPRO-Tegenlicht (2017), they stated that the vertical farms can assure the highest quality of the crops to a certain point. This is due to the innovative technology of the vertical farms. The vertical farm can assure the highest quality, because they can give the perfect amount of water with the best nutrients and influence taste and texture. In this way, they can create the perfect circumstances to grow the crops. But how do they know what these best circumstances are? There are large databases which contain information concerning the circumstances per year and also the quality rate of the final product. So, when the lettuce was perfect in the first quarter of 2006, they look up what the right circumstances where and mimic these conditions and so they can create the perfect lettuce. AeroFarms (2018) is using around 130.000 data points to create the best product with the best flavour. These data points provide the vertical farms with real time information on the growth of the crops and so ensures the highest quality of the crops. With data points a vertical farm can monitor its crops in an easy and not time-consuming way. Using these data points, AeroFarm is minimizing the typical risk that would occur with traditional farming (AeroFarms, 2018). AeroFarms (2018) states that chefs agree with them, that their greens have superior flavour. Greenhouses in the Netherlands can also create good to perfect circumstances for a crop to grow, the difference is that at the moment the greenhouses are manly using High Pressure Sodium (HPS) lamps (Van Ieperen & Trouwborst, 2007). According to Philips (2015) their LED lights can ensure a higher quality crop than the HPS. With these LED lights a vertical farm can regulate the colour, taste, texture, growth and even the vitamin content of a crop by using LED lights (Staay Vertical Farm, 2018).
By creating the perfect circumstance to grow a crop a vertical farm can ensure that their quality will be higher than crops from a conventional farm or greenhouse.

High level of food safety	According to AeroFrams the vertical farms use: “less fertilizers, zero pesticides, herbicides, fungicides.” Despommier (2011) stated that a vertical farm does not use pesticides or herbicides. The crops from a vertical farm have a higher level of food safety, because no pesticides are used.
High Quality	The companies can assure the highest quality, because they can set the right temperature, give the perfect amount of water and the best nutrients. LED growing lights of a vertical farm are better than the High Pressure Sodium lamps the greenhouses are using, this ensures a higher quality for the vertical farm crops.

Table 3. Overview of the quality per subject.

Innovation

In the article of Bernroider (2002) they choose the variables ‘knowhow embedded in the company’ and ‘access to new technologies’ when looking at the innovation variable in the competitive advantage analysis. When looking at the Knowhow embedded in the company, a company should look at how much knowledge, in this case about the vertical farm, is present in the company.
Before creating the vertical farm Staay Food Group conducted numerous researches and started to work within a consortium, which is called Staay Vertical Farm, to get more knowledge embedded in the company. In the Philips GrowWise research centre, Philips is part of the consortium, there has been examined and proven that it would be possible for crops to grow without natural light and only use LED lighting (Staay Vertical Farm, 2018). Staay Vertical Farm also looked at which varieties of lettuce would be best suitable to

grow in a vertical farm, this research was conducted by Rijk Zwaan who is also part of the consortium (Staay Vertical Farm, 2018). By partnering up with different companies that have experience in different fields of knowledge Staay Vertical Farm ensures that there will be a lot of 'knowhow embedded in the company'. Another way to create enough 'knowhow embedded in the company' is to employ the right people like AeroFarms did. They created their company in 2004 and have since then employed people that have experience in different fields of knowledge. AeroFarm has a team of people that have expertise in "plant science, biology, engineering, data science, food safety, and nutrition" (AeroFarms, 2018). to ensure there was enough knowledge in the company to cultivate crops in a vertical farm and sell them in a profitable way.

When looking at the technologies a vertical farm is using that will create a competitive advantage over conventional farms and greenhouses, there should be looked at the LED lights, the use of aeroponics and the intelligent climate computers. First the LED lights, in 2015 Philips created new LED lights which they called the Greenpower LED. These LED lights are perfect for a vertical farm, because to its low heat radiation, the long-life span of the LED light and they are energy eficient. The LED lights has also different colours that a vertical farm could use to meat different growing requirements (Philips, 2015). Secondly the use of aeroponics has a lot of benefits over hydroponic systems that greenhouses use. A aeroponics system uses less water than a hydroponic system and also, when looking at the nutrition intake Alshrouf (2017) states that with the use of aeroponics the plants will absorb almost all the nutrients that are provided to them. Lastly, vertical farms use intelligent climate computers with which they can regulate lighting, temperature, irrigation and air humidity all while being energy efficient (Staay Vertical Farm, 2018).

These three technological innovations will give the vertical farm a competitive advantage, because these are resources a greenhouse and a conventional do not possess.

Knowhow embedded in the company	A vertical farm needs partners or employees that have a lot of knowledge in different fields of studies, AeroFarms has a team that has expertise in these fields: "plant science, biology, engineering, data science, food safety, and nutrition".
Technologies	The Greenpower LED lights from Philips (2015) can ensure the perfect crop. With aeroponics you can create more crops in an efficient way (Alshrouf, 2017). The intelligent climate computers keep an eye on everything, and so can ensure to create the best crop while being energy efficient (Staay Vertical Farm, 2018).

Table 4. Overview of the innovation per subject.

Customer responsiveness

In the article of Pehrsson (2014) about firm's customer responsiveness and performance, Pehrsson defines customer responsiveness as "an activity of market orientation". According to Deshpandé and Farley (1998) market orientation includes different cross-functional activities that can create superior value for the company's customers. Bernroider (2002) stated that when measuring the customer responsiveness there should be looked at the product diversity, price levels and customer satisfaction. Daugherty et al. (1992) found in their research that a company can achieve a competitive advantage if they realize the importance of understanding the needs of their customers. So, if a company has a good customer responsiveness this can be seen as a competitive advantage and thus as a strength. However, Daugherty et al. (1992) also found that when being customer responsive is jeopardizing the profitability of the firm then the customer responsiveness can be seen as a weakness.

First the product diversity will be discussed, there will be looked at the length and depth of the product mix to determine what the product diversity is of the vertical farm. The price levels will not be discussed in this chapter, but in chapter 6. Last there will be looked at the customer satisfaction. For the customer satisfaction the quality of the crops and other factors will be taken into account.

A product mix is the set of all products and items a particular seller offers. In this case it refers to all the products the vertical farm is selling. The product mix has a certain Length. When talking about the length of a product mix "this refers to the total number of items in the mix" (Kotler & Keller, 2012, p. 359). As an example, AeroFarms (2018) has 9 farms at the moment and has a total product mix length of 250 different varieties of leafy greens and herbs. At the moment, most greenhouses in the Netherlands are cultivating around 20 species of a vegetable (Bos, 2017). When comparing this to the statement of AeroFarms the product mix length of a vertical farm is way bigger, and this is thus a competitive advantage. However, not every vertical farm will have such a big product mix length as AeroFarms and then this will not be a competitive advantage.

Till now there has been no research done that looks at the customers satisfaction of crops from a vertical farm, in this case articles are used that look at customer satisfaction in general. Juhl et al. (2002) found that product quality is the most import driver for customer satisfaction. When the quality of a product is high there can be said that the customer satisfaction will also be high. In this research, there was concluded that the quality of a crop from a vertical farm is higher than a crop from a conventional farm, so the customer satisfaction will be higher with crops from a vertical farm. However, there should also be taken into account that the crops of a vertical farm will be expensive which will have a negative effect on the customer satisfaction, this will be further explained in chapter 6.1. According to AeroFarm (2018) they do have resources than can have a positive effect on the customer satisfaction. For instance, their diversity in products is a factor that has a positive effect on the customer satisfaction. Other big positive points of the products AeroFarm are that they are grown locally, grown with non-GMO seeds, they use less fertilizers, zero pesticides, herbicides, fungicides and overall are growing their crops in a durable way. Conner and Christy (2004) found that people will be willing to pay more money when they can avoid GMO's, bio solids and irradiation. This means that people find these factors important. Also, AeroFarm says that "Our greens have longer shelf life and the highest possible food safety controls from seed to package". All these factors ensure that their overall customer satisfaction will be high.

Thus, to conclude there can be said that there are various resources that create a positive customer responsiveness and thus give a competitive advantage.

Product diversity	AeroFarms (2018) has a big product mix length of 250 different varieties of leafy greens and herbs, against a product mix length of normally 20 species in a greenhouse.
Customer satisfaction	According to Juhl, Kirstensen and Østergaard (2002) quality is the most important driver for customer satisfaction. AeroFarm is growing locally, use non-GMO seeds, use less fertilizers, zero pesticides, herbicides, fungicides and overall are growing their crops in a durable way. Which also create a higher customer satisfaction.

Table 5. Overview of the customer responsiveness per subject.

5.2. Other

"In industrialized countries such as the United States, up to 20% of the fossil fuels used annually is for farming" (Despommier, 2011). When looking at the use of fossil fuel, a vertical farm uses far less than a conventional outdoor farm or greenhouse. Despommier (2011) states that a vertical farm uses little fossil fuels to harvest and transport their crops. According to Association for vertical farming (2015) food travels around 2400 and 4000 km from the farm to your plate. This distance is long, because a lot of the vegetables that are sold in supermarkets are imported from other countries, by boat, airplane or truck. With vertical farming the food will be grown locally in the city and in this way the food does not have to travel big distances. The vertical farm does not use fossil fuel powered tractors to harvest their crops so there will be less to none fossil fuel used during harvest. A greenhouse also does not use fossil fuel powered tractors,

but greenhouses are not build in the city, so the crops still need to be transported. When looking at the use of fossil fuel, a vertical farm is more sustainable then a conventional farm and a greenhouse.

5.3 Overview

In Figure 2 the strengths of the vertical farm are shown.

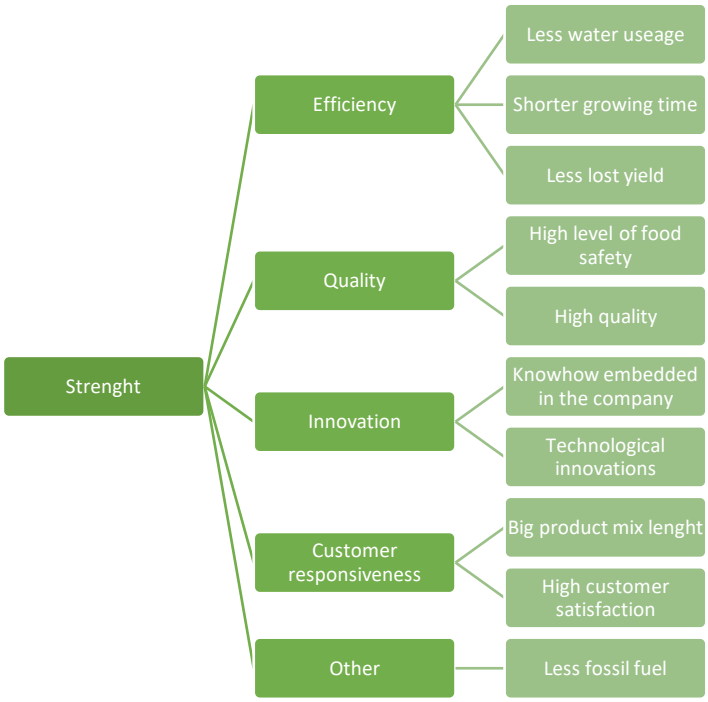

Figure 2, Overview of the Strengths.

6. Weaknesses

6.1. Competitive advantage and resource-based view

Customer responsiveness

In the strengths, the customer responsiveness is explained and there is stated which subjects of the customer responsiveness will be discussed in this SWOT analysis. A few of these subjects are labelled as a strength, there are also subjects that can be seen as a weakness. In this chapter, there will be looked at the small width of the product mix and the high price of the crops from the vertical farms will be discussed. The information of the prices come from Staay Food Group and AeroFarm.

The Length of the products mix has been explained in chapter 5., in this chapter the width of the product mix will be explained and discussed. The width of a product mix "refers to how many different products lines the company carries" (Kotler & Keller, 2012, p. 359). For the vertical farm a product line is for example lettuce or herbs. When looking at crops that are best suitable to grow in a vertical farm, you should think of crops that don't need to much space to grow. For example, lettuce, mushrooms or herbs are perfect crops for a vertical farm. There are also numerous crops that are not able or will be difficult to grow in a vertical farm. For example, fruits that come from trees will be difficult to grow in a vertical farm. At this moment AeroFarm, which is the biggest vertical farm that is selling its products, is growing a variety of lettuce and herbs. For Staay Vertical Farm this is the same. For now, there can be said that the width of the product mix narrow, because the vertical farms are mostly growing lettuce and herbs. Valstar (2018) is a company in the Westland that is specialized in cultivating greenhouse vegetables, they are cultivating 12 different types of vegetables and also a variety of fruits. So, when looking at the width of the product mix a greenhouse has at the moment a competitive advantage over a vertical farm.
The price of a product is determined by the total costs plus a desired profit margin. The high cost will be explained in depth later on. The total costs of a vertical farm are which automatically means that the profit margin will be high which will conclude in a high selling price. According to the Director of Staay Food Group the cost price of the cultivate lettuce will be two times as high as normal lettuce (Verbeek, 2017). This high price can put people off from buying these products. In a sense, the vertical farm is prizing itself out of the market, because the competitors have far lower prices. And according to Daugherty et al. (1992) in this case the customer responsive is jeopardizing the profitability of the vertical farm and thus the high costs can be seen as a weakness.

Product mix	A greenhouse has at the moment a competitive advantage over a vertical farm when looking at the width of a product mix, because Aerfarms is cultivating 2 different types of vegetables while Valstar cultivates around 12 different types of vegetables.
Price	According to the Director of Staay Food Group the cost price of the cultivate lettuce will be two times as high as normal lettuce (Verbeek, 2017)

Table 6. Overview of the customer responsiveness per subject.

6.2. Costs

The first cost driver that makes a vertical farm expensive is all the technology that is needed for a vertical farm to cultivate crops. The LED lights, the irrigation system, the water and nutrient reservoir, all the supporting racks that keep the vertical farm together, the climate control computer and all the equipment that ensures the right climate are all factors that make the building costs of a vertical farm expensive. To show how expensive a vertical farm could be, an example will be given where the building cost of the vertical farm of Staay Food Group will be compared with the building costs of a greenhouse. Staay Vertical

Farm will start building a vertical farm in Dronten which will have 3000 square meters of cultivation space. They estimated that their building costs will be around 8 million dollars in total for all the factors mentioned above and more. (Staay Food Group, 2018). According to Breukers et al. the building costs of a heated greenhouse in 2008 was around 55 euros per square meters, so for a greenhouse in the Netherlands of 3000 square meters the building cost would be around 165 thousand euro's. Looking at the numbers of this example there can be said that a vertical farm could cost around 48 times more than a greenhouse. In the building costs of the vertical farm of Staay Vertical Farm the cost of actually building a building are also taken into account and that is why the building cost will differ with other vertical farms. When looking at AeroFarms they are building their farms in vacant buildings, this means that the buildings cost will differ. When building a vertical farm in a vacant building, this does however not mean that the cost of buying or renting a vacant building in a city will be cheap. AeroFarms has at this moment a number of vertical farms, which are located in New York next to large distribution routes (AeroFarms, 2018). This placement is positive for the supply chain, but the land prices in a city are much higher than the land prices of farm land. In the USA, Farm land has an average price per hectare of 6091 (AG-WEB, 2015). When you compare this to the land prices of a big city, take for instance New York where AeroFarm is located, the land prices are almost 1700 times higher (Florida, 2017). In the Netherlands, the price of farm land is on average 50,000 euros per hectare (Künzel, 2014). Comparing this to our capital, Amsterdam, the land value per hectare is on average € 8.4 million euros, with a lowest average price of 5 million euro's and a highest average of 11,9 million euros per hectare (Gemeente Amsterdam, 2014). This means that the land price in Amsterdam are almost 170 times higher than farm land in the Netherlands. When comparing the prices of farm land to urban land prices there can be stated that the price of urban land is extremely expensive. The competitors of a vertical farm are growing their crops on farm land and so have far lower land costs as a vertical farm will have.

The second cost driver is the high amount of energy which is needed to grow crops in a vertical farm. Kozai et al. (2016) state that the LED lights are for around 70 to 80% accountable for the total energy costs, so this ensures that the LED lights are one of the most important aspect when looking at the energy use of a vertical farm. In comparison with HPS lamps the LED light have decreased the energy use drastically. There are different factors that ensure that LED light use less energy, overall the LED lights are less erngy demanding than HPS lights (Yeh & Chung, 2009). However, when looking at a vertical farm who does not use sunlight and is dependent on LED lights this is still seen as the main use of energy. There is stated that the energy costs are high, however there is no research done on whether a vertical farm uses less energy than a greenhouse. There can be said that the high amount of energy is a weakness, but there is no hard evidence that this will be a weakness without real numbers.

When the costs are high these will be compensated by a high selling price to create profit. This means that the competitors will have a competitive advantage over the vertical farm, because they have lower cost and thus have a lower selling price.

Building costs	According to the example explained above, the building costs of a vertical farm could be around 48 times higher than that of a greenhouse (Staay Food Group, 2018) (Breukers et al., 2018). In the USA the land prices in the city, for instance New York where AeroFarm is located, are almost 1700 times higher than land prices in the countryside. For the Netherlands the land price in Amsterdam is almost 170 times higher than farm land.
Energy costs	Kozai et al. (2016) state that the LED lights are for around 70 to 80% accountable for the total energy. However, there are no numbers of vertical farms to set off against a greenhouse to see whether a greenhouse or vertical farm uses more energy

Table 7. Overview of the costs per subject.

6.3. Overview

In Figure 3 the weaknesses of the vertical farm are shown.

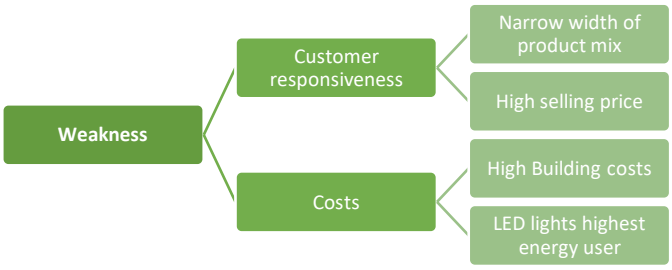

Figure 3, Overview of the Weaknesses.

7. Opportunities

7.1. PESTLE Analysis

Political

For the topic Political, you should think of government policies, changes in power/influence that will have a favourable effect on the vertical farm. In the Netherlands, there is a subsidy that can be given by the regions and the government with the aim to stimulate innovations in small and medium sized enterprises. This subsidy is called Mkb-innovation stimulation Region and Top Sectors (MIT), Mkb stands for small and medium sized business (Mkb-innovatiestimulering Regio en Topsectoren (MIT),2018). In December 2017 a company in the province of South-Holland, the Netherlands, got this MIT subsidy to develop a vertical farm (van Achter, 2017). Without this subsidy, it would have been really difficult for the company to get enough money to develop the vertical farm. When the government will give out more a subsidies for creating vertical farm, this could be a big positive trend for the vertical farm.

Economic

For the topic economic, you should think of any favourable economic change or new economic opportunities like selling opportunities or new markets. When looking at selling opportunities for the vertical farm Ernst et al. (2006) found that when they asked people about the most important characteristics to purchase food (in this research locally grown berries), the results stated that taste/quality was the most important characteristic after price. As stated in the strengths, the quality and taste of a crop from a vertical farm is higher than that of a greenhouse and conventional farm. Conner et al. (2009) found that people are also willing to pay more for locally grown food. They found that 49% of the people that were questioned are willing to pay 3 dollars for locally grown food. 19% is even willing to pay more than 3 dollars for locally grown food in comparison to food that needs to travel more miles from farm to supermarket. Looking at AeroFarms they are growing their crops in the city and the crops have a high quality, so this could be seen as selling opportunities. Conner and Christy (2004) found results in their research that could also state that people will be willing to pay for crops grown in a vertical farm. They found that customers are willing to pay more money when they can avoid GMO's, bio solids and irradiation. A vertical farm is not using the GMO's, bio solids or irradiation, and so there can be said that customers would be willing to pay more for crops from a vertical farm. This, because the crops are grown locally and in a durable way have a higher level of food safety are better tasting and have a higher quality than crops from a greenhouse or conventional farms.

Another economic opportunity for the vertical farm is a niche market where the vertical farm can focus on. The niche market of master chefs is interested in the products of a vertical farm. The Growx company in Amsterdam are for instance focussing on this niche market, because the chefs are looking for something special (Spoelman, J. ,2016). They want their greens to be fresh, with minimal time between harvest and plate and with a customized taste. In a vertical farm, it is possible to create arugula that is spicy. The LED lights used in a vertical farm can influence the plants morphology and taste (Yeh & Chung, 2009). The plant morphology refers to the external structure of the crop. In 2017 a research was conducted in which they examined the effect of different light ratios on two lettuce variations, they found that spicy lettuce can be grown using blue light (Yelton & Ohzourk, 2017). This makes the products from a vertical farm attractive for the master chefs, because you can adjust the taste and morphology to their liking.

Another economic opportunity can come from funding by large companies or investors. In 2017 Plenty, which is a vertical farming start-up in the USA, has raised over 200-million-dollar investment to create a 100,000-square foot vertical farm in Seattle (Garfield, 2017a). This will be their second vertical farm which will start production in 2018. According to experts these investments could help the whole vertical farming

industry. Dickon's Despommier also said that these investments could make vertical farming more ordinary and can also encourage other investors to invest in vertical farming (Garfield, 2017b).

Social

For the topic social, you should think of favourable behavioural patterns towards the products or company, but also if there are any opportunities for the company to help the community. A vertical farm could be used to educate children on farming, but also the vertical farm on its own could help the community. When a school would build a vertical farm on top of the school it could not only teach children about farming, but also produce their own food for the school. In Amsterdam, there are promoters for this idea, they have created the A Lab (A Lab, 2017). They are curious how children will perceive the food production in a vertical farm, whether it will be accepted and if it makes them more aware of where their food comes from (Hetkanwel.net, 2017).

A positive social trend that can also be an opportunity for the vertical farm is a life style trend. An example of a life style trend is "Going vegan", which means that you do not eat any meat or fish and also no products that come from animals like eggs or milk. Just Eat, a food delivery service in 15 countries, saw a 33 percent raise in vegan option of its partner restaurants which also means that more people are eating vegan (Rise Of The Vegan, 2018). This also means that people are eating more vegetables, and this can be an opportunity for the vertical farm to sell their vegetables to vegans. The crops from a vertical farm are grown with no pesticides, herbicides and fungicides which assures that the crops have a higher level of food safety this is important for vegan's. Some vertical farm already have a vegan certificated in America when they are not using animal manure, or animal by products (Lampert,2016).

Technological

For the topic technological, you can think of innovations, changes in technology usage that could help the vertical farm. In the agricultural sector, technological change is a major driver and thus technological changes can create great opportunities. For the vertical farm a positive trend and thus an opportunity can come from new technological developments of the GreenPower LED from Philips (2015). Philips is still conducting research and doing experiments to optimize their GreenPower LED lights and stay ahead of the competitors. According to Ed Harwood from AeroFarms (2018) Lighting is the most important decision when building a vertical farm. He stated that vertical farms could become more efficient and sustainable when lighting will be optimized (Nijs, 2016). So, there is a positive trend if we look at the technology for the vertical farm.

Legal

For the topic legal, there can be looked at upcoming legislation or treaties and international agreements that can create a positive trend. There are at the moment no laws that specially mention the vertical farm, so for now there is a big chance that the vertical farm will legally be seen the same as a greenhouse. This could be positive for the vertical farm, because in many ways the vertical farm outperforms greenhouses. For example, on January 1 2018 a new law in the Netherlands obligates all greenhouses to purge their wastewater to get rid of protection agents (Rijksoverheid, 2017). Greenhouses need to spend money on purge systems to comply with the law, a vertical farm does not use protection agents so this law will not affect the vertical farm. There are also laws that state that greenhouses have a maximum CO2 emission, which will also have no effect on the vertical farm. The high efficiency and low CO2 emission of the vertical farm ensure that CO2 emission related laws have no effect on the vertical farm. This means that the vertical farm has at the moment nothing to worry about when looking at legislation concerning climate change. The fact that the laws are not creating a boundary for the vertical farm can be seen as an opportunity, because this means that there is no barrier for the vertical farm to grow.

Environmental

For the topic environmental, you should think of what the vertical farm can do for the environment. Circular economy is a big topic at the moment and can be a positive trend for the vertical farm. A vertical farm can become a circular economy when it will reuse its input resources and can ensure that these input resources won't turn into waste (Macarthur, 2012). During the annual summit of the Association of the vertical farming in 2016 the circular economy theme was the main topic. Jose Ruiz form the European Commission's Agricultural and Rural Development Department, said this about the circular economy: "A whole new sector needs to be developed, which provides chances for new industries and platforms, and vertical farming is one of them (Nijs, 2016)."

There are at this moment not yet circular economy vertical farms, there are however already vertical farms that are energy efficient. Metropolis farms in the USA has built the first vertical farm that is completely solar-powered and is thus reducing its carbon footprint (Foodable Network, 2016). Metropolis farms built a massive solar array in Philadelphia which can generate over half a megawatt of energy with which they can power their vertical farms (Metropolis Farms, 2017). When more farms will follow the energy efficient way of Metropolis farms this could be a big positive trend for the vertical farm to become more sustainable.

7.2. Overview

In Figure 4 the opportunities of the vertical farm are shown.

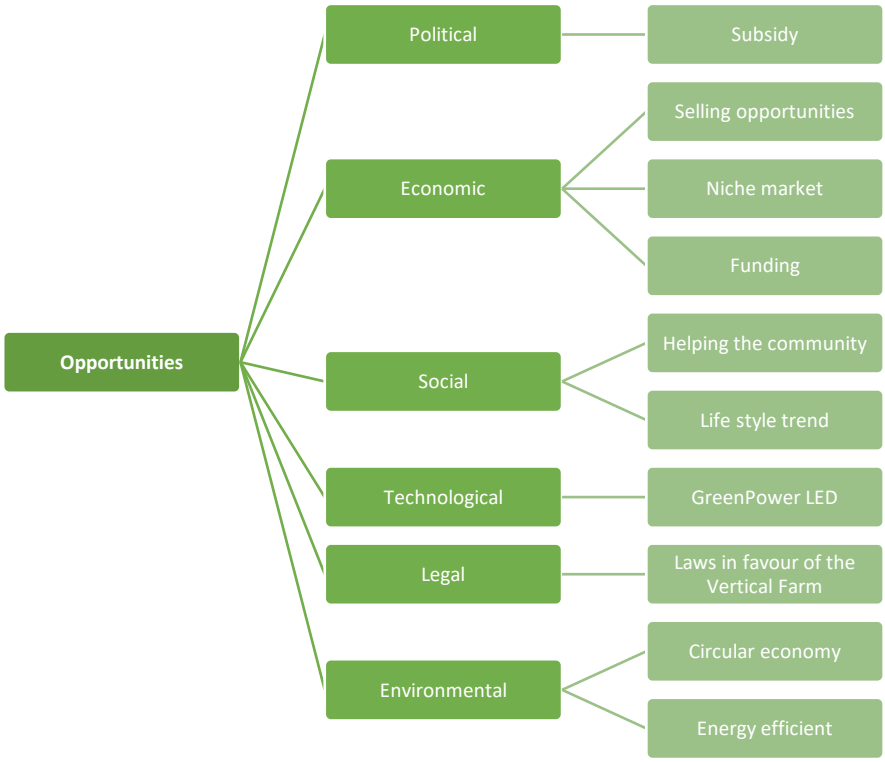

Figure 4, Overview of the Opportunities.

8. Threats

8.1. PESTLE Analysis

Political

For the topic Political, you could think of government policies, changes in power/influence that will create a negative trend for the vertical farm. When looking at a vertical farm a big positive point of the vertical farm is that it can reduce the supply chain and thus use less fossil fuel, by building farms in the city centre. However, there is a possibility that the government is not too keen with the idea to build these vertical farms in the city in old company building, because of the urban development plan. In an urban development plan the development and design of land use in a city are stated. At the moment vertical farm are not specifically mentioned in urban development plans. If the government does not allow vertical farms to be developed or put constraints on future growth this will form a threat.

Another threat for the vertical farm could come from lobbying by the agriculture sector. They can for instance influence the government, via social media or the press, to create policies, undertake action or make decisions that will be against the vertical farm. They can see the vertical farm as a threat for their conventional farmers and greenhouses and that is why they would want to eliminate this threat by lobbying.

Economic

For the topic economic, you should think of any negative economic change. For instance, new competitors and difficulties with selling your product. When looking at the vertical farms that are selling their products in the supermarket, there is a lot of competition. The crops of the vertical farm have a higher quality which is a competitive advantage, but the crops from the greenhouses are cheaper and this creates a competitive advantaged for the greenhouses. However, when the greenhouses will start using the same technology and create the same high quality crop this will create a big threat for the vertical farm, because then they will have no competitive advantage over the greenhouses.

In chapter 7.1 selling opportunities are mentioned, but none of these articles that are used are based on crops from a vertical farm. This means that there is no clear evidence that states that there will be enough selling opportunities for a vertical farm. As there is no clear evidence that customers would pay more for crops of a vertical farm this could be a threat. In the research of Chalabi (2015) the high selling price is seen a weakness for the vertical farm. When the people are not willing to pay the high price, the vertical farm will not be profitable, and this will be an economic threat for the vertical farm.

Social

For the topic social, there should be looked for behavioural patterns against the products or company, but also if there are any threats coming from the community. According to some, the vertical farm will also experience a social barrier. Chalabi (2015) states that many customers could perceive growing crops in a vertical farm as ‘food made from chemicals’ and ‘not natural,’ and so this can be a barrier for customers to buy the crops from the vertical farm. When people won’t buy the crops of a vertical farm because of this social barrier this could be a threat for the vertical farm.

Another social threat could come from the agricultural labour union. The agricultural labour union represents farm workers in a number of agricultural sectors the question is will the labour union also be there for the vertical farm. The high-quality crops of the vertical farm, can give the vertical farm such a strong competitive advantage that the greenhouses will lose customers and there is even a possibility that they will eventually go bankrupt. The greenhouses that cannot or will not adopt to the innovative technology need to find other ways to create a high quality crop if they want to keep competing with the

vertical farms. When the greenhouses are not able to create the high quality, they could go bankrupt and leave room for the vertical farm to expand. If this will starts happening it could be possible that the labour union would want to stop this and will be against the vertical farm. The agricultural labour union consist of people that are employed in the agricultural sector, so when the trade union will turn against the vertical farm this means that a large social group will be against the vertical farm. This can form a great threat for the vertical farm.

Technological

For the topic technological, you can think of innovations, changes in technology usage that could be negative for the vertical farm. Nanotechnology could become a technological threat for the vertical farm, because this technological development could be used in greenhouses and can create a competitive advantage for the greenhouses. According to Van der Horst from the research institute ''Wageningen Food & Biobased Research' intelligent robots and other post-harvest technologies could ensure that the shelf life of fruit and vegetables is optimized (van Huijgevoort, 2016). This Institute is focused on developing intelligent robots, post-harvest technologies and other innovative technologies that could ensure freshness of fruits and vegetable. According to Sekhon (2014) nanotechnology could play an important role in agriculture and food sector. With nanotechnology farmers could creating crops with different tastes and textures and ensure higher efficiency by create crops that will use pesticides, fertilizers and water more efficiently (Sekhon, 2014). When nanotechnology will be used more commonly this could be an enormous threat for the vertical farm, because then the vertical farm could lose several competitive advantages to greenhouses.

Legal

For the topic legal, there can be looked at legislation, treaties and international agreements that can form a threat for the vertical farm. When looking at the legislation which is also mentioned in chapter 7.1.5. there are at this moment no laws for the vertical farm, so when laws, negative or positive, will be made and implemented this will have a great impact on the vertical farm. When the government decides that the vertical farm is threatening the conventional farmers and greenhouses, they can create laws that will be a threat for the vertical farm. For instance, when they create laws that stated that city land is not used for farming or when they decide that you need a special permit to build a vertical farm and make it difficult to obtain this permit. All laws and other legal actions can create a threat for the vertical farms.

Environmental

For the topic environmental, you should think of pollution by the vertical farm and also landscape/ visual pollution. A potential environmental threat for the vertical farm could be visual pollution. When the number of vertical farms in the cities start to grow, there is a possibility that the already existing vacant buildings will no longer be vacant. This means that there will be new high-rise buildings built for vertical farms. These high-rise vertical farms are then creating visual pollution, which impairs the view of people living in the city.

8.2. Overview

In Figure 5 the threats of the vertical farm are shown.

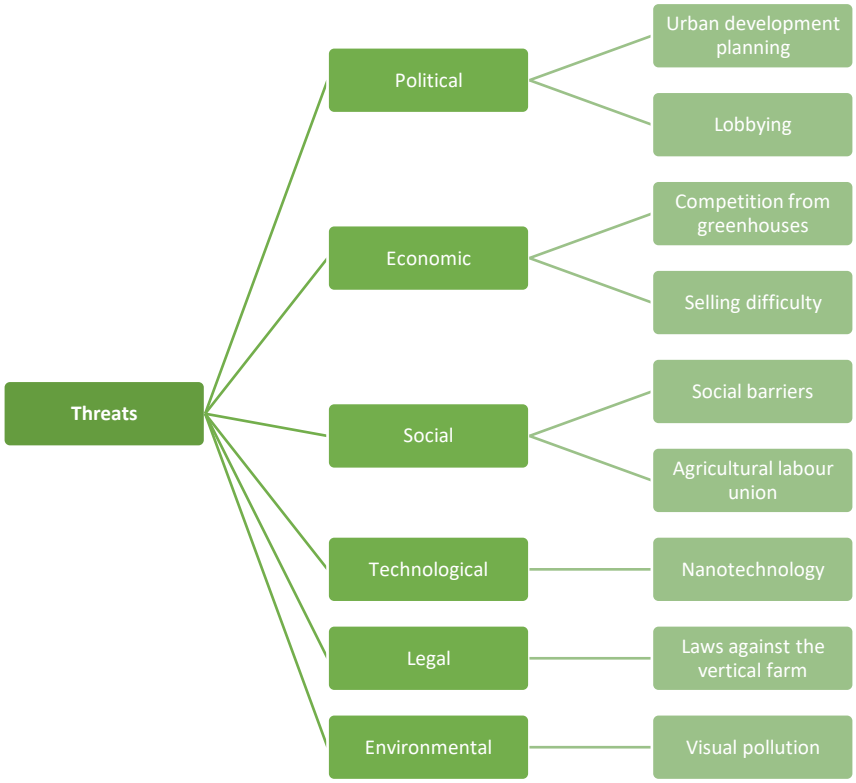

Figure 5, Overview of the Threats.

9. Conclusion

This study sought to answer the question: “What are the most promising opportunities and most dangerous threats for the vertical farm?”. This research looked at the strength, weaknesses, opportunities and threats of a vertical farm. The high efficiency, the high quality, the innovative technology and the high costs are the most recurrent themes in the strengths, weaknesses, opportunities and threats of the vertical farm. Many opportunities and threats have been found during this research and in this chapter the most promising opportunities and the most dangerous threats for the vertical farm will be discussed.

This SWOT analysis showed that there are different factors that create a competitive advantage for the vertical farm over a greenhouse and conventional farming which have the potential to maximize opportunities. These are the two most promising opportunities:
The first opportunity for the vertical farm is the environmental opportunity, which is when the vertical farm can become a circular economy and become energy efficient. The high efficiency created by the technology used in a vertical farm is a competitive advantage and could maximize the environmental opportunity. If the vertical farm keeps enhancing their innovative technology, the vertical farm has the potential to become energy efficient and a circular economy. In this way the strength of the vertical farm could maximize the environmental opportunity for the vertical farm to become a circular economy. Becoming a circular economy and be energy efficient will be important for companies, because in this way the vertical farm can reduce greenhouse gas emissions.
The second opportunity for the vertical farm is the economic opportunity, which are new market opportunities. The high quality of the crops and the higher level of food safety are a competitive advantage and could be used to maximize opportunities. The high quality of the crops from a vertical farm could open up new market opportunities. For example, culinary restaurants want the best ingredients a vertical farm can ensure the best quality and can even adjust the taste and texture of crops to wishes of the chefs. The higher level of food safety is created by using no pesticides, herbicides or fungicides. Greenhouses are still using pesticide and so their crops have a lower level of food safety then crops from a vertical farm, which can also open up new market opportunities. So, when looking at the strength high quality of the crops and the higher level of food safety these can be used to maximize the market opportunities of the vertical farm.

This SWOT analysis also showed that there are different factors that could make it difficult for the vertical farm. When looking at the threats of the vertical farm, we looked at all external factors that could make the future of the vertical farm uncertain. The vertical farm can use its strengths and opportunities to minimize or even eliminate their threats. There are three most dangerous threats:
The first threat is the technological threat, which is when nanotechnology will be applied in greenhouses. At the moment researchers are experimenting with nanotechnology in greenhouses, with nanotechnology you could improve taste, texture, shelf life and reduce the lost yield. When greenhouses would start using this technology this could eliminate the high quality competitive advantage of the vertical farm. To eliminate this threat the vertical farm needs to improve their technology and also create a higher quality. At the moment Philips is constantly improving their LED lighting so there is a chance you will stay in front of the competition by having the best quality. There is the possibility for the vertical farm to also use nanotechnology, however there has only been tests with nanotechnology in greenhouses so there is no guaranty that it will also work for vertical farms.
The second threat is the social and economic threat, which are the social barrier when the crops are perceived as non-natural, and the economic barrier if people would want to pay more for the crops of a vertical farm. There has been no research done on these two threats, so there is not known if people would be willing to pay more for these crops and if people would perceive these crops different than crops from

a greenhouse. When these threats become reality, it will be difficult for the vertical farm to sell crops and stay profitable. So, it is important for the vertical farm to show people that crops from a vertical farm are safe and have a high quality, before people think otherwise. This can be done by advertising and using these strengths to stimulate people to form positive opinions towards the vertical farm and so you could eliminate these threats. For example, Staay Vertical Farm (2018) has created a package for their lettuce which mentioned the 'Premium quality', the low energy use, the low water usages and no use of pesticides in this way they make the customer aware of the strength of the vertical farm.
The last threat is the political threat, which is the urban development planning. In an urban development plan the development and design of land use in a city are stated. At the moment, vertical farms are not specially mention in urban development plans. If the government does not allow vertical farms to be developed or put constraints on future growth this will form a threat. To eliminate this threat the vertical farm needs to show the government the advantages of the vertical farms opposite from a greenhouse so that they can get government clearance.

Below the TOWS matrix is shown with different strategies that use strengths to maximize opportunities, use strengths to minimize threats, minimize weaknesses by taking advantage of opportunities and strategies that minimize weaknesses and avoid threats. These strategies are based on the outcomes of this SWOT analysis.

TOWS matrix	**External Opportunities (O)** 1. Political Subsidy's 2. Economic Selling opportunities Niche market Funding 3. Social Helping the community Life style trends 4. Technological GreenPower LED 5. Legal Laws in favour of the vertical farm 6. Environmental Circular economy Energy efficient	**External Threats (T)** 1. Political Urban development planning Lobbying 2. Economic Competition from greenhouses Selling difficulties 3. Social Social barriers Agricultural labour union 4. Technological Nanotechnology 5. Legal Laws against the vertical farm 6. Environmental Visual pollution
Internal Strengths (S) 1. High efficiency Less water usage Shorter growing time Less lost income 2. Quality High quality High level of food safety 3. Innovation High Knowhow embedded in the company High-end technologies 4. Consumer responsiveness Big product mix length 5. Other Less fossil fuels	SO - Further enhance technologies to create a circular economy. - Advertising with the high quality and the high level of food safety as most important factor to open up niche markets.	ST - Staying in front of the competition by constantly improving the quality of the crops. - Using advertisement to show people why these crops have a higher level of food safety and have a higher quality, this could lower the social barrier. - Making the government aware of the advantages of the vertical farm to get political clearance.
Internal Weaknesses (W) 1. Customer responsiveness Narrow product mix width. High selling price 2. Costs High building costs LED lights highest energy user	WO - Stimulate the government to grant subsidy's and so lower the costs and high selling price - Widening the width of the product mix which will create market opportunities.	WT - Minimizing cost will lower the selling price and could ensure a better market position.

Table 8. The TOWS matrix of the vertical farm

10. Discussion

A limitation of this article is that the opportunities and threats are for a part based on speculations. When looking for opportunities and threats you will always have some speculation, because opportunities and threats are uncertain. However, the opportunities and threats that are named in the chapters are partially based on scientific articles and on other comparable SWOT analysis's. None of these opportunities and threats are according to our opinion far-fetched and thus are all able to occur.

Another limitation is that a few of the subjects discussed in the SWOT analysis are not explained in dept. For example, the high costs are mentioned and the factors that ensure these high cost, but there is not looked at the cost of the factors separately. For this research a lot of subjects are mentioned and discussed that there was chosen to not go to in depth with all of the subjects.

The vertical farm is in its early state, leaving many questions unanswered and many open gaps in our current level of knowledge. The last limitation is that there are at the moment not that many scientific articles on the vertical farm. This has ensured that on a few subjects in this SWOT analysis no scientific literature on the vertical farm was used, because there was none. However, this was replaced by using information from existing vertical farms. After this SWOT analysis there are still important areas that need more research to overcome the knowledge gap.

Areas that need to be examined are;

- The profitable of the vertical farm.
- If there is an economic barrier.
- If there is a social barrier.
- A cost analysis of the vertical farm.
- A sustainability analysis of the vertical farm.

These areas where chosen to explain, this does not mean that other areas don't need research.
A research that needs to be done is if a vertical farm is profitable, in this research there should also be investigated if there is an economic barrier and or a social barrier. It will be crucial for the vertical farm to know if there will be barrier, because when people are not willing to pay for crops from a vertical farm, the vertical farm will never be profitable.
A cost analysis needs to be carried out to give a clear overview of the costs. There is at the moment no clear overview of where the building costs are coming from and what the weekly/monthly or even yearly costs will be. This would also be useful information to use in a profitability analysis.
At last, a research that needs to be done to create more knowledge on the vertical farm is how much more sustainable a vertical farm actually is opposite to a greenhouse. At this moment, there is know that a vertical use less CO2, water and no pesticides. However, there are no clear numbers on the sustainability of a vertical farm, real numbers of the CO2 reduction and energy use are missing.

At this moment, there is no other article that conducted a in depth SWOT analysis of the vertical farm. There are articles that discuss the advantages/strengths of the vertical farm but are not as profound as this one. The of Despommier (2013) which discusses the advantages of vertical farm is used as comparison. Despommier mentions that a vertical farm uses less water than a conventional farm, but

he does not mention how and why. He also does not take the greenhouses into account but looks only at conventional farming. In this SWOT analysis the greenhouses are taken into account and the strength and weaknesses are supported with numbers from different researches. This article also explains how and why a vertical farm uses less water for example, which ensures that this article differs from the article of Despommier and is thus an addition to the existing literature.

Overall, when looking at most promising opportunities and the most dangerous threats, it will be crucial for the vertical farm to use its strengths to maximize its opportunities and minimize its threats. When the vertical farm can manage this there is a possibility that the vertical farm could become the answer in the future.

11. References:

AeroFarms (2018). Retrieved from: http://aerofarms.com

Agri Holland. (2018). *Innovatieve kasconcepten*. Retrieved may 21, 2018, from: https://www.agriholland.nl/dossiers/kassenbouw/toekomstkassenbouw.html

AG-WEB (2015). *Farmland Value Guide*. USDA. Retrieved January 24, 2018, from: https://www.agweb.com/land/farmland-value-guide/

A Lab, (2017, June 30) Did you know that we are opening an A Lab Vertical Farm? Retrieved February 2, 2018, from https://www.a-lab.nl/events/opening-lab-vertical-farm

AlShrouf, A. (2017). *Hydroponics, aeroponic and aquaponic as compared with conventional farming*. American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS), 27(1), 247-255. Retrieved from: http://asrjetsjournal.org/index.php/American_Scientific_Journal/article/viewFile/2543/1028

Al-Chalabi, M. (2015). *Vertical farming: Skyscraper sustainability?* Sustainable Cities and Society, 18, 74-77. Retrieved from: http://www.sciencedirect.com/science/article/pii/S2210670715000700

Aslan, I., Çınar, O., & Kumpikaitė, V. (2012). *Creating strategies from tows matrix for strategic sustainable development of Kipaş Group*. Journal of Business Economics and Management, 13, 95-110. Retrieved from: http://www.tandfonline.com.ezproxy.library.wur.nl/doi/abs/10.3846/16111699.2011.620134

Association for vertical farming (2015). *That's good food sense: A look at horizontal (conventional) farming and vertical farming*. Retrieved from: http://www.urbanorganicgardener.com/wp-content/uploads/2016/12/FoodSense_infographic_090615rev_AVF_FNL.png

Barney, J. (1991). *Firm resources and sustained competitive advantage.* Journal of management, 17, 99-120. Retrieved from: https://www.business.illinois.edu/josephm/BA545_Fall%202011/S10/Barney%20%281991%29.pdf

Barney, J. B., & Arikan, A. M. (2001). *The resource-based view: Origins and implications.* Handbook of strategic management. Retrieved from: https://c5c4a0c5-a-62cb3a1a-s-sites.googlegroups.com/site/hyoungkang/mnc/BarneyTheResource-basedView.pdf?attachauth=ANoY7cq0OEC8guPZraFohHzP4EhjbxZwaxm1aFnc6NuQsOiyZeCNmDfJkXhJEwhcWSrkSPNqtWX7mo6AakeTgxyy_e4BEx-J1ZltljJk59-LZAzgLaD-4n8AzxRlkkv5sStxRkjbJoHJoXK4BHghqGS4vcmQB23KR3ekek9vuUJHMGV9y9S-XvatVBXhpoi48fddYsKwcdBeIkf9hst7fypoKPxlrd-Radu7BE0dX8IKN4KjkxynwQ0%3D&attredirects=1

Bernroider, E. (2002). *Factors in SWOT Analysis Applied to Micro, Small-to-Medium, and Large Software Enterprises: an Austrian Study*. European Management Journal, 20(5), 563-573. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0263237302000956

Bos, E. (2017) *Urban greenhouses in The Netherlandsto 'feed' the city and its citizens*. Wageningen University Research. Retrieved from: http://edepot.wur.nl/424608

Breukers, A., Hietbrink, O., & Ruijs, M. N. A. (2008). *The power of Dutch greenhouse vegetable horticulture: An analysis of the private sector and its institutional framework*. LEI Wageningen UR. Retreived from: http://edepot.wur.nl/27928

Bravo-Ureta, B. E., & Evenson, R. E. (1994). *Efficiency in agricultural production: the case of peasant farmers in eastern Paraguay.* Agricultural economics, 10(1), 27-37. Retrieved from: https://ac-els-cdn-com.ezproxy.library.wur.nl/016951509490037X/1-s2.0-016951509490037X-main.pdf?_tid=6776f4cc-0508-11e8-925f-00000aacb35e&acdnat=1517239609_39bc7b308476aae6a7725ac51d0beb42

Buckseth, T., Sharma, A. K., Pandey, K. K., Singh, B. P., & Muthurajc, R. (2016). *Methods of pre-basic seed potato production with special reference to aeroponics—A review*. Scientia Horticulturae, 204, 79-87. Retrieved from: http://www.sciencedirect.com.ezproxy.library.wur.nl/science/article/pii/S0304423816301601?_rdoc=1&_fmt=high&_origin=gateway&_docanchor=&md5=b8429449ccfc9c30159a5f9aeaa92ffb&ccp=y

Carvalho, F. P. (2017). *Pesticides, environment, and food safety*. Food and Energy Security, 6(2), 48-60. Retrieved from: https://onlinelibrary.wiley.com/doi/epdf/10.1002/fes3.108

Chang, J. (2017). *Helping a food desert flourish*. Specialty food magazine. Retrieved july 4, 2017, from: http://specialtyfoodmagazine.epubxp.com/i/838473-summer-2017

Conner, D., Christy, R. (2004). *The organic label: how to reconcile its meaning with consumer preferences*. Journal of Food Distribution Research, 35, 40–43. Retrieved form: http://ageconsearch.umn.edu/record/27135/files/35010040.pdf

Conner, D. S., Montri, A. D., Montri, D. N., & Hamm, M. W. (2009). *Consumer demand for local produce at extended season farmers' markets: guiding farmer marketing strategies*. Renewable Agriculture and Food Systems., 24 (4), 251-259. Retrieved from: https://www-cambridge-org.ezproxy.library.wur.nl/core/services/aop-cambridge-core/content/view/AD0E690FF78B16C5B04A151D26F9BA21/S1742170509990044a.pdf/consumer_demand_for_local_produce_at_extended_season_farmers_markets_guiding_farmer_marketing_strategies.pdf

Daugherty, P. J., Sabath, R. E., & Rogers, D. S. (1992). *Competitive advantage through customer responsiveness*. Logistics and Transportation Review, 28(3), 257. Retrieved from: https://search.proquest.com/docview/197444558?pq-origsite=gscholar

Deshpandé, R. and Farley, J.U. (1998). *Measuring market orientation generalization and synthesis.* Journal of Market-Focused Management, 2 (3), 213-232. Retrieved from: https://link-springer-com.ezproxy.library.wur.nl/content/pdf/10.1023%2FA%3A1009719615327.pdf

Despommier, D. (2009). *The rise of vertical farms.* Scientific American, 301(5), 80-87. Retrieved from: http://www.westfield.ma.edu/uploads/cbraun/verticalfarming.pdf

Despommier, D. (2011) *The vertical farm: controlled environment agriculture carried out in tall buildings would create greater food safety and security for large urban populations.* Journal für Verbraucherschutz und Lebensmittelsicherheit, 6, 233-236. Retrieved from: http://link.springer.com.ezproxy.library.wur.nl/article/10.1007%2Fs00003-010-0654-3

Despommier, D. (2013, June 19). *Farming up the city: the rise of urban vertical farms*. Trends in biotechnology, 31, 388-389. Retrieved from: http://www.sciencedirect.com.ezproxy.library.wur.nl/science/article/pii/S016777991300070X

Erfgoedhuis-ZH. (2017) Retrieved June 7, 2017, from: https://www.geschiedenisvanzuidholland.nl/locatie/geschiedenis-westland

Ernst, S., Batte, M. T., Darby, K., & Worley, T. (2006). *What matters in consumer berry preferences: price? Source? Quality?* Journal of Food Distribution Research, 37(1), 68. Retrieved from: https://www.researchgate.net/profile/Stan_Ernst/publication/23944135_What_Matters_in_Consumer_Berry_Preferences_Price_Source_Quality/links/0912f50ae6b71f4214000000.pdf

Florida, R., (2017). *The Staggering Value of Urban Land*. CITYLAB. Retrieved January 24, 2018, from: https://www.citylab.com/equity/2017/11/the-staggering-value-of-urban-land/544706/

Foodable Network. (2016). *America's First Vegan-Certified Vertical Farm Leaps Into the Future of Agriculture.* Retrieved 26 February 2018, from: https://www.foodabletv.com/blog/2016/11/2/vertical-farming-making-leaps-into-our-future-agriculture

Fozer, D., Sziraky, F. Z., Racz, L., Nagy, T., Tarjani, A. J., Toth, A. J., ... & Mizsey, P. (2017). *Life cycle, PESTLE and Multi-Criteria Decision Analysis of CCS process alternatives*. Journal of Cleaner Production, 147, 75-85. Retrieved from: http://www.sciencedirect.com.ezproxy.library.wur.nl/science/article/pii/S095965261730063X?_rdoc=1&_fmt=high&_origin=gateway&_docanchor=&md5=b8429449ccfc9c30159a5f9aeaa92ffb

Freight Farms (2017). *Data from our growers: how the LGM stacks up*. Retrieved December 9, 2017, from: https://www.freightfarms.com/blog/data-from-our-growers-how-the-lgm-stacks-up

Garfield, L. (2017a). *A new Jeff Bezos-backed warehouse farm will grow enough produce to feed over 180,000 people per year.* Business Insider. Retrieved February 22, 2018, from: https://www.businessinsider.nl/vertical-farming-company-plenty-investment-second-farm-seattle-2017-11/?international=true&r=US

Garfield, L. (2017b). Investors are sinking hundreds of millions into a technology that could revolutionize the way we eat. Business Insider. Retrieved February 22, 2018, from: https://www.businessinsider.nl/food-investment-vertical-farming-2017-8/?international=true&r=US

Gemeente Amsterdam. (2014). *Grondprijzenbrief 2015*. Retrieved from: https://www.amsterdam.nl/wonen-leefomgeving/erfpacht/grondprijzenbrief/

Green, J. (2009). *Interview with Dickson Despommier, professor, Colombia University*. Retrieved from: https://www.asla.org/ContentDetail.aspx?id=22548

Hussey, D. (2001). *Creative strategic thinking and the analytical process: critical factors for strategic success.* Strategic Change, 10, 201-213. Retrieved from: http://onlinelibrary.wiley.com.ezproxy.library.wur.nl/doi/10.1002/jsc.537/epdf

Juhl, H. J., Kristensen, K., & Østergaard, P. (2002). *Customer satisfaction in European food retailing*. Journal of Retailing and Consumer Services, 9(6), 327-334. Retrieved from: http://www.sciencedirect.com.ezproxy.library.wur.nl/science/article/pii/S0969698902000140?_rdoc=1&_fmt=high&_origin=gateway&_docanchor=&md5=b8429449ccfc9c30159a5f9aeaa92ffb

Kotler, P., & Keller, K. L. (2012). *Marketing management* (14th ed.). Harlow, United Kingdom: Pearson Education.

Künzel, T. (2014) *EU farmland: The costs country-by-country*. Agribusiness. Retrieved from: http://www.agrifuture.net/fileadmin/agrifuture/binary/14_summer/16_17_af0214.pdf

Lampert, E. (2016). *These guys are responsible for the first vegan, hydroponic, vertical farm*. Ecorazzi.com. Retrieved 22 February 2018, from: http://www.ecorazzi.com/2016/03/01/these-guys-are-responsible-for-the-first-vegan-hydroponic-vertical-farm/

Macarthur, E. (2012). *Towards the circular economy*. Circular foundation. Retrieved 26 February 2018, from: http://circularfoundation.org/sites/default/files/tce_report1_2012.pdf

Martinez, V. (2018). *Re-utilisation of drainage solution from soilless culture in protected agriculture.* Life drainuse. Retrieved from: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=5283&docType=pdf

Mendelsohn, R. (2007). *What causes crop failure*? Climatic Change, 81, 61-70. Retrieved from: https://link-springer-com.ezproxy.library.wur.nl/content/pdf/10.1007%2Fs10584-005-9009-y.pdf

Metropolis Farms. (2017). *Metropolis Agricultural Technology*. Retrieved February 26, 2018, from: https://www.metropolisfarmsusa.com/technology

Moreau, P., Ruiz, L., Mabon, F., Raimbault, T., Durand, P., Delaby, L., . . . Vertès, F. (2012). *Reconciling technical, economic and environmental efficiency of farming systems in vulnerable areas*. Agriculture, Ecosystems & Environment, 147, 89-99. Retrieved from: https://www-sciencedirect-com.ezproxy.library.wur.nl/science/article/pii/S0167880911001964?_rdoc=1&_fmt=high&_origin=gateway&_docanchor=&md5=b8429449ccfc9c30159a5f9aeaa92ffb&ccp=y#bib0090

Mkb-innovatiestimulering Regio en Topsectoren (MIT), (2018). Rvo.nl. Retrieved February 13, 2018, from: https://www.rvo.nl/subsidies-regelingen/mkb-innovatiestimulering-regio-en-topsectoren-mit

Mullerbeck, E. (2015). *SWOT and PESTEL understanding your external and internal context for better planning and decision-making*. UNICEF Tools. Retrieved from: https://www.unicef.org/knowledge-exchange/files/SWOT_and_PESTEL_production.pdf

Nijs, B. (2016). *Circular economy drives sustainability in vertical farming*. Horti daily. Retrieved 26 February 2018, from http://www.hortidaily.com/article/26868/Circular-economy-drives-sustainability-in-vertical-farming

Oxford Dictionaries (2017). Retrieved June 19, 2017, from: https://en.oxforddictionaries.com/definition/us/efficient

Pardossi, A. (2011). *Fertigation management in greenhouse hydroponics.* University of Pisa. Retrieved from: https://www.wur.nl/upload_mm/1/c/f/26821c36-eb95-4fcb-9dbb-d6c51639a253_Alberto_Pardossi_English_version.pdf

Pehrsson, A. (2014). *Firms' customer responsiveness and performance: the moderating roles of dyadic competition and firm's age*. Journal of Business & Industrial Marketing, 29(1), 34-44. Retrieved from: http://www.emeraldinsight.com.ezproxy.library.wur.nl/doi/full/10.1108/JBIM-01-2011-0004

Philips. (2015). *LED lighting for multilayer cultivation*. Retrieved January 24, 2018, from: http://images.philips.com/is/content/PhilipsConsumer/PDFDownloads/Global/ODLI20150722_001-UPD-en_AA-CL-LED-production-module-EN.pdf

Pickton, D. W., & Wright, S. (1998). *What's swot in strategic analysis?* Strategic Change, 7, 101-109. Retrieved from: http://onlinelibrary.wiley.com/doi/10.1002/(SICI)1099-1697(199803/04)7:2%3C101::AID-JSC332%3E3.0.CO;2-6/epdf

Platt, P. (2007*). Vertical Farming: An Interview with Dickson Despommier*. The Journal of Critical Food Studies, 7(3), 80-87. Retrieved from: http://gcfs.ucpress.edu/content/7/3/8.full.pdf+html

Pretty, J. N., Ball, A. S., Lang, T., & Morison, J. I. L. (2005). *Farm costs and food miles: An assessment of the full cost of the UK weekly food basket.* Food Policy, 30(1), 1-19. Retrieved from: http://www.sciencedirect.com.ezproxy.library.wur.nl/science/article/pii/S0306919205000059?_rdoc=1&_fmt=high&_origin=gateway&_docanchor=&md5=b8429449ccfc9c30159a5f9aeaa92ffb&ccp=y

Rijksoverheid. (2017) *Zuivering afvalwater glastuinbouw vanaf 1 januari 2018 verplicht*. Retrieved may 31, 2018, from: https://www.rijksoverheid.nl/actueel/nieuws/2017/07/14/zuivering-afvalwater-glastuinbouw-vanaf-1-januari-2018-verplicht

Rise Of The Vegan (2018). *Going vegan is predicted to be the biggest food trend of 2018*. Retrieved February 22, 2018, from https://www.riseofthevegan.com/blog/going-vegan-biggest-trend-for-2018

Robbins, S. P., DeCenzo, D. A., & Coulter, M. (2015). *Fundamentals of management* (9th ed.). Harlow, United Kingdom: Pearson Education.

Sekhon, B. S. (2014). *Nanotechnology in agri-food production: an overview*. Nanotechnology, science and applications, 7, 31. Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4038422/

Showler, A. T. (1995). *Locust (Orthoptera: Acrididae) outbreak in Africa and Asia, 1992–1994: an overview*. American Entomologist, 41(3), 179-185. Retrieved from: https://academic-oup-com.ezproxy.library.wur.nl/ae/article/41/3/179/2389456/Locust-Orthoptera-Acrididae-Outbreak-in-Africa-and?searchresult=1

Spoelman, J. (2016). Vertical farming in Nederland: de stand van zaken. Verse Stad. Retrieved February 13, 2018, from: http://versestad.nl/2016/10/vertical-farming/

Staay Food Group (2018). Retrieved from: http://www.staayfoodgroup.com/news/sla-kweken-zonder-een-straaltje-zon

Staay Vertical Farm. (2018). Retrieved from: https://www.verticalfarmconsortium.com

Hetkanwel.net (2017). Zijn dit de schooltuinen van de toekomst? Retrieved February 1, 2018, from: https://www.hetkanwel.net/2017/11/01/vertical-farms/

Touliatos, D., Dodd, I. C., McAinsh, M. (2016). *Vertical farming increases lettuce yield per unit area compared to conventional horizontal hydroponics.* Food and energy security, 5, 184-191. Retrieved from: http://onlinelibrary.wiley.com.ezproxy.library.wur.nl/doi/10.1002/fes3.83/abstract;jsessionid=B1F25188FCE40F56ADED934FAC0C0598.f02t01

Valstar. (2018) Retrieved May 24, 2018, from: https://www.valstar.com/en/serve-you#value-assortment

Van Achter, B. (2017). *MIT subsidie voor Vertical Farming systeem*. Ictvalley.nl. Retrieved February 13, 2018, from http://www.ictvalley.nl/nieuws/mit-subsidie-voor-vertical-farming-systeem

van Huijgevoort, S. (2016). *'Over 20 jaar is ons voedsel flink veranderd'*. Retrieved may 17, 2018, from: https://www.rtlz.nl/life/lifestyle/over-20-jaar-is-ons-voedsel-flink-veranderd

Van Ieperen, W., & Trouwborst, G. (2007). *The application of LEDs as assimilation light source in greenhouse horticulture: a simulation study*. In International Symposium on High Technology for Greenhouse System Management: Greensys2007 801 (pp. 1407-1414). Retrieved from: http://edepot.wur.nl/42563

Verbeek, J. (2017) *Familiebedrijf gaat grootschalig sla kweken zonder daglicht.* Financieel dagblad. Retrieved June 6, 2017, from: https://fd.nl/ondernemen/1189884/familiebedrijf-gaat-grootschalig-sla-kweken-zonder-daglicht

Vijverberg, A. J. (1996). *Glastuinbouw in ontwikkeling. Beschouwingen over de sector en de beïnvloeding ervan door de wetenschap* (Doctoral dissertation, Eburon). Retrieved from: http://edepot.wur.nl/137977

VPRO-Tegenlicht. (2017) *Boer zoekt voedselflat*. Retrieved from: https://www.npo.nl/vpro-tegenlicht/23-04-2017/VPWON_1265900

Weihrich, H. (1982). *The TOWS matrix—A tool for situational analysis*. Long range planning, 15(2), 54-66. Retrieved from: http://ac.els-cdn.com.ezproxy.library.wur.nl/0024630182901200/1-s2.0-0024630182901200-main.pdf?_tid=069b1dc0-5b37-11e7-bb7f-00000aacb35e&acdnat=1498567935_2a13a6f1c9539450a14e3037132f5865

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), 2175-2180. Retrieved from: https://www-sciencedirect-com.ezproxy.library.wur.nl/science/article/pii/S1364032109000471

Yelton, M., & Ohzourk, N. (2017). *Optimizing Lettuce Quality, Taste and Morphology with LED Lighting*. LumiGrow Inc. Retrieved from: https://www.lumigrow.com/content/wp-content/uploads/2017/04/research-optimize_lettuce_quality_morphology-lumigrow-led.pdf

Yüksel, I., & Dagˇdeviren, M. (2007). *Using the analytic network process (ANP) in a SWOT analysis – A case study for a textile firm.* Information Sciences, 177(16), 3364-3382. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0020025507000230