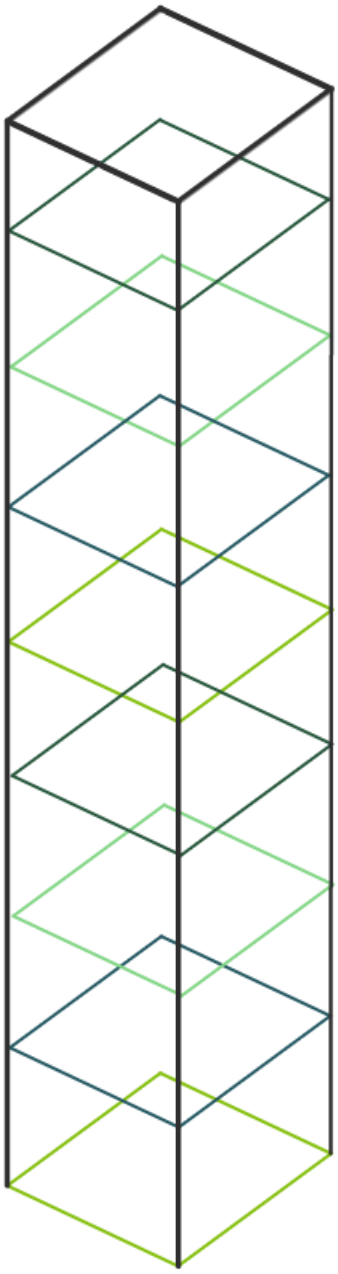
VERTICAL, CONTROLLED & RESOURCE-INTEGRATED URBAN AGRICULTURE

Driving and Scaling-up a Potential Transition in the Contexts of Linköping and Singapore



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PREFACE

For me personally, urban agriculture combines the two most vital aspects of sustainability in this moment in time. It is the combination of 'urban', which is the most contemporary and inevitable form of development; and that of 'food', which is our most direct and every-day relationship with nature. It furthermore combines our quest for development and wellbeing, with the reality of how we produce, consume and basically eat, from food, to energy to water. What furthermore appeals to me about urban agriculture is its actual potential to become part of a graspable solution. It relates to the problem-solving and multi-disciplinary mind-set of this MSc in Sustainable Development and Environmental Governance at Utrecht University.

With the risk of sounding cliché, I dare to say that this master programme has had a positive and life-changing influence on my education and personal mind-set. It has given me the opportunity to dive into the field of sustainability that has previously been so foreign to me, but now feels like such a logical and fundamental part of life. Furthermore, it has stimulated me to question, to doubt, to travel and to contribute. For me, it has addressed the increasing spatial and mental gaps between humans and the natural environment supporting them, which is among other things grounded in the way we live, eat and value. Personally, I feel that these gaps become most sensible in the provisioning of food, which is turning into one of the most un-transparent, processed and environmentally unsustainable parts of our lives. As cities continue to grow, people become more urban and the supermarket is our closest connection to food; an opportunity arises to rethink existing structures and become more innovative, creative and sustainable. This is where UA becomes relevant. Not by presenting it as a world-changing idea, but as an interesting innovation that has the potential to change a part of our urban worlds.

When I reflect on the research process, my main challenges have been the formulation of clear research questions and the integration of all the theoretical concepts in order to arrive at a useful analytical framework for empirical validation. Furthermore, the length of my thesis has been quite a challenge, as my enthusiasm and the interdisciplinary and complex character of this topic has led to quite an extensive report. Diving into the topic of UA and its potential for structural change has also shown how large and fruitful this research field can be. Future research around my constructed definition of vertical-, controlled- and resource-integrated-UA could for example be devoted to; impact assessments and comparisons with other agricultural systems, life-cycle-assessments, cost-benefit-analyses, discourse analyses with the inclusion of community actors and to more technical aspects of energy use. When writing down the final words of this master thesis research, I look back with a feeling of appreciation for all the research challenges and feedback that has helped me in improving my work and arriving at this result.

PLANTAGON

Internship

Besides being the final step in the MSc in Sustainable Development at Utrecht University, this thesis has also been conducted along an internship at Plantagon International in Stockholm, Sweden. The internship with Plantagon has been a voluntary experience to guide and increase the feasibility of this research on UA. The Swedish-American Companization has been initially founded (2008) and funded by Onondaga nation, an alliance of Native Americans, and the communal efforts of Hans Hassle, Göran Pettersson and Åke Olson as Swedish leaders in innovation and business.
The Companization model stands for a unique business structure that is both encompassing a for-profit company and a non-profit association. Plantagon has been initiated on the aspiration of

combining business with environmental values and long-term social impact, which came together in the concept of urban agriculture (Plantagon International, n.d.-e). Plantagon's (n.d.-a) business concept focuses on the development of *"innovative solutions to meet the rising demand for locally grown food in cities all around the world, by minimizing the use of transportation, land, energy and water – using waste products in the process but leaving no waste behind"*. By focusing on the increasing pressures of urbanisation on ecosystems and the interdependency of food-, nutrient-, water-, energy- and waste- cycles, Plantagon has been able to become a worldwide expert and leader on innovative solutions for urban food systems (Plantagon International, n.d.). Its overall mission is to combine agriculture with technology and architecture in order to feed cities and build the future.

Acknowledgements

Overall, I would like to express my gratitude towards prof. dr. Peter Driessen, as I could not have wished for a more knowledgeable, constructive and pleasant guidance during this master thesis. Especially considering the fact that I have not been present in Utrecht due to the internship in Stockholm, I am thankful for the cooperation and process that have made this result and experience possible. I would also like to thank dr. Caroline Uittenbroek as the second reader of my master thesis, for her willingness to read and evaluate my work. Furthermore, I would like to thank everyone at Plantagon for giving me the opportunity to become part of their team and for sharing their extensive knowledge and network with me throughout this research process. I would particularly like to thank Sepehr Mousavi as my supervisor at Plantagon for believing in me, providing me with inspirational feedback and introducing me to the world of urban food systems beyond solely academia. Additionally, I would like to express my gratitude for all the interviewees who have participated in this research an who have been willing to share their knowledge, experiences and time with me. Finally, I would like to thank all the wonderful people around me that have made this process more endurable than it would have been without them.

ABSTRACT

Potential local solutions for the provisioning of food, like urban agriculture (UA), become intriguing when looking at food against the background of a growing urban world population, globalised food structures, environmental degradation and an increasing scarcity of resources like water, energy and land. By focusing on UA within a vertical-, controlled- and resource-integrated setting, this research has chosen to focus on a newly emerging form of UA that is rather large-scale, high-tech and has the potential to trigger structural change. Its hypothesised potential to challenge existing food structures has resulted in a theoretical approach based on the multi-level-perspective (MLP) on socio-technical transitions, specifying a niche-, regime- and landscape-level, while furthermore building on concepts of governance. Firstly, potential transition drivers have been classified in landscape developments and niche pressures. Secondly, the capacity of an urban system to govern or 'scale-up' such a transition process has been analysed and expressed in a degree of governance capacity on the regime-level. By drafting and applying an analytical framework, this research has been able to analyse transition drivers and the scale-up potential in two specific case studies of vertical-, controlled- and resource-integrated-UA. By conducting two in-depth analyses through desk research and semi-structured-interviews in the urban context of Linköping and Singapore, this research has been able to gain more insights into the world's first initiatives of vertical-, controlled- and resource-integrated-UA. In short, the main conclusions show that both niches rest upon a strong knowledge foundation and expertise. Despite the underexposed role of stressful landscape developments in theory, they seem of essence in the articulation of expectation and visions by niche actors. They furthermore seem to play a major role in the degree of awareness, willingness and power that determine the governance capacity of a regime. Vertical-, controlled- and resource-integrated-UA seems to be strongly driven by the private sector, in which financial investments and economic viability are currently playing crucial roles. Generally, this research has aimed to be of scientific relevance by addressing knowledge gaps in transition theories when it comes to understanding drivers of change and the analytical capacity for empirical validation, furthermore touching upon the underexposed role of agency or governance. It has been able to provide an operationalisation of the landscape-, regime- and niche-level, including independent variables, hypotheses, indicators and corresponding research methods. By turning descriptive transition and governance concepts into a more analytical tool for assessment, this research has furthermore been able to provide context-specific feedback and lessons for vertical-, controlled- and resource-integrated UA.

ABBREVIATIONS

CEA	=	Controlled Environment Agriculture
CDL	=	City Developments Limited
CLC	=	Centre for Liveable Cities (Singapore)
CSR	=	Corporate Social Responsibility
ES	=	Eco-system Service
GHG	=	Greenhouse Gas
LED	=	Light Emitting Diode
MND	=	Ministry of National Development (Singapore)
MLP	=	Multi-Level-Perspective
NTU	=	Nanyang Technical University
PFAL	=	Plant Factory with Artificial Lighting
UA	=	Urban Agriculture
UN	=	United Nations
WEF	=	Water-Energy-Food

1. INTRODUCTION

1.1 Research Problem

1.1.1 Food & the Urban Context

The year 2009 marked the first moment in history in which there were more people living in urban than rural areas (Wiskerke, 2015). Nowadays, it is estimated that by 2050, the world population will count around 9.7 billion people, of which at least 70% will be living in cities (Cash, 2016; Morley, Mcentee, & Marsden, 2014; United Nations Department of Economic and Social Affairs Population Division, 2015). Within these urban areas, rapid population growth and migration streams are putting more and more pressure on facilities, infrastructure and human wellbeing (Morley et al., 2014). Urban growth is with that one of the most contemporary, human induced and extremely disruptive drivers of global climate and environmental change, which becomes among other things visible in extreme weather-events, biodiversity degradation, pollution and global warming (McPhearson, Andersson, Elmqvist & Frantzeskaki, 2015; Rodin, 2014). As Wiskerke (2015, p. 2) shows, *"cities consume 75% of the world's resources, while covering only 2% of the world's surface"*, which make them net importers of natural resources and exporters of waste. Rapid urbanisation and the linked consumption patterns of urban citizens are therefore putting increasing pressure on Earth's ecosystem, in which food plays a main role (Rockström et al., 2009; Wiskerke, 2015). The provisioning of food can be defined as an ecosystem service (ES), which refers to "*the benefits human populations derive, directly or indirectly, from ecosystem functions*" (Bolund & Hunhammar, 1999, p. 295; Elmqvist et al., 2013; MEA, 2005). Food is in that sense one of human's most direct and every-day relationships with nature (Burkhard, Kroll, Nedkov, & Müller, 2012). This relationship between the production and consumption of food has however become more distant, due to the rapid transition from rural to urban lifestyles worldwide. This increasing gap between where food is produced and where it is consumed is resulting in a variety of environmental impacts.

1.1.2 Food & its Environmental Impacts

Since the mid of the 20th century, food systems have been increasingly dominated by free-market ideals and globalisation trends within agriculture and industries (Morley et al., 2014; Rodríguez-Rodríguez, Kain, Haase, Baró, & Kaczorowska, 2015). In an economic sense, these trends mainly refer to the creation of international markets in which products and capital are able to move freely between countries (Lambin & Meyfroidt, 2011). Globalisation has in this way also facilitated the transportation of food products all over the world and has led to only a few actors controlling the largest parts of production (Marsden & Morley, 2014). The transportation of food over large distances has resulted in a high dependency of urban areas on arable land and resources outside of a city (Gómez-Baggethun et al., 2013). The increasing spatial and mental gap between urban citizens and their food *"is more than symbolic, as it indicates an acceleration of human activity away from direct food production, and therefore a greater reliance on trade and global capital and therefore on currently long and complex supply chains"* (Andersson et al., 2014a; Haysom, 2015; Morley et al.,2014, p. 34). First of all it is important to emphasise that globalisation trends within conventional food structures are complex and have globally contributed enormously to an increase in life expectancy, human wellbeing and a large decrease in poverty and hunger (Flynn & Bailey, 2014; Morley et al., 2014; Wiskerke, 2015). On the other side, a lot of this progress has been able to take place at the expense of the environment (FAO, IFAD, & WFP, 2015; FAO, 2011; Morley et al., 2014; United Nations, 2011). With that the physical and mental distances between consumers and their food has also caused a multitude of negative environmental effects (World Health Organization, 2016). Furthermore, the world is still an inefficient place in which almost 1 billion people suffer from under-

nutrition, while around the same number is diagnosed with obesity and around 1.3 billion tonnes of food is wasted annually (FAO, 2016; Marsden & Morley, 2014).

As the world population and cities will grow, so will the import of natural resources over long distances. With that, the security of food[1] and its embedded resources are becoming an increased issue of concern on both the Northern and the Southern hemisphere (Asian Development Bank, 2013; FAO, 2011; Godfray et al., 2010). Figure 1 on page 10 gives a visual representation of the environmental risks resulting from agricultural production systems worldwide, ranging from water scarcity towards desertification, loss of soil fertility and erosion. The aim of this research is not to discuss all these risks in details, but to shortly show the complex environmental impacts of food systems and the unequal geographical distribution of them. Those who consume are not necessary dealing with the resulting environmental risks and those who produce are not automatically food secure (Duru, Therond, & Fares, 2015; FAO et al., 2015; Marsden & Morley, 2014). Inequalities in the access to and quality of food, together with a strong rise in global food prices in 2008, partly due to a rise in oil prices and bio-fuel demand, has led the international community to even talk about a food security 'crisis' (Morley et al., 2014; United Nations, 2011). In a more global sense, the imbalances between the consumption of natural resources (ecological footprint) and the availability of them (bio-capacity) can also be seen in Figure 2 on page 10. Countries who are dealing with an ecological deficit are either *"importing bio-capacity through trade, liquidating national ecological assets or emitting carbon dioxide waste into the atmosphere"*(Global Footprint Network, 2016). This research is not able to extensively explain all the embedded problems of food systems, but in light of this research it is important to zoom in on the dependency of food provisioning on other resources.

1.1.3 Food & its Embedded Resources

When further investigating the issue of food security, it can be seen that it is connected to the availability of and access to other natural resources embedded in its production. The provisioning of food is highly dependent on water, energy and land and a scarcity of one resource directly influences the functioning of the other (Hoff, 2011). Combinations of population growth, urbanisation and globalisation have therefore not only led to a high demand for food, but also to the intensive use of these other embedded natural resources (Eigenbrod & Gruda, 2015; FAO et al., 2015; Godfray et al., 2010; Hoff, 2011; Smajgl, Ward, & Pluschke, 2016). For a further debate on food systems within the urban context, it is therefore important to shortly zoom in on some facts around water, energy and land for food.

First of all, the issue of water plays a major role within the provisioning of food, as blue (surface and groundwater), green (rainwater) and grey (waste water, excluding sewage water) water is needed throughout the entire life cycle of a product, from irrigation to waste disposal processes (Wiskerke, 2015). Agriculture alone accounts annually for 70% of the global fresh water-use, in which meat and dairy products play the biggest role (UNEP, 2013). Wiskerke (2015, p. 11) even states that *"if the entire world population were to adopt a Western-style diet, 75% more water would be necessary for agriculture"*, which will lead to an intensification of an already emerging water crisis. Dinesh Kumar, Bassi, Narayanamoorthy and Sivamohan (2014, p. 1) even state that *"there will be a 40% overall gap between global water supply and demand by 2030".*

[1] Food security can be defined as the availability of and access to nutritious food for everyone (World Health

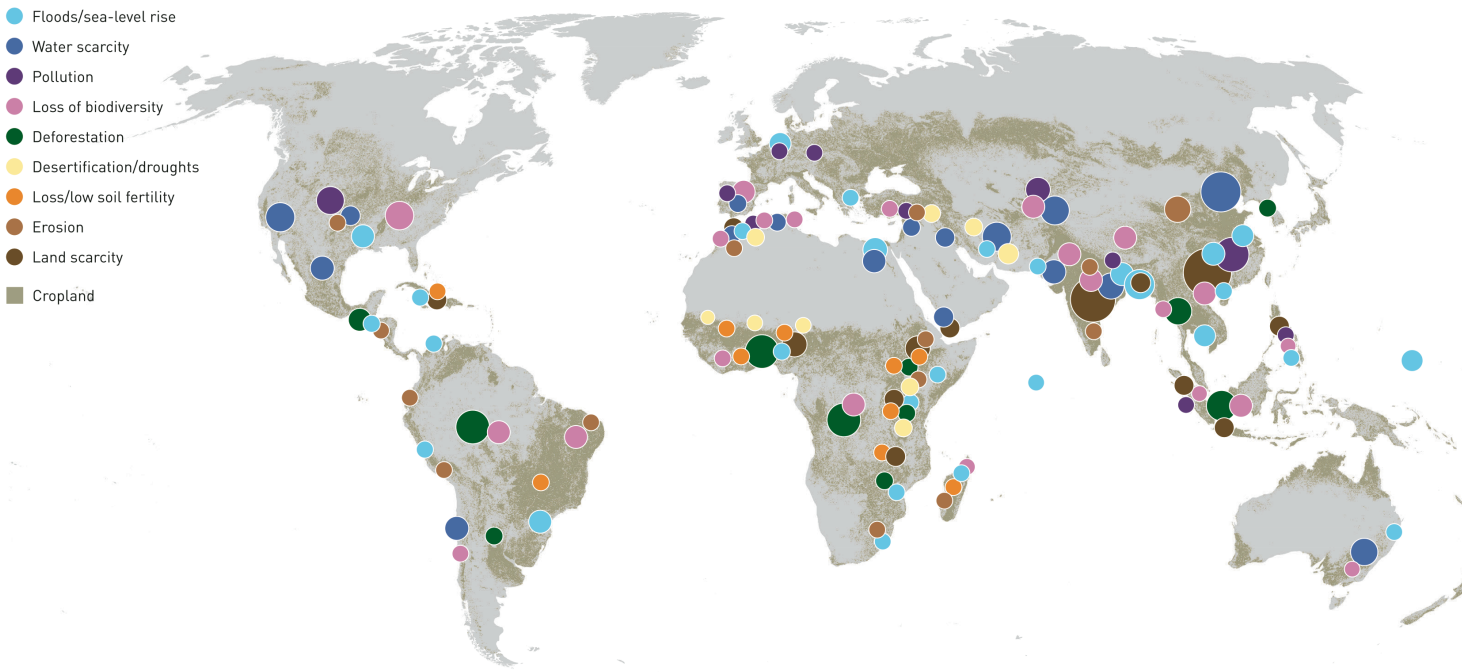

Figure 1: Global Distribution of Risks Associated with Main Agricultural Production Systems (FAO, 2011, p. 133)

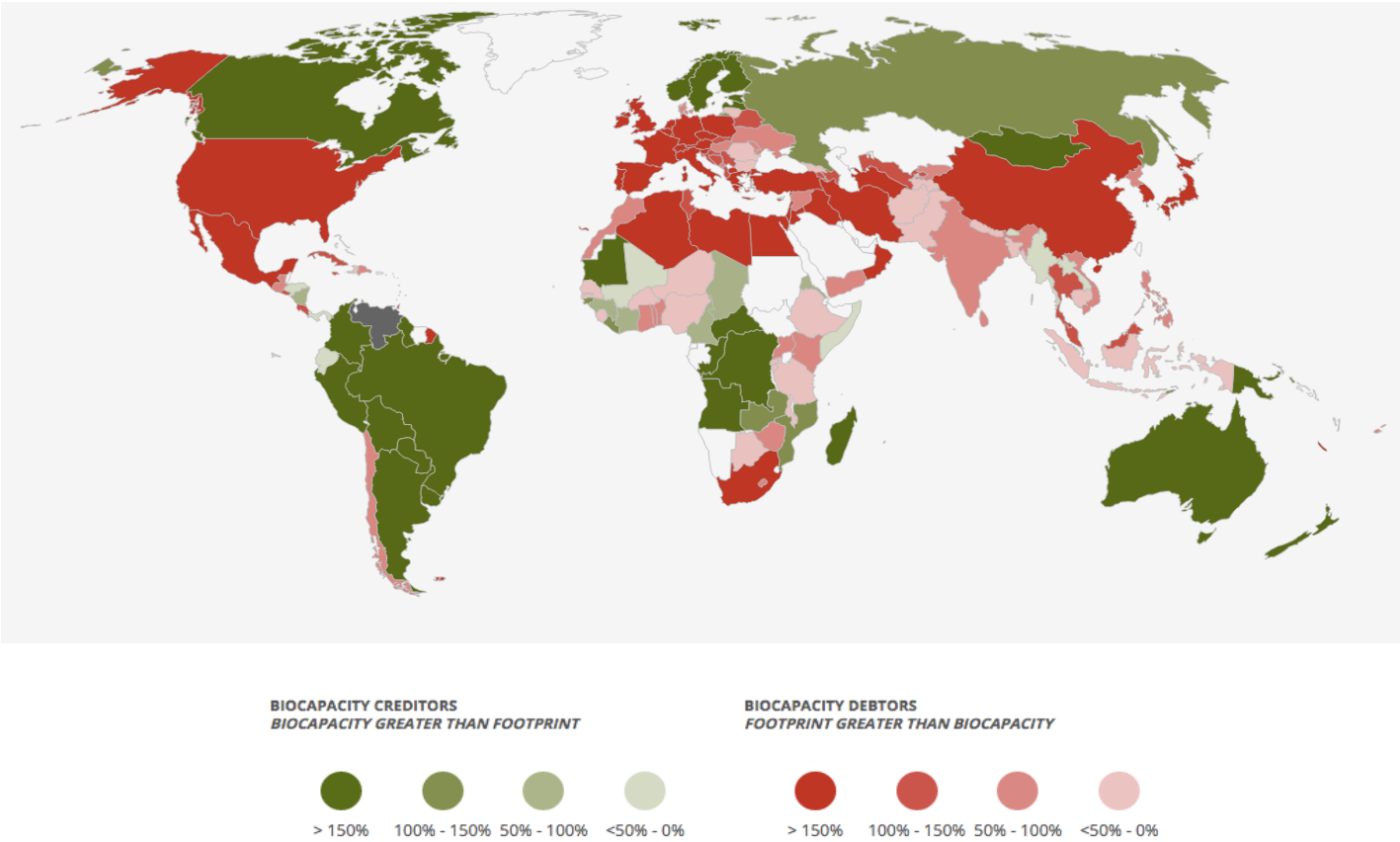

Figure 1: Global Ecological Deficits & Reserves (Global Footprint Network, 2016)

Secondly, there is a lot of energy needed for the provisioning of food, of which nowadays the largest part is based on fossil fuels (Wiskerke, 2015). Fossil fuel resources are mainly embedded in the production of synthetic fertilizers and throughout transportation and distribution processes. Overall, agricultural practices are responsible for around 14% of all greenhouse gas (GHG) emissions world-wide, which makes this sector the second largest contributor (Morley et al., 2014; Russell, 2014). This high dependency of conventional food systems on fossil fuels, therefore also creates a high vulnerability to their availability and prices-levels (Wiskerke, 2015).

Next to water and energy, arable land is surely the third conventional condition for the provisioning of food. The world's arable land is estimated on 10,9% of the total land area and most of that is nowadays already in use for the production of food (FAO et al., 2015; World Bank, 2013). However, agricultural practices and overgrazing have been one of the main causes of land degradation, putting more pressures on the availability of arable land (Eigenbrod & Gruda, 2015). Estimations within climate science furthermore show that *"for every 1° of increase in atmospheric temperature, 10 % of the land where we now grow food crops will be lost*" (Despommier, 2011, p. 233). The scarcity of land is also increased by a continuous competition between land for urbanization, agriculture (largely focused on feed for livestock), industries and biofuel, to only name a few (Wiskerke, 2015).

To sum up, urbanisation and globalisation are causing large spatial disparities in the production and consumption of food, leading to conventional food structures that result in a variety of negative environmental effects and resource security issues world-wide. Water, energy and land for food are furthermore all dealing with increasing pressures that affect their availability and quality. As Hoff (2011, p. 11) indicates; *"resource limitations in all sectors require a shift towards increased resource use efficiency, demand management and more sustainable consumption patterns"*. Debates around food systems should therefore not be isolated from its relationship with other resources like water and energy (Adnan, 2013; Smajgl et al., 2016; World Economic Forum, 2011; Yillia, n.d.).

Local food provisioning systems, like urban agriculture (UA), are currently emerging as a response to these interrelated problems. By growing and distributing agricultural products within the boundaries of a city, UA aims to be an alternative way of food production and consumption, while using resources in a more efficient way (McPhearson et al., 2015; Sonnino & Spade, 2014; Wiskerke, 2015).
In doing so, UA could become a part of a potential solution for the previously described research problems. Even though, it does not proclaim to be a solely solution for a global set of problems, it does hold the potential to change conventional food structures to a certain extent (Ackerman et al., 2014; Eigenbrod & Gruda, 2015; FAO, 2007; Luc J A Mougeot, 2006; Pearson, Pearson, & Pearson, 2010). UA is however a newly emerging field, which can be defined and applied along a lot of different scales and methods. In the light of this problem setting it is therefore important to narrow down the scope of this research, by formulating a more specific perspective on UA and structural change.

1.2 Research Perspective

In order to turn the previously explained research problem into a feasible research project, it is important to provide a more specific view on UA as part of a potential solution and to zoom in on those aspects on which further research is needed. This research will therefore look at, UA in combination with the water-energy-food (WEF) nexus, UA as a potential socio-technical transition and UA and the role of governance.

1.2.1 Urban Agriculture & The Water-Energy-Food Nexus

UA refers to a local food system in which the production and consumption of agricultural products takes place within the boundaries of the same city (Mougeot, 2005). As introduced, UA could however range from a home or community garden, towards a large-scale commercial greenhouse and its application is highly dependent on a city's context and involved stakeholders. Within developing regions, UA has for example often been seen as a vital way of increasing food security for the poorer inhabitants of a city, mainly focusing on home or community gardens that grow food for self-consumption. Within more developed region, UA is often perceived as tool to make urban spaces more green, to grow food that is more local and fresh and to reduce the environmental footprint of a city (Ackerman et al., 2014; Leitgeb, Schneider, & Vogl, 2015; L. Mougeot, 2000; L.J.A. Mougeot, 2005b; Plantagon Nonprofit Association, n.d.; Poulsen, McNab, Clayton, & Neff, 2015; Slingerland & Rabbinge, 2009). UA is currently developing from rather small-scale, unorganised initiatives, into large-scale vertical plant factories and symbiotic systems. The latter is of interest of this research, as it implies a potential for productivity, sustainability and with that structural change (further discussed in chapter 2).

In order to do so, an UA system should ideally not only produce food, but also consider its use of other resources, like water and energy. An emerging concept that could be related to this type of UA is therefore the water-energy-food (WEF) nexus. The WEF nexus addresses the interconnectedness of water, energy and food, something that is often lacking within theory and practice (FAO, 2014; Hoff, 2011; Rasul & Sharma, 2015). It is mainly an integrated way of thinking that could guide the design and governance of resource-systems (Hoff, 2011). The nexus acknowledges the scarcity of resources and tries to look for ways in which different resource systems can complement each other and become more efficient. When applying the nexus to agriculture within the urban context, it would be possible to create synergies with local water, energy and even waste systems (Adnan, 2014; Dinesh Kumar et al., 2014; Villarroel Walker, Beck, Hall, Dawson, & Heidrich, 2014). Its principles relate to Wiskerke (2015, p. 15-18) his definition of a sustainable urban food systems, in which it is first of all important to take *"a city region perspective on urban food systems",* secondly *"to connect different urban flows, allowing resources in waste to be recovered for flows creating value"* and thirdly to create *"spatial synergies".* In this research UA will therefore be defined along these lines, narrowing down the scope of this research. Chapter 2 will give a more extensive definition on how these two concepts can be integrated, working towards a definition of vertical-, controlled- and resource-integrated-UA. With that, chapter 2 will also provide the foundation for the case study selection in the empirical analysis, further explained in chapter 4 and 5.

1.2.2 Urban Agriculture & A Potential Socio-Technical Transition

As stated, UA has the potential to decrease the environmental footprint of a city by bringing food production closer to the consumer, while creating synergies between water, energy and food (Despommier, 2011; International, n.d.; Kozai & Niu, 2016c; Wiskerke, 2015). However, the previously described form of UA is still in its infancy and in order for vertical-, controlled- and resource-integrated-UA to become an established mode of food production and consumption, cities require structural change. An urban area can in this sense be described as a socio-technical system along which the provisioning of food, water and energy is organised; and structures, cultures and practices are defined (De Haan & Rotmans, 2011; Haysom, 2015; Terry Marsden, 2013; Morrissey, Mirosa, & Abbott, 2013). Vertical-, controlled- and resource-integrated-UA could be defined as a niche that is aiming to change these established structures when it comes to the issue of food and its embedded resources. In order for a system to structurally change into a desired outcome, it has been hypothesised that pressures are needed to create stress within the status quo (George Papachristos,

Sofianos, & Adamides, 2013; Smith, Stirling, & Berkhout, 2005). Such pressures could occur on differences levels, both from the niche- as a from a more external landscape-environment, and often includes multi-level and multi-stakeholder interactions over a longer period of time (Smith, Voß, & Grin, 2010). This process of arriving at successful structural change is often referred to as a socio-technical transition.

The notion of steering systematic change in a desired way has been widely appealing within sustainability issues and with that a multitude of transition theories have been explored (Shove & Walker, 2007). It also provides an interesting research perspective when looking at a potential socio-technical transition around UA. According to Smith et al. (2005) the conventional agriculture system can be seen as a regime that has developed along technological and economic processes focused on productivity, monocultures and global markets into the status quo. At the same time, innovative and alternative food systems, like UA, can be perceived as niche environments that are trying to exert pressure on the existing system in order for it to adapt and structurally change (Morley et al., 2014; Morrissey et al., 2013; Mount, 2012; Sonnino & Spade, 2014). As Marsden and Morley (2014, p.13) also state, urban food systems are aimed at creating *"a new counter-paradigm as a significant counterforce to the global intensive food agenda"*. A socio-technical transition is however the result of a multitude of pressures, multi-level and multi-stakeholder interactions over time (Geels & Schot, 2007; Geels, 2002; Smith et al., 2010). The complexity of a potential transition causes transition theories to be rather descriptive in nature, in which mainly the pressures behind or drivers of transitional change are often discussed as the first step in understanding long-term processes (De Haan & Rotmans, 2011; Geels & Schot, 2007; Markard, Raven, & Truffer, 2012). As vertical-, controlled- and resource-integrated-UA systems are only recently emerging and structural change has often not yet occurred, it is initially important to understand what drives this form of UA before being able to further analyse a transition potential. So, in order to make any claims about the potential of this transition process, chapter 3 will provide a more extensive perspective on transition theories when it comes to drivers of change.

1.2.3 Urban Agriculture & the Role of Governance

A third perspective worth exploring, is the role of governance within such a potential social-technical transition around vertical-, controlled- and resource-integrated-UA. Socio-technical transitions are not automatically a result of certain drivers, but also dependent on the capacity within an urban system to deal with change and steer it in the desired direction (Haysom, 2015; Konefal, 2015; Terry Marsden, 2013; Shove & Walker, 2007; Van den Bosch & Rotmans, 2008). This capacity of an actual system to govern or 'scale-up' a transition is however underexposed within transition theories. This is why this research will secondly aim to investigate the scale-up potential of UA by including a broader base of literature on governance. In general, governance could be defined as all processes that *"make a purposeful effort to guide, steer, control, or manage sectors or facets of societies"* (Lange, Driessen, Sauer, Bornemann, & Burger, 2013, p. 406). Governance in this sense could refer to government actors, but also to the private sector or community members.

When looking at UA, governance challenges can first of all vary depending on its scale, type, urban context and involved network. Secondly, governance processes are involved in different stage of UA development, from design to implementation and regulation. A city could for example have to deal with governance challenges when it comes to city planning or the safety of food and the role of pollution. On the other hand, a city could deal more with strategic governance challenges on how to introduce new ways of producing food, when for example looking at creating certifications or financial incentives. When furthermore looking at UA within a resource-integrated setting, governance challenges become even more multi-level, cross-boundary and complex (FAO, 2014; Haysom, 2015; Hoff, 2011; Konefal, 2015; Terry Marsden, 2014; McMichael, 2011; Wiskerke, 2015). Governance

could in this sense be a necessary response to unanticipated problems within a city, as well as a more strategic or systemic process to envision and implement change (Ackerman et al., 2014; L.J.A. Mougeot, 2005b; Luc J A Mougeot, 2006; Sonnino & Spade, 2014). As this research will focus on a newly emerging type of UA at the verge of a potential socio-technical transition, the latter becomes most interesting. By zooming in on the capacity of a city to deal with pressures related to this form of UA, the transition perspective can be taken one step further. Chapter 3 will therefore not only zoom in on what drives a potential socio-technical transition, but also consider its scale-up potential; building both on transition theories and governance concepts.

So, these three perspectives on UA together form the foundation for this research, further guiding the following chapters. As shortly stated, the integration of UA and the WEF-nexus into vertical-, controlled- and resource-integrated-UA will be further explained in chapter 2. The aim of this chapter is mainly to provide a more extensive background on the niche environment of vertical-, controlled- and resource-integrated-UA and a clear demarcation and justification for the case study selection in chapter 4. Chapter 3 will provide the theoretical foundation of this research, by zooming in on theoretical concepts that could assist in explaining what drives and scales-up a potential socio-technical transition. The actual empirical analysis will be central in chapter 5 and 6, leading up to an overall synthesis, discussion and conclusion. Before arriving at the specific research objective and research questions, it is important to zoom in on some existing knowledge gaps that have led to these previously described perspectives and justify the relevance of this research.

1.3 Knowledge Gaps

First of all, there is insufficient debate on the interconnectedness of food with other natural resources like water and energy within the urban environment (Hoff, 2011). When looking at existing case studies on sustainable transitions, it can be seen that issues of water, energy and food have mainly been investigated in an isolated way (Flor Avelino, 2009; René Kemp, Loorbach, & Rotmans, 2007; Loorbach, Rotmans, Frantzeskaki, & Thissen, 2010; Marcotullio & Mcgranahan, 2007; Roorda et al., 2014). Especially within the urban context, food has overall been an underexposed theme (Goldstein, Birkved, Fernandez, & Hauschild, 2016; T. Marsden & Morley, 2014; Morley et al., 2014; Luc J A Mougeot, 2006; Wiskerke, 2015). The FAO (2014) furthermore indicates that there is still insufficient knowledge regarding the implications of making water- energy and food-system less sector-independent and more cross-boundary, currently leading to large inefficiencies and waste. The UN Sustainable Development Goals (SDGs) show as well how issues of e.g. food security, urban sustainability and consumption and production patterns are all on the international agenda, but are addressed in complete separation from each other (United Nations, n.d.)[2]. There is insufficient attention for the interconnectedness of these different issues and the role urban areas could play in achieving these multiple goals. In order for UA to be a part of a solution for resource security and more sustainable urban environments, it is therefore important to effectively integrate water and energy flows within the design of food systems (chapter 2) (Association for Vertical Farming, 2016c; Despommier, 2011; International, n.d.; Wiskerke, 2015). By contributing to the research field of UA and by zooming in on a type of system that is vertical-, controlled- and resource-integrated, this research aims to address some of these neglects.

[2] Examples of SDGs that could relate to food within the city: *"[2] End hunger, achieve food security and improved nutrition and promote sustainable agriculture", "[11] Make cities and human settlements inclusive, safe, resilient and sustainable", "[12] Ensure sustainable consumption and production patterns" (United Nations, n.d.).*

Secondly, knowledge gaps remain when it comes to potential of UA to actually trigger transitional change within cities. According to Markard, Raven, and Truffer (2012, p. 955), systems or sectors are characterised by *"strong path-dependencies and lock-ins"* and any transition would require mechanisms that are able to put pressure on these. The question becomes important of how established socio-technical systems could be pushed into and transition towards more sustainable alternatives, like UA (Duru et al., 2015; Feret & Moore, 2015; Geels, 2011; T. Marsden & Morley, 2014; Morley et al., 2014). In general, research on transitions has been growing during the last years and have gained a prominent role within the field of sustainable development (Foxon, Reed, & Stringer, 2009; Geels & Schot, 2007; Geels, 2002; René Kemp et al., 2007; Loorbach et al., 2010; Peter & Swilling, 2014; Rauschmayer, Bauler, & Schäpke, 2015; Roorda, Frantzeskaki, Loorbach, Steenbergen, & Wittmayer, 2012; Smith et al., 2005). However, debates and critiques remain on how to turn transition theories into a clear analytical framework for empirical validation (Geels, 2011; Holtz, 2011; Shove & Walker, 2007). Another important factor is that transition theories often have descriptive power when it comes to the overall complexity of transition processes, but on the other hand lack analytical power when it comes to specific phases of transitions. So in order to explain what drives a potential socio-technical transition around UA in practice, the challenge in theory is to turn descriptive concepts into a useful analytical framework (chapter 3).

Thirdly, the role of governance has been underexposed when it comes scaling-up socio-technical transitions and relates to the same lack of analytical power. It is currently still a challenge to envision how UA will continue to develop and transition studies on empirical cases of UA are still very rare (De Haan & Rotmans, 2011; Elmqvist et al., 2013; Gaston, Ávila-Jiménez, & Edmondson, 2013; Schewenius, McPhearson, & Elmqvist, 2014). A socio-technical transition is a long-term process that does not only require technological and agro-ecological insights, but largely depends on interactions between different levels and networks that drive the need for change. How such interactions in a city take place are highly context-specific and are dependent on the structure of a city (René Kemp et al., 2007; Konefal, 2015; Smith et al., 2005). In order for UA to scale-up and structurally change the socio-technical system of a city, governance becomes to play a large role (Avelino & Rotmans, 2009; Geels, 2011; Haysom, 2015; Shove & Walker, 2007). However, questions on how governance is exactly defined within a socio-technical transition and contributes to its scale-up potential are still very rare. Governance is in this sense often related to the notion of adaptive capacity or *"adaptation readiness"* within a system (Ford & King, 2015, p. 505). As Ford and King (2015, p. 505) state *"knowledge on the extent to which governance systems are prepared for adaptation is limited"*. Chapter 3 will therefore also take on the theoretical challenge of explaining what enables a potential socio-technical transition to scale-up, by not only building on transition theories, but also including useful governance concepts.

To conclude, these knowledge gaps and the preceding research problem and perspectives have together formed the foundation for the following objective and research questions.

1.4 Research Objective & Research Questions

In any research, Verschuren and Doorewaard (2010) argue that it is important to formulate a research objective that is useful, realistic, feasible, clear and informative. These requirements mainly relate to the fact that a research should aim to make a useful and realistic contribution within a clearly defined research field and should at the same time be able to achieve this aim with the available time and resources. This research aims to comply with these criteria, by narrowing down the scope of this research to a specific form of UA and by focusing on two main aspects of a potential socio-technical transition, namely 'driving and scaling-up'. Furthermore, socio-technical transitions are highly context specific and a theoretical perspective on transitions is mainly useful in explaining phenomena in practice. As implied throughout this introduction, this research will therefore be diagnostic and

explanatory in nature. A diagnostic research looks in general terms at *"the causes, background, and interrelated aspects"* of specific phenomena, in which explanatory knowledge is required (Verschuren & Doorewaard, 2010, p. 95). This research therefore chooses to analyse the main causal mechanisms in two case studies of UA that are bound to time and place; namely the city of Linköping in Sweden and in the city of Singapore. These are two urban contexts in which the first examples of vertical-, controlled- and resource-integrated-UA (chapter 2) in the world are emerging and for which a further justification for this methodological choice will be provided in chapter 4.

The objective of this research is to explain the emergence of *vertical-, controlled- and resource-integrated-UA* and its potential to drive a socio-technical transition; to furthermore derive lessons on the governance capacity of a city to scale-up this process, by conducting an analysis in the contexts of Linköping and Singapore based on a qualitative research consisting of desk research and semi-structured interviews.
This objective shows that this research needs to build, among other things, on knowledge of socio-technical transitions and vertical-, controlled- and resource-integrated-UA (efficiency). It furthermore requires desk research and semi-structured interviews with involved actors in order to apply this knowledge in the urban context of Linköping and Singapore (steering capacity) (Verschuren & Doorewaard, 2010). In order to reach this objective, the research will revolve around two main research questions:

Main Question 1		
1	**What explains the emergence of vertical-, controlled- and resource-integrated-UA and could assist in driving a potential socio-technical transition, based on the contexts of Linköping and Singapore?**	**Chapter 7**
Sub-Questions		
1.1	How could vertical-, controlled- and resource-integrated-UA be defined?	**Chapter 2**
1.2	What drivers of transitional change can be found in theory?	**Chapter 3**
1.3	What drives vertical-, controlled- and resource-integrated-UA in the contexts of Linköping and Singapore?	**Chapter 5+6**
Main Question 2		
2	**What lessons could be derived for scaling-up this process in both cities?**	**Chapter 7**
Sub-Questions		
2.1	What factors assist in scaling-up a transition process according to theory?	**Chapter 3**
2.2	What is the capacity of the cities of Linköping and Singapore to scale-up vertical-, controlled- and resource-integrated-UA?	**Chapter 5+6**

Table 1: Research Questions

1.5 Research Framework

Figure 3 on page 20 provides a visual representation of the research framework, as it provides an overview of the main steps within this research and the corresponding research questions (Q), sub-questions (SQ) and chapters (CH).

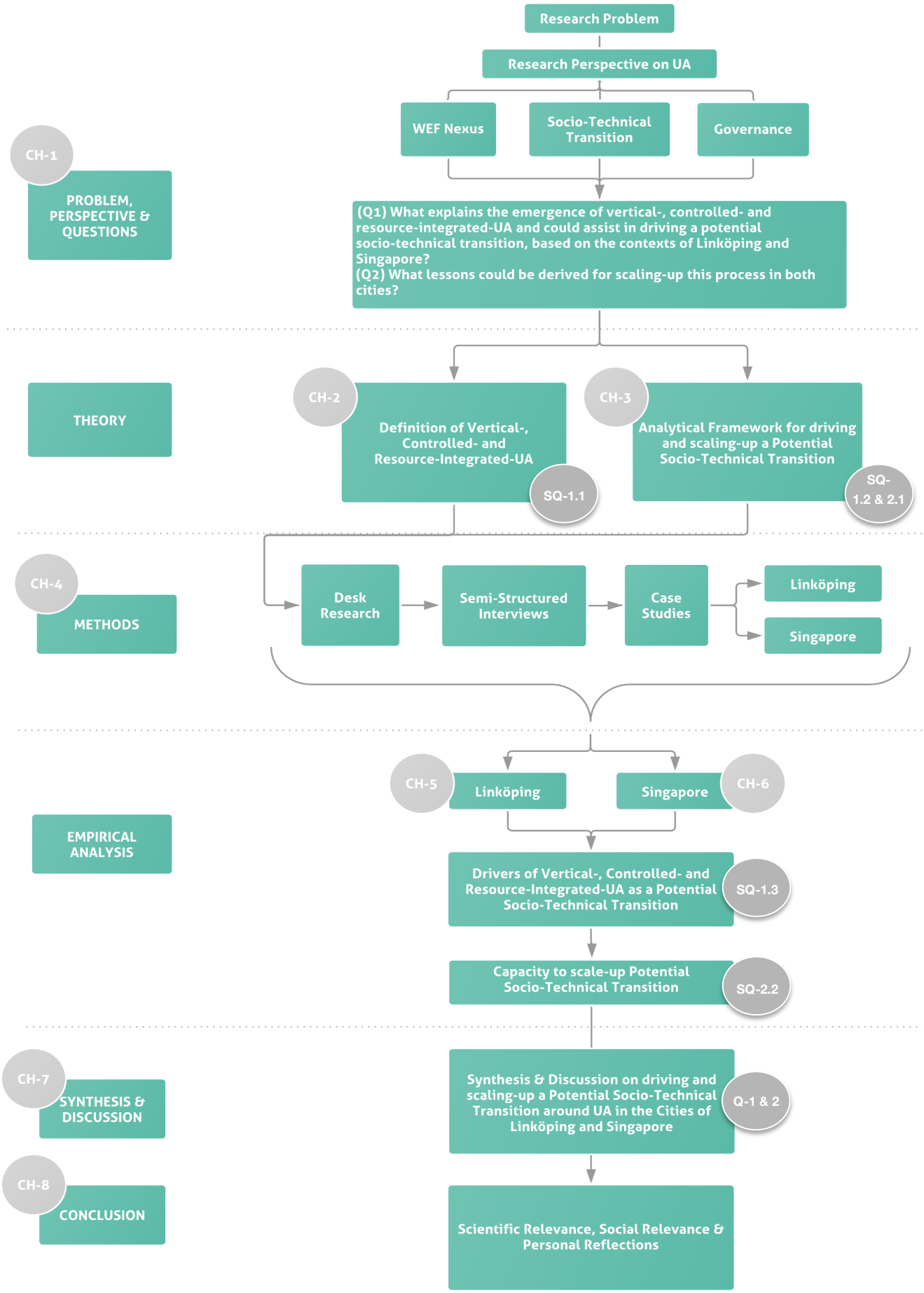

Figure 3: Research Framework

1.6 Scientific Relevance

The objective of this research aims to be of scientific relevance to the previously described knowledge gaps in section 1.3. First of all this research addresses the role of food within the environmental footprint of cities, by focusing on UA as a potential solution to a wider spectrum of pressures as shown in the problem setting. By bringing food on the urban agenda in vertical, controlled and resource-integrated way, this research revises the large spatial-gap between the production and consumption of food and the environmental impact of food systems. In this way it addressed the underexposed but emerging nexus between water, energy and food. Furthermore, this research will add to the scientific literature on socio-technical transitions by specifically focusing on driving and scaling-up a potential socio-technical transition around UA. This research will not only build on transition theories, but will also look for complementary concepts on governance and reflect on some theoretical shortcomings in order to arrive at a useful analytical framework. Through the construction of such a framework, the research will also provide feedback on the usefulness of these theoretical concepts when applying them to empirical data (De Haan & Rotmans, 2011; Geels & Schot, 2007; Loorbach, 2010; Mees & Driessen, 2011). So, overall this research aims to engage in and contribute to the scientific debates on local food solutions related to UA within a vertical, controlled and resource-integrated environment, by zooming in on its potential to trigger transitional change and scale-up in order to structurally change the provisioning of food within a city.

1.7 Social Relevance

Next to its scientific relevance, this research could also be considered to be of social value. The social relevance of this research becomes clear when looking at the negative consequences of increasing urbanisation, conventional food systems and the resulting environmental exploitation and degradation (Dubbeling, 2013; Morley et al., 2014; Secretariat of the Convention on Biological Diversity, 2012). Rural areas produce the most food, but deal simultaneously with most of the issues related to food security compared to developed urban areas (FAO et al., 2015; United Nations, 2011). One of the main reasons is the fact that the large import of food over large distances by developed regions and urban areas have created a large imbalance between the supply of and demand for food. Simultaneously, urban consumers have been able to distance themselves from the direct environmental impacts of these conventional supply chains. UA, as described earlier, is able to reduce the spatial and mental gap between the consumption and production of food (Morley et al., 2014). At the same time, linkages can be made with local water and energy systems, using resources and urban waste in a more efficient way. Next to the environmental and economic benefits of using natural resources more efficiently, the nexus approach could in this way also enable a more integrated governance of the separate sectors (FAO, 2014, p. 3). UA therefore has the potential to on the one hand create more sustainable and green urban landscapes, provide citizens with fresh and safe food and generate local employment within a new sector, while at the same time reducing the large imbalances in food security and environmental burdens (Despommier, 2011; International, n.d.; L. Mougeot, 2000; Wiskerke, 2015).

The social relevance of this research could furthermore be found in the potential context-specific feedback it will generate for pushing a potential socio-technical transition around UA forward in the cities of Linköping and Singapore. By explaining what drives UA and zooming in on the scale-up potential within these cities, involved actors could gain better insights in pushing a socio-technical transition forward. A better understanding of the urban context, drivers of change and the governance capacity of a city to scale-up UA, is in this way not only of academic, but also of socio relevance.

In conclusion, this chapter has been an introduction to the problem driving this research and has resulted in the research perspective, knowledge gaps, objective, questions, framework and relevance. Chapter 2 will now provide a more in-depth description of what can be understood as vertical-, controlled- and resource-integrated-UA, in order to narrow down the scope of this research and provide a demarcation for the empirical analysis. Chapter 3 will then provide a theoretical background of socio-technical transitions and will draft an analytical framework to assess what drives and assists in scaling-up a potential transition around UA. Chapter 4 will explain the methodological choices made within this research, including the two case studies of the cities of Linköping and Singapore, furthermore leading to the main analysis in chapter 5 and 6 and the following concluding chapters

2. VERTICAL, CONTROLLED & RESOURCE-INTEGRATED

As this research will zoom in on a potential socio-technical transition around UA, it is important to be clear about the type of UA that will be central. As different forms of UA in different urban contexts might be dealing with different pressures and governance challenges. It is important to be clear about what type of UA the eventual results of this research will relate to. When furthermore analysing UA in the light of a potential socio-technical transition, this research implies a form of UA that is able to compete with conventional food structures and with that requires structural change. It in other words requires a form of UA that is able to produce food on a larger-scale and is sustainable when it comes to its use of resources (Association for Vertical Farming, 2016c; Besthorn, 2013; Plantagon, Sweco, & SymbioCity, n.d.; Wiskerke, 2015). By working towards an answer to the sub-question: 'How could vertical-, controlled- and resource-integrated-UA be defined?' this chapter is able provide a more in-depth definition and justification of a form of UA that has the potential to create structural change. The reason why this chapter is important is first of all the need for a clear demarcation of the research scope and a justification for the case studies in chapter 4. This chapter will lay the foundation for the two chosen niche environments of vertical-, controlled- and resource-integrated-UA in chapter 4, which will be central in the empirical analysis of chapter 5 and 6.

2.1 Urban Agriculture

Mougeot (2000, p. 10) defines UA as *"an industry located within (intra-urban) or on the fringe (peri-urban) of a town, a city or a metropolis, which grows or raises, processes and distributes a diversity of food and non-food products, (re-) using largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area".* Within this definition, UA can still differ when it comes to technique, scale, type of products, destination or location (Eigenbrod & Gruda, 2015; L. Mougeot, 2000). However, it is the integration of food production with functions of the urban socio-technical system that makes UA unique. According to Pearson et al. (2010), UA is the result of several trends, which is firstly, the need for structural changes in a city due to security and population pressures, secondly the increasing awareness on complex and unsustainable supply chains and thirdly, the general need for innovation in how food is produced and resources are used.

UA can first of all include several different types of products, ranging from growing vegetables, to beekeeping and livestock. Horticulture is however often accounting for the largest part of UA and refers specifically to the growing of plants (mainly fruits and vegetables) (Orsini, Kahane, Nono-Womdim, & Gianquinto, 2013). There is not one universal typology of UA and classifications of UA differ greatly within literature. Pearson et al. (2010) however provide a useful distinction between scale (micro, meso and macro) and between ownership (private/individual, corporate, public/government). UA on the micro level could refer to a backyard or green wall, the meso level to e.g. a community garden or rooftop and the macro level to large-scale agriculture, in the form of e.g. a commercial vertical greenhouse. Besides scale and ownership, UA can be characterised by several designs and cultivation methods; ranging from outdoor to indoor farming and from organic to soilless cultures (de Bon, Holmer, & Aubry, 2015; Dubbeling, 2013; Eigenbrod & Gruda, 2015; FAO, 2007; Wiskerke, 2015). According to the (FAO, 2007), it is this variety of forms that gives UA its strengths, as it can be designed according to the context of a specific city and its stakeholders.

Generally, it is estimated that UA already *"produces between 15 and 20 per cent of the world's food"* (Pearson, Pearson, & Pearson, 2010, p. 7). This contribution however consists of a variety of formal and informal practices, for different purposes, in both developing as well as developed regions. Orsini et al. (2013, p. 700) give a broad overview of UA in the developing world, in which a substantial part of the urban population is involved in some sort of UA, with for example *"50 % in Accra (Ghana), 80 % in Brazzaville (Congo), 68 % in the five biggest cities of Tanzania, 45 % in Lusaka (Zambia), 37 % in Maputo (Mozambique), 36 % in Ouagadougou (Burkina Faso), 35% in Yaoundé (Cameroon) and about 29% in Kenyan cities".* In most of these cities, UA is mainly contributing to the food security of the relatively poorer inhabitants, as food is grown for private consumption. It furthermore associated with health benefits, the social inclusion of especially women and the unemployed and the creation of local economies and green spaces (Orsini et al., 2013). When looking at developed regions, interests in and experimentations with UA are also emerging. Within developed or high-income regions UA is more associated with innovation, a greening of the city and a reduction in the environmental footprint of food. To provide a few examples; Rotterdam is for example known for its focus on local food production through UA, by using roofs and open spaces to cultivate food and connecting this production with local markets and restaurants (de Graaf, 2012). In New York City, The Five Borough Farm project shows a broad collaboration between citizens and city officials when it comes to the development of UA plots on rooftops and empty spaces within the city. The initiator of this project, Design Trust For Public Space (2016), states that over *"700 food-producing urban farms and gardens"* have already been established throughout the city of New York. In Toronto the push for healthy food on a local scale has also been pushed by representatives of the municipality related to departments on Public Health and the Environment (Dubbeling, 2013; Sonnino & Spade, 2014). The Swiss company UrbanFarmers is one of the pioneers when it comes to the development of urban food systems, with projects throughout Switzerland, Germany and The Netherlands (UrbanFarmers, 2013). Singapore is also highly investing in the opportunities of UA, of which the first vertical farm initiated by Sky Greens is an example (Sky Greens, 2014a). The Swedish-American Companization Plantagon International is another UA leader that shows how the provisioning of food can be integrated into a vertical and symbiotic systems that combines agriculture, technology and architecture (Plantagon International, n.d.; Plantagon International, n.d.-c, 2011). Such newly emerging initiatives of UA often combine growing food with technological innovations and controlled indoor environments.

This short overview shows that multiple cities are currently already involved with UA on different scales and for different reasons, ranging from mostly small, diffused and unorganised allotments, towards more large-scale, controlled, greenhouse projects. The latter are most rare and therefore also become most interesting for the purpose of this research, as large-scale UA projects are more likely to have a structural impact within an urban environment (Ackerman et al., 2014; Despommier, 2010; Eigenbrod & Gruda, 2015; International, n.d.; Morgan, 2009; Wiskerke, 2015). However, the design and purpose of an UA system play a large role in its ability to trigger transitional change for more sustainable modes of food production and consumption. Before arriving at a more precise description of how such a UA system could be best designed, it is important to gain a better insight into the interconnectedness between food and other resources, like energy and water. The next section will therefore built further on the WEF-nexus and explain why food should not be looked at in an isolated way.

2.2 Water-Energy-Food Nexus

As already introduced, water, energy and food are highly interdependent, which becomes essential when talking about a potential socio-technical transition around food within the urban context. How water and energy is used within the production of UA largely determines how healthy, sustainable and viable UA is. The WEF nexus aims to combine these three resource systems or flows that have been

insufficiently connected in the past (Bizikova, Roy, Swanson, Venema, & McCandless, 2013; Endo, Tsurita, Burnett, & Orencio, 2015; Hoff, 2011; Leck, Conway, Bradshaw, & Rees, 2015; Smajgl et al., 2016). By connecting resource flows and using waste of one system as input for another, the nexus approach concentrates on the increasing scarcity of water, energy and land (Hoff, 2011). It looks for ways in which the different sectors can exchange resource flows, create synergies and reduce external costs or waste. The nexus approach is however not only considering technical aspects of how to connect different resource flows, but also includes the governance of these conventionally divided sectors in a more coherent way (FAO, 2014; Wallis, 2015). The nexus approach exists first of all of an analysis of all the different resources flows, their needed input and their produced waste. Secondly, an assessment should be conducted on how a change in one resource affects the others. Thirdly, it is important to address the necessary governance actions and processes when aiming to combine water, energy and food systems (Adnan, 2013). In the end, the WEF nexus is aiming to insure a higher degree of water, energy and food security (Leck et al., 2015). The interconnectedness of water, energy and food and will be shortly discussed in the following sections and has been presented in figure 4.

2.2.1 Water & Food

First of all, water can be seen as one of the most essential components within the ecosystem and as the central resource within food production (Hoff, 2011). The water footprint of products is normally divided into blue, green and grey water. Blue water refers to surface- and groundwater that is directly consumed by for example a plant, and overall agriculture accounts for 80-90% of the global blue water use (Hoff, 2011). The blue water intensity however differs between types of crop and the need for irrigation based on location or climate. Also livestock play a major role within this blue water use, as livestock is fed with a large part of the world's crops, including the water embedded in these crops. Green water furthermore refers to the intake of rainwater throughout the cultivation process and grey water is an indication of the water pollution throughout a production process and refers to the fresh water that is needed to clean a polluted source, from for example used chemicals. Another term that has been used to calculate the water footprint of a product is virtual water trade, which refers to the indirect water flows that are embedded in the supply chain of a product that has often been transported over longer distances (Arjen Y Hoekstra, Chapagain, Aldaya, & Mekonnen, 2011). As shown, food needs water, but the access, safety and affordability of water is simultaneously affected by how food is grown and how land is used. Pollution of land can affect rivers and ground-water reservoirs when transported by rain, while land degradation can lead to a lower uptake of rainwater by the soil and run-off affecting downstream areas (Hoff, 2011).

2.2.2 Energy & Food

Over the last century, agricultural practices and food production in general have become increasingly productive and efficient, largely due to the influence of energy. Access to energy has led to intensification within agriculture, to higher yields and to a wider distribution of food worldwide. Energy resources are nowadays mostly fossil fuel-based and the energy footprint of products is often calculated based on the amount of GHG-emissions that have been emitted throughout a product's life cycle. As introduced, the link with energy and food can be found in among other things the production of synthetic fertilizers, irrigation and greenhouse systems and distribution and transportation processes. The availability of fossil fuels and their price levels therefore directly influences the food sector and there has been a growing competition between land for food, for mining or for biofuels (FAO, 2014; Hoff, 2011).

2.2.3 Water & Energy

Water and energy also need each other to function and it therefore also important to shortly explain this relationship. As Hoff (2011, p. 22) first of all states "*energy is required for lifting, moving, distributing, and treating water*". As blue water or groundwater needs to be pumped up in order for it to be used, this is often the most energy intensive process. Furthermore irrigation systems also need energy, compared to rain-fed crops. Yillia (in press) shows that the largest part of energy cost within a municipality are often assigned to the treatment and distribution of water. Chang, Li, Yao, Zhang, & Yu (2016) state that in 2010, around 15% of the world's total withdraw of water is used for the energy sector. Another process that is highly related to water and energy is desalination. Desalination can be defined as *"a water treatment process that removes dissolved minerals from seawater, brackish water, or treated waste- water as alternative sources to address increasing demands on limited fresh water resources"* (Yillia, in press p. 6). On the other hand, water is also an essential part of the extraction of energy, as it is mainly needed for the drilling, cooling and processing of fossil fuels (Dinesh Kumar et al., 2014; Hoff, 2011; Yillia, in press). Other parts of the energy sector that have the highest demand for water, are nuclear and thermal power plants, which need water for cooling and converting nuclear power and heat into usable electricity (Yillia, in press). The most direct relationship between water and energy can be found in hydropower, often generated by dams, in which water movement is directly used as an energy source. Hydropower is in that sense often seen as a renewable energy source, as it doesn't have a substantial effect on the quantity of water. However, dams are often associated with other risks related to changes in river flows, environmental effects and trans-boundary water governance issues, which will not be of further subject to this research. This very short summary of the relationship between water and energy is meant to give an indication of the complexity and interconnectedness of these resources, as are the relationships between water and energy with food. Figure 4 gives a visual representation of these links between water, energy and food, in which the WEF nexus aims to incorporate these complex relationships (Bizikova et al., 2013; Chang et al., 2016).

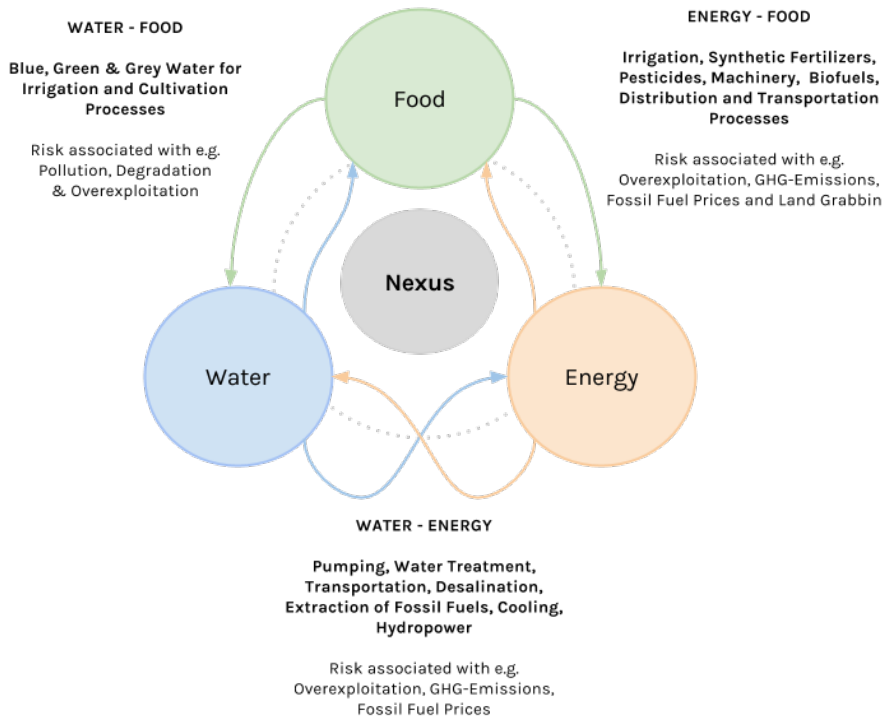

Figure 4: Interconnectedness of Water, Energy and Food

Overall, it is important to emphasise that the WEF nexus is a recently emerging concept that is still encountering a lot of research challenges (Adnan, 2013; Hoff, 2011; Leck et al., 2015; Scott, Kurian, & Wescoat Jr., 2015; World Economic Forum, 2011). The WEF nexus should mainly be perceived as a governance, policy development or innovation tool (Bizikova et al., 2013). Knowledge gaps however remain, and relate to a lack of data on complete life-cycle assessments of energy and water consumptions patterns, a missing nexus analytical framework and inadequate insights in the social, governmental and institutional implications of this approach (Hoff, 2011). Despite these challenges of a new research field, Adnan (2013, p. 6) points out that the nexus has potentially three main benefits, which are; an improvement of resource security, the creation of trade-offs and synergies between systems and their management and thirdly a stimulation of *"a transition towards sustainability".* With that, the WEF nexus provides a very useful lense through which to view UA. By integrating water and energy systems with food production and city planning, it has the potential to structurally change the socio-technical structures of a city. The next section will provide a definition of this integration, by explaining how UA and the WEF nexus come together in a vertical, controlled and resource-integrated environment.

2.3 Synthesis: Vertical, Controlled and Resource-Integrated

Combining UA and the WEF is a rather new approach, but when looking at the UA spectrum there are some newly emerging methods that combine the growing of food with this holistic perspective on resources. It could be stated that these have the highest potential of triggering transitional change towards a more sustainable form of food production. To reach this potential, UA can be designed in a vertical, controlled and resource-integrated environment. These three possible aspects of urban food production will be discussed separately to arrive at a clear perspective on the form UA that will be central within this thesis.

2.3.1 Vertical

First of all, vertical farming is a form of UA that makes use of the vertical dimension within the boundaries of a city, in which it grows food (mainly vegetables) on multiple floors or storeys in a certain area (Association for Vertical Farming, 2016c; Despommier, 2011; Eigenbrod & Gruda, 2015; Germer et al., 2011; Plantagon International et al., n.d.). The concept of vertical farming has already been introduced in the beginning of the 20th century, but has since then evolved into a high-tech farming approach that often incorporates natural processes of the ecosystem within the controlled environment of a greenhouse or building (Besthorn, 2013; Despommier, 2010). Vertical farming systems are nowadays often identified as a type of plant factory with artificial lighting (PFAL), often in the form of a greenhouse and based on soilless cultures, which will be further explained in the following section (Kozai & Niu, 2016b; Winterborne, 2005). In essence vertical farming is able to multiply the yield per square meter in proportion to the amount of floors. With that, a vertical farm is able to grow more food on less land (Despommier, 2011; Garg & Balodi, 2014; Plantagon International et al., n.d.) As Garg and Balodi (2014) state, vertical farming is in this way able to use the urban space more effectively, while contributing substantially less to land degradation and deforestation, associated with farming on open land. The vertical dimension in UA could overall generate a high productivity on a small plot of land, without contributing to the environmental risks associated with traditional agricultural practices related to land use. Growing crops in a vertical setting furthermore enables water and energy to be used in a more efficient way due to a compact construction, heat exchange and possibilities for recycling. Especially when it comes to water, it has been estimated that *"vertical farming uses up to 98% less water compared to open field agriculture"* (Association for Vertical Farming, 2016b, p. 10).

2.3.2 Controlled

Secondly, it becomes interesting to zoom in on UA within a controlled environment, which is often inherent to vertical farming. UA within an indoor, controlled environment is often called controlled environment agriculture (CEA). A controlled environment refers to an indoor greenhouse system that is able to regulate the use of light, water and airflows, including water vapour, CO_2 and oxygen (Association for Vertical Farming, 2016a; Kozai & Niu, 2016b). In this way the growing climate can be specifically designed and optimised for the type of crops that are grown. Within CEA crops are often grown with the help of LED-lightning, though often in combination with natural lightning, depending on the location and climatic conditions in which a system is placed (Association for Vertical Farming, 2016b; Kozai & Niu, 2016c; Plantagon International, 2011). Furthermore, CEA is in most cases characterised by the use of soilless cultures, which means that crops are grown without soil. Soilless cultures refer to methods in which no soil is used for the cultivation process of a plant, but instead a system of often hydroponics (water), aquaponics (aquaculture) or aeroponics (air or mist) is used (Association for Vertical Farming, 2016a; Eigenbrod & Gruda, 2015) Hydroponic and aquaponic systems are most commonly used within the soilless cultivation of plants (Eigenbrod & Gruda, 2015; Kozai & Niu, 2016b; Winterborne, 2005). Hydroponics refers to the method of growing plants in water with nutrient- and mineral-rich solutions. It is known for its ability to control the growing-environment, no need for chemical fertilizers and its high yield (Winterborne, 2005). Aquaponics combines the growing of plants with an aquarium with fish or other aquatic animals. The waste produced by aquatic animals is used as fertilizer for plants and the water cycles, after being treated between the fish tank and the plant system (Kozai, 2013; Wiskerke, 2015). Especially when talking about UA, the import of soil over large distances to the city would be an unsustainable practice. Hydro-, aqua- or aero-ponic systems in a controlled environment furthermore allow to grow healthy food without the use of pesticides and synthetic fertilizers (Besthorn, 2013; Eigenbrod & Gruda, 2015; Kozai & Niu, 2016b; Plantagon International, n.d.-b).

In general, the choice between outdoor and indoor UA is highly dependent on the conditions within an urban area, considering for example the access to arable land, climatic conditions and levels of pollution (de Bon et al., 2015; Eigenbrod & Gruda, 2015). Outdoor UA mainly occurs within smaller areas of unused space within the city, for home or community purposes. As urban areas are often characterised by a high level of industrial activity, transport and pollution, open spaces and soil within these areas are not always suitable or safe to produce healthy foods. Furthermore, the climatic conditions and seasonal change play a large role in outdoor farming. An indoor, controlled UA system on the other hand could provide fresh and healthy food, all-year round, by designing a controlled environment in which plants can grow (Eigenbrod & Gruda, 2015). This controlled environment however should be designed according to the urban context and climate in which it is placed. For example, warmer climates closer to the equator would need lower or no artificial lighting compared to colder regions; while more arid regions would require a different perspective on water-use, compared to cities with an abundance of rainfall. CEA should therefore be seen as a tailor-made solution, both for the type of crop as well as the region in which it is built. This is both its strength as well as its challenge, as it requires innovative technological, agrological and architectural insights (Association for Vertical Farming, 2016b; Despommier, 2010, 2011; Kozai & Niu, 2016c; Plantagon International et al., n.d.; Winterborne, 2005). When looking at vertical farming within a controlled environment, a third aspect related to the use of resources becomes important.

2.3.3 Resource-Integrated

As said, the degree to which UA and agriculture in general is sustainable, heavily dependent on its use of land, water, energy and other types of resources (Despommier, 2011; Kozai & Niu, 2016c; Plantagon International, n.d.-c). This also applies to vertical farming in a controlled-environment, in which the input and output of water and energy should be dealt with.

When looking at water, it is important to consider the access to water, the water-intensity of crops and the degree of water-pollution that could occur during the cultivation and production process, in order to secure water efficiency and the possibility to recycle water flows over time (FAO, 2014; Hoff, 2011). Next to eliminating the virtual water (related to transportation and distribution processes) embedded in food, soilless cultures in UA could largely reduce the need for water, due to a more efficient water use and the possibility to recycle water flows multiple times (Despommier, 2011; FAO, 2014). Secondly, it is important to create a more sustainable relationship between energy and food, by introducing alternatives energy sources and creating access to them (Hoff, 2011). More specifically, this would not only imply a shift toward renewable energies, but also include a decrease in other embedded energy sources. As stated UA in a controlled environment is able to eliminate the use of fossil fuel-based pesticides and synthetic fertilizers, while also reducing food waste by shortening the supply change and therefore reducing the time between harvest and the plate of the consumer (Association for Vertical Farming, 2016c; Despommier, 2010; Kozai & Niu, 2016b). However, indoor controlled environments for growing food often do have a high demand for energy when it comes to the lightning and technological innovations (Kozai & Niu, 2016c) Therefore, questions become relevant on what type of energy source is used, to what extent energy or warmth can be stored and how these could possibly be exchanged between different parts of a system (Hoff, 2011; International, n.d.; Plantagon International, n.d.-c). With all of these points in mind and against the background of chapter 1, UA is most promising within a resource-integrated setting.

When combining the three conditions of vertical-, controlled- and resource-integrated within a UA-system, it has the largest potential to have a large-scale impact and become a sustainable alternative for the provisioning of food. Despite these possibly large competitive and environmental advantages of vertical-, controlled- and resource-integrated-UA, some points of criticism have also been expressed. For the purpose and further justification of this research some of this scepticism will therefore be discussed in the following section.

2.3.4 Some Criticism

Next to its promising character, UA in mainly a vertical and controlled environment, has also received some criticism over the last years and it would be ignorant to not shortly touch upon these critiques (Despommier, 2011; Kozai & Niu, 2016a; The Urban Vertical Project, 2016). Criticism on vertical farming has mainly been raised on online blogs and in newspapers, where questions or conservative comments have been raised on how food is grown and who will be able to affordably access it (Bhanoo, 2014; Cox & Van Tassel, 2010; The Economist, 2010). Despite more conservative comments on the safety aspects of growing food within a controlled indoor environment, without the use of soil, this criticism has already been invalidated by a large amount of research (Tsukagoshi & Shinohara, 2016). Also doubts have been expressed on the financial investment for these forms of UA that would lead to higher vegetables prices and result in becoming a market for only the rich part of society (The Economist, 2010; The Urban Vertical Project, 2016). The role of financial resources is however a well-debated aspect within the development of such UA-systems and will also become to play a more prominent role within this research. Another criticism has mainly been raised towards the diversity of crops that can be grown, which are currently still rather limited due to the fact that UA

within a vertical and controlled environment is a rather new research field (Bhanoo, 2014; Despommier, 2010; Garg & Balodi, 2014). Overall it is important to explain that UA should be seen as one of the possible alternatives to the provisioning of food, not as the solely solution (Despommier, 2011; Eigenbrod & Gruda, 2015; International, n.d.; The Urban Vertical Project, 2016). It furthermore does not aim to eliminate open farming or promises to completely solve food security issues and environmental degradation. However, this form of UA has the potential to become part of a solution for the research problem depicted in chapter 1 and is therefore a currently emerging and worth-exploring research field. As stated by The Urban Vertical Project (2016) *"Just because a solution to a problem does not save the world does not detract from the validity of that solution".* Overall, further research should be stimulated when it comes to the technological, agricultural and financial aspects of UA-systems, on which the scope of this research unfortunately cannot do justice.

It is mainly criticism related to energy use that is worth mentioning in light of this research (Barbosa et al., 2015; T. Kozai & Niu, 2016a, 2016b; Kozai, 2013). Vertical farming within a controlled environment often acquires all year-round LED lightning to create an optimal growing climate for plants. Kozai and Niu (2016c) have calculated that, depending on the crop, only around 0.7% of all the electrical energy used for the cultivation of 1 kg of yield is converted in 'digestible energy' within the edible plants. They furthermore state that the energy use is the only aspect in which controlled environment agriculture is very demanding and currently not likely to improve to a level of more than 3% of energy use efficiency (Kozai & Niu, 2016c). However, the most important aspect of growing food within a controlled environment is to consider the overall picture of resource use efficiencies compared to open land farming or conventional greenhouses. Exact calculations and comparisons of resource use efficiencies are however still very difficult to make and research on this matter has been growing over the last few years. The main challenge with comparing controlled environments to other types of farming, is the fact that there is often no available data when it comes to the exact water, energy and land use on an open farm or open greenhouse and a lot of embedded resources or CO2-emissions throughout the life-cycle of a product are therefore lost in calculations (Bailey et al., 2003; Barbosa et al., 2015; Canakci & Akinci, 2006; Kozai & Niu, 2016c; Pimentel, Berardi, & Fast, 1983; Yousefi, Khoramivafa, & Zarei Shahamat, 2015). However, when considering the possible reductions in resource use, vertical farming within a controlled environment mainly becomes an interesting alternative when additionally integrating different resource flows. Its high demand of energy should in that sense not be analysed without considering the main source of energy (fossil fuels vs. renewables) and without looking for example at yield, water-use or the elimination of transportation processes and fossil fuels for pesticides and fertilizers (Despommier, 2011; Eigenbrod & Gruda, 2015; Plantagon International, n.d.; Kozai & Niu, 2016a; Plantagon International et al., n.d.).

Overall, one of the most renowned studies on UA in vertical- and controlled-environments estimates that compared to normal open greenhouses, these UA-systems are able to achieve *"100% reduction in pesticide application, 95% reduction in water consumption by recycling transpired water vapour, 90% reduction in land area, 90 % reduction in variation of yield and quality, 50% reduction in fertilizer reduction, 50-70% reduction in labour hours per unit of yield and 30% reduction in plant residue loss"* (Kozai & Niu, 2016a, p. 396). Despite the fact that this research will not be able to further dive into the specifics of these numbers, they do provide an interesting summary on what makes vertical-, controlled- and resource-integrated-UA so interesting against the background of chapter 1. With these calculations in mind, this form of UA becomes a more sustainable alternative to open land farming or open horizontal greenhouses for at least a part of the global food production. As stated, it however does not aim to completely replace conventional agriculture, but intends to add to it by providing a sustainable alternative. In this way, UA could furthermore ease some of the current pressures for intensive agriculture practices and its impacts on resources like land, water and energy.

2.4 Conclusion

As an answer to the posed sub-question in this chapter: UA in a vertical, controlled and resource-integrated environment can be best defined as an urban industry that makes efficient use of the urban space; by growing food along the vertical dimension to generate relatively higher yields per square meter, within a controlled environment to ensure all-year round, healthy, pesticide- and synthetic-fertilizer-free food and within a resource-integrated way, to minimise the need for and smartly use water-, energy- and air-flows. The vertical dimension first of all acknowledges the scarcity of arable land and need for high agricultural yields. A controlled environment is able to create ideal growing climates for plants, while regulating all resource-flows within the system. This furthermore enables an integration of the food system with other local resources system, in which for example water, energy, CO_2 and oxygen flows can be regulated and redistributed in such a way that synergies can be created, within a greenhouse or with other type of buildings.

As UA is generally perceived as part of a potential solution for the research problem in chapter 1, this chapter has been working towards a form of UA that has the biggest potential to trigger desired and structural change. Vertical-, controlled- and resource-integrated-UA is strongly built upon technological innovation and affects the infrastructure and resource-flows within an urban context. In doing so, it is large-scale, high in productivity and efficient in resources. The latter plays an important part in calling UA a 'sustainable solution'. As stated, how land, water and energy are used within the production system of UA largely determines how healthy, sustainable and viable UA is. It is important to emphasise that the definition of vertical, controlled and resource-integrated sets the priorities for UA, it does not result in a one-size-fits-all model. The three aspects should be smartly designed according to the urban context and climate in which it is placed. With this definition and justification of vertical-, controlled- and resource-integrated-UA in mind, the case study selection in chapter 4 becomes clear. The analytical framework drafted in the next chapter will be applied in two empirical cases of this form of UA to provide more insights into the potential to drive and scale-up transition change. Vertical-, controlled- and resource-integrated-UA can in this sense be seen as a niche environment that has the potential to change the structures of a city. To further investigate the concepts of driving and scaling-up a potential socio-technical transition and arrive at an analytical framework, the following theoretical chapter becomes important.

3. THEORY

To gain a better of understanding of the transition potential of vertical-, controlled- and resource-integrated-UA, it has been introduced that this research will (1) first of all zoom in on the drivers behind the emergence of this type of UA; and will (2) secondly investigate the governance capacity of a city to scale-up this process. This chapter provides the theoretical background for the focus of this research, in which the following two sub-questions are central:

1.2 What drivers of transitional change can be found in theory?
2.1 What factors assist in scaling-up a transition process according to theory?

In order to answer these sub-questions, this chapter will take a multi-level-perspective (MLP) on socio-technical transitions, in which the concepts of regime, landscape and niche will be explained (section 3.1). Through the MLP, this research will first of all identify drivers of transitional change (section 3.2). Before moving on to the concept op 'scaling-up' within a transition process, some theoretical shortcomings of the MLP will be discussed (section 3.3). To overcome some of these shortcomings, section 3.4 will zoom in on the scale-up potential of a socio-technical transition, by building both on transition theories as well as on governance concepts (section 3.3). The analytical framework (section 3.5) will eventually be the foundation for the empirical analysis in chapter 5 and 6.

3.1 Multi-Level-Perspective

A transition is defined as the structural or fundamental change of a socio-technical system that generates new ways of functioning within that same system (De Haan & Rotmans, 2011). A socio-technical system can be defined along different sectors, for example an infrastructure system, an energy system, a food system or even a water-energy-food system. Systems could also be defined on different levels; globally, nationally and locally, as for example a city (Markard & Truffer, 2008; Murphy, 2015; Papachristos, 2011; Smith et al., 2010). When talking about systems in this way, their complexity becomes quickly visible and selecting their boundaries becomes highly challenging within research. Despite their challenges, the notions of socio-technical systems and transitions have become increasingly popular within research on innovation and human-environmental relations, as it provides insights in how desired systemic change takes place (De Haan & Rotmans, 2011; Geels & Schot, 2007; Geels, 2011; René Kemp et al., 2007; Roorda et al., 2014; Shove & Walker, 2007; Smith et al., 2010). Transition theories (like Strategic Niche Management, Technical Innovation Systems, Transition Management and the Multi-Level Perspective) are highly interrelated and generally provide a different perspective on roughly the same phenomena.

As this research is aimed at gaining more insight into driving and scaling-up a potential transition around vertical-, controlled- and resource-integrated-UA the Multi-Level-Perspective (MLP) initially provides a valuable theoretical perspective. The MLP looks at transitions of socio-technical systems by distinguishing between the regime-, the landscape- and the niche-level and argues that the interactions between these three levels drive transitional change (figure 5) (De Haan & Rotmans, 2011; Geels, 2011; Genus & Coles, 2008; Smith et al., 2010). The division between the three levels is helpful in conceptualising interactions between an emerging innovation, an established regime and an external landscape (Geels & Schot, 2007; Geels, 2002, 2011; Genus & Coles, 2008; Smith et al., 2010). The MLP will therefore be taken as the main theoretical framework for looking at drivers of vertical-, controlled and resource-integrated-UA and the capacity of a city to scale-up a potential socio-technical transition. However, it will also be complemented with relevant concepts from other research fields. Before diving into what drives (landscape- and niche-level) and what scales-up (regime-level) transitional change according to theory, it is relevant to define what is meant with the

regime-, landscape- and niche-level. The following sections will also show that a conceptualisation of a transition is not so straightforward and that certain theoretical shortcomings remain when it comes to the analytical capacity of transition theories (De Haan & Rotmans, 2011; Geels, 2011; Morone, Lopolito, Anguilano, Sica, & Tartiu, in press; Shove & Walker, 2007; Smith et al., 2010). Before paying deserved attention to some of these theoretical shortcomings (section 3.4), the MLP and its usefulness in light of this research will be explained.

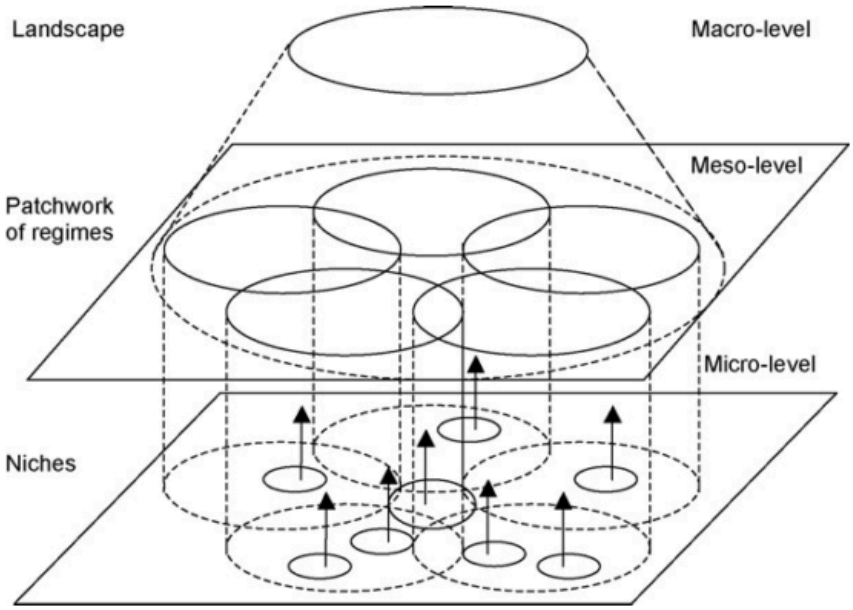

Figure 5: A MLP on a Socio-Technical System (Genus & Coles, 2008)

3.1.1 Regime Level

The regime- (meso) level refers to an established system or status quo that guides existing socio-technical activities, defines cognitive structures and with that largely determines the behaviour of regime actors (Geels & Schot, 2007). As stated by Duru, Therond, and Fares (2015, p. 1244), the regime *"supports the evolution of the dominant forms of production".* The regime level defines the general functioning of a socio-technical system and is characterised by path-dependency. Transition theories often divide the regime level in three components, which are structures (e.g. *"formal, physical, legal and economic aspects"),* cultures (e.g. *"cognitive, discursive, normative and ideological aspects*") and practices ("routines, habits, formalisms, procedures and protocols of actors") (De Haan & Rotmans, 2011; Loorbach & van Raak, 2006, p. 92).

Change on the regime level generally occurs in an incremental way in which the stable functioning of the regime is secured (Smith et al., 2010). However, Geels (2011, p. 27) state that a regime is not only embedded in technological structures, *"but also in cultural, political, scientific, market and industrial dimensions".* The interactions between all these sub-regimes also complicate the dynamics of a regime, as a change of one can (in) directly have an impact on the other. Figure 6 gives a visual representation of these sub-regimes and show how they are integrated and influence each other over time. With all of this in mind, the concept of a regime is often one of the most difficult ones to grasp and define in reality (De Haan & Rotmans, 2011; Geels & Schot, 2007; Konefal, 2015; Morone et al., in press; Smith et al., 2005)

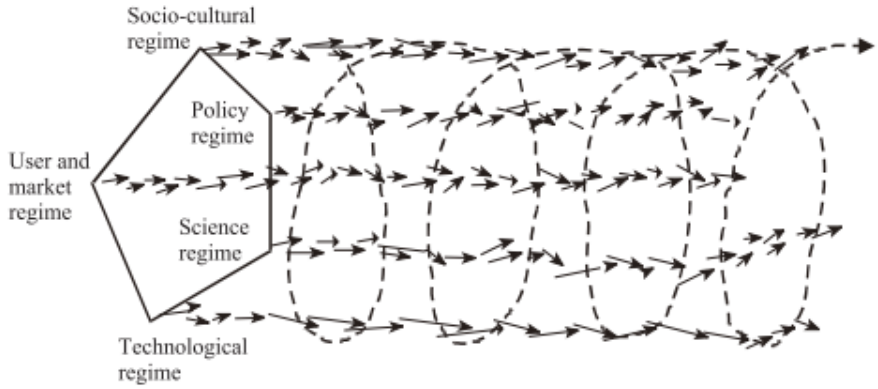

Figure 6: Regime Dimensions (Geels, 2011)

The regime is however the level on which a possible transition needs to takes place, as a transition implies a structural change in the functioning of a system on the regime level. In order for this to happen, the regime needs to encounter certain instabilities due to which it loses some of its legitimacy and so-called 'windows of opportunity' open up (Geels & Schot, 2007; Geels, 2002; René Kemp et al., 2007; Schot & Geels, 2008; Smith et al., 2010). Instabilities of the regime can mainly occur through landscape developments or niche pressures (De Haan & Rotmans, 2011; Geels & Schot, 2007; Geels, 2011; Rene Kemp, Schot, & Hoogma, 1998; Morone et al., in press). Landscape developments and niche pressures are therefore seen as the main processes that drive a potential transition and will be separately discussed in the section 3.2. The regime level however is required to adapt to these pressures and will become to play a prominent role in the scaling-up of a socio-technical transition, further elaborated in section 3.3.

3.1.2 Landscape Level

The landscape- (macro) level refers to the macro environment, e.g. cultural, political, and economical conditions, outside the direct control of a regime and often taking shape over a longer period of time. The stability of a socio-technical system is largely dependent on this exogenous landscape that provides the overall structural and cultural environment in which regimes and niches are able to evolve. As stated by Hodson and Marvin (2010, p. 479), landscapes *"create a broader context of opportunities and constraints within which actors and coalitions of actors operate".* A landscape is therefore a physical or rather stable environment that changes over a relatively long period of time (De Haan & Rotmans, 2011; Geels & Schot, 2007; Hodson & Marvin, 2010; Morone et al., in press). However, certain landscape developments are able to change the structure of a system, leading to stress on the regime level, further explained in section 3.2.

3.1.3 Niche Level

A niche is a rather isolated network of actors within a socio-technical system that aims to competes with the established regime in order to change its fundamental functioning (Caniëls & Romijn, 2008b; Rene Kemp et al., 1998; Nykvist & Whitmarsh, 2008; Schot & Geels, 2008). Niches are often formed around a technological innovation that could be seen as a radical alternative to the regime. They are developed on the micro-level within a small network of actors outside of the existing socio-technical regimes and are with that often less sensitive to certain landscape developments than regime actors (Smith et al., 2010). As Smith et al. (2010, p. 440) clearly explain, *"niches provide 'protective spaces' for path-breaking, radical alternatives whose performance may not be competitive against the selection environment prevailing in the regime"*. However, niches are therefore also developed in a new and still unstable sociotechnical setting, making them less powerful than the dominant

established regime (Geels & Schot, 2007; George Papachristos et al., 2013; Rauschmayer et al., 2015). Niches are often created through innovation experiments, the opening-up of new markets or through financial opportunities in the form of subsidies (Smith et al., 2010). Niches heavily revolve around experimentation and learning in order to improve their functioning and strengthen their actor network (Rene Kemp et al., 1998; Loorbach & van Raak, 2006).

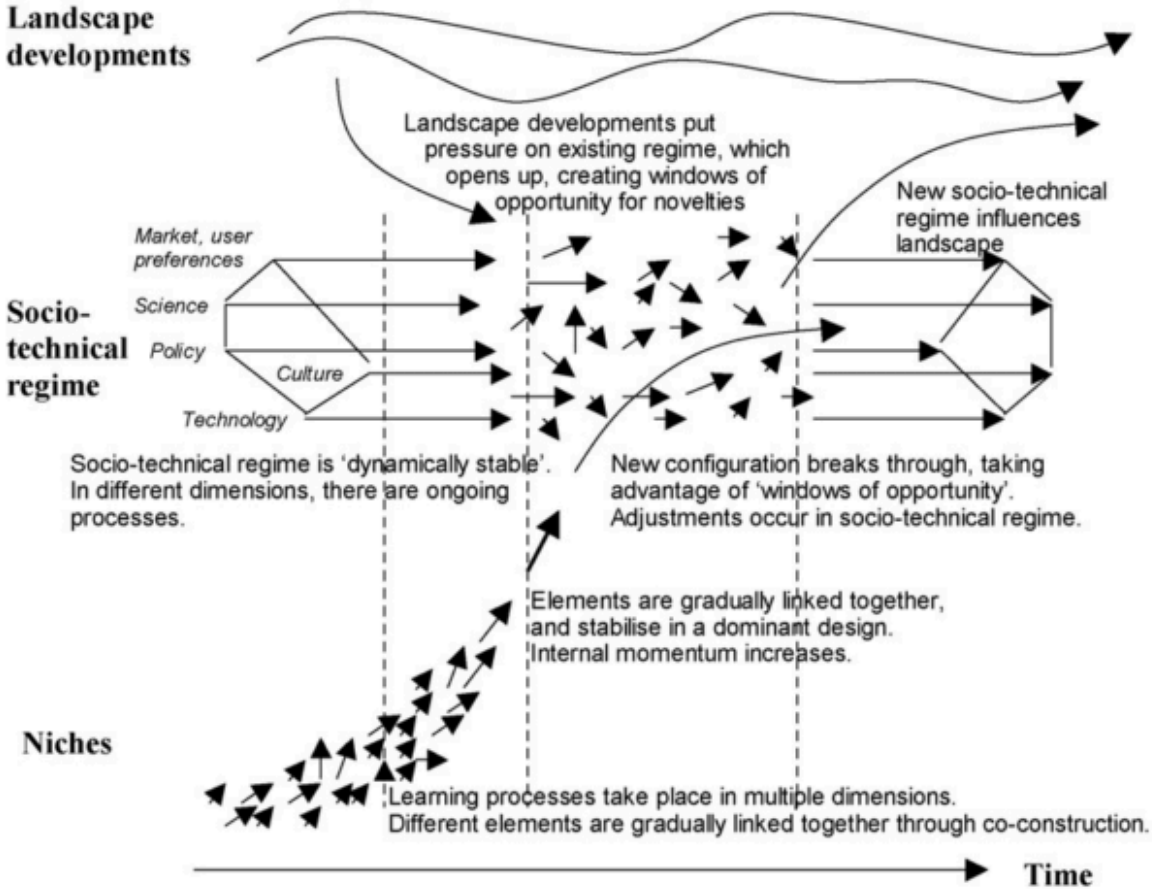

Figure 7: Interactions between the Regime, Landscape and Niche Level (Genus & Coles, 2008)

So, according to Geels and Schot (2007), Geels (2002; 2011), Genus and Coles (2008) and Smith et al. (2005), the nested hierarchy between landscape, regime and niche leads to certain interactions that potentially create windows of opportunity for structural change. The previously described levels and the potential for socio-technical transition come together in figure 7, in which it can be seen that a generally stable regime can potentially experience stress through top down landscape developments and bottom up niche pressures. In this way stress opens up a window of opportunity for structural change As this research is initially interested in drivers of change, the following section will look more specifically at the two main interactions that potentially drive a socio-technical transition, which are landscape developments and niche pressures.

3.2 Driving a Socio-Technical Transition

The sub-question that will be central within this section is: 'what drivers of transitional change can be found in theory?' By zooming in on landscape developments and niche pressures the answer becomes more clear and will eventually lead to the analytical framework in chapter 3.5. This sub-question and the resulting analytical framework could be helpful in explaining the emergence of vertical-, controlled- and resource-integrated UA as a niche environment, embedded within the other levels of regime and landscape.

3.2.1 Landscape Developments

On the landscape level certain developments can take place that touch upon the stability of a regime and create regime stress as previously indicated. Within literature a variety of landscape developments have been investigated, some more extensively explained than others (De Haan & Rotmans, 2011; Driel & Schot, 2005; Geels & Schot, 2007; Morone et al., in press; Smith et al., 2010). Overall there is not one unified definition of landscape developments, but some examples from transition studies are helpful in gaining a more specific idea of what drives a socio-technical transition from the landscape level. First of all, De Haan and Rotmans (2011) for example make a distinction between structural tensions and cultural tensions, in which the first emphasise tensions, related to structural changes within e.g. the physical environment, economic structures or legislation. The later relates more to normative trends or changes that might occur within an overarching ideology or discourse. Driel and Schot (2005) make a more specific distinction between landscape developments based on the timespan and scale on which they occur, namely exogenous shocks (e.g. economic crisis), long-term trends (e.g. demographics, economics) and the physical environment (e.g. climate).

Exogenous shock could be related to a macro-economic crisis or national security issues, which put relatively rapid and sudden stress on the regime level. Morone et al. (in press, p.3) also refer to these exogenous shocks as *"unpredictable activities",* opposed to other more *"intentional sources of pressures"* in the form of political or economic incentives. The latter relates to Driel and Schot (2005) their definition of long-term trends, which refers to any political, market or knowledge trends that is not as abrupt as an exogenous shock, but is able to change the structure of a regime on the longer term. Thirdly, the physical environment related to a more fixed context in which a socio-technical regime is embedded and is generally stable or changing slowly over a longer period of time. Examples of the physical environment are for example physical resource availability and climatic conditions (Driel & Schot, 2005; Geels & Schot, 2007). The independent variables belonging to landscape developments in this research will therefore be divided in the physical environment, long-term trends and exogenous shocks (figure 8 and section 3.5).

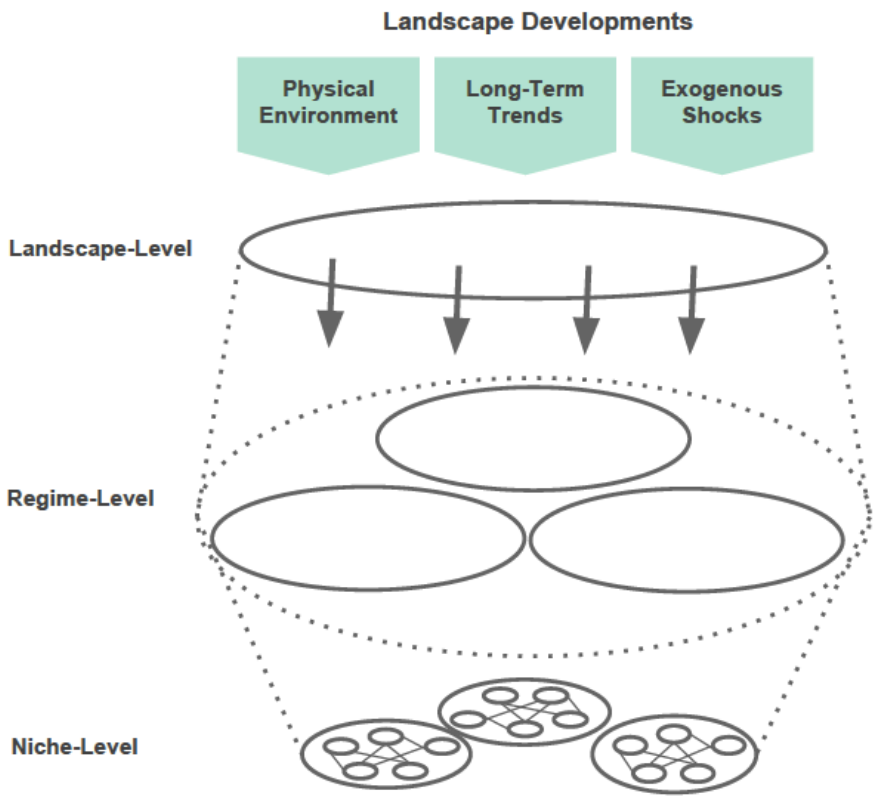

Figure 8: Landscape Developments

3.2.2 Niche Pressures

In order to create structural change on the regime level and drive a transition, niche actors need to exert pressure through certain mechanisms. As indicated, windows of opportunity on the regime level should occur in order for a niche experiment to gain transitional power. (De Haan & Rotmans, 2011; Geels & Schot, 2007; Geels, 2011; Loorbach & van Raak, 2006; Smith et al., 2005). Such windows often open up when the established regime experiences certain stresses from either the earlier described landscape developments or niche pressures or a combination of both. When zooming in on niche pressures, there have been a lot of different classifications within transition theories. Most concepts have been derived from SNM, which is the transition theory primarily focused on the successful acceleration of niche experiments (Loorbach & van Raak, 2006; Schot & Geels, 2008) In order to gain a better understanding of niche pressures, it is valuable to zoom in on some of the main definitions. According to (Geels, 2011, p. 28) niches can exert pressures through *"the articulation of expectations, the building of social networks and learning processes".* Lopolito et al. (2011) formulate three similar main mechanisms within niche formations that could contribute to their stability and ability to put pressure on an existing regime, which are the expectation-, power- and knowledge-mechanisms. This distinction is highly related to factors provided within other literature on socio-technical transitions and more specifically on SNM (Coenen, Suurs, & van Sandick, 2010; Rene Kemp et al., 1998; Loorbach & van Raak, 2006; Nykvist & Whitmarsh, 2008; Schot & Geels, 2008). Therefore, the expectation-, knowledge- and power-mechanism function as the three main independent variables in this research (figure 9 and section 3.5). The expectation mechanism first of all exists of a clear vision and shared expectations by all actors within the niche. Secondly, it includes a shared understanding of the functioning and benefits of the innovation represented by the niche. Secondly, the knowledge mechanism focuses on the importance of knowledge improvement in order to take away the insecurities that may be posed around the innovation. The knowledge mechanism can be expressed in *"learning-by-doing"* and *"learning-by-interacting"*, which emphasise the importance of experimentation and knowledge-exchange within the network of a niche (Lopolito et al., 2011, p. 1782) Thirdly, the power mechanisms refers to the ability of a group or individual actor to

drive the innovation, as niches often exists of a relatively small, but devoted group of people. This mechanism includes the support of powerful individuals or groups, as well as a financial resource-cooperation within the network (Lopolito et al., 2011).

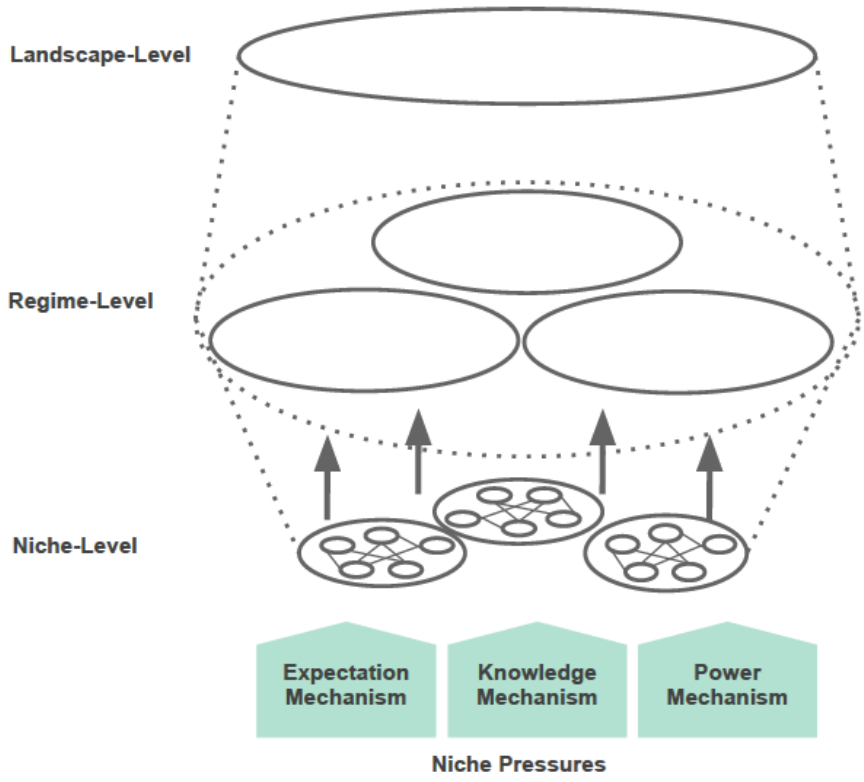

Figure 9: Niche Pressures

To sum up, there are several processes within and between the regime-, landscape- and niche level that contribute to a socio-technical transition. However, it can be concluded that drivers behind a socio-technical transition have mainly been formulated on the landscape and niche level, in the form of landscape developments (existing of changes in the physical environment, long-term trends and exogenous shocks) and niche pressures (existing of an expectation-, power- and knowledge mechanism). As shown, these different processes, often in combination with each other, are able to create windows of opportunity on the regime level. Through these, in other words, gateways of transitions, a niche is able to break through and create structural change (Geels, 2002, 2011; Genus & Coles, 2008; Smith et al., 2010). As stated, the regime level is however ultimately dealing with these drivers of change and is required to adapt. Only when the regime is able to fruitfully govern the triggered transition-change, a socio-technical transition could be scaled up (De Wildt-Liesveld, Bunders, & Regeer, 2015; Ford & King, 2015; Foxon et al., 2009; Konefal, 2015; Smith et al., 2005; Van den Bosch & Rotmans, 2008). The MLP has hypothesised that windows of opportunity on the regime-level can result from pressures coming from the landscape- and niche-level. However, what exactly happens on the regime-level, once such a windows is opened, is less clear (Geels & Schot, 2007; Geels, 2011; Konefal, 2015; Shove & Walker, 2007). The MLP does not provide a specific analytical approach to identify the capacity of a regime to turn an opportunity into desired change, instead of a collapse. When it comes to vertical-, controlled- and resource-integrated-UA the MLP is therefore not sufficient to explain how triggered transitional change could actually be scaled-up in order to structurally change the food provisioning within an urban context. Some theoretical shortcomings of the MLP will therefore be discussed, before arriving at a more comprehensive framework for 'scaling-up'.

3.3 Theoretical Shortcomings

In the light of this research there are a few theoretical shortcomings that are worth mentioning, to move from solely drivers of transitional change to the scale-up potential of a system. Geels and Schot (2007) indicate that the MLP on socio-technical transitions has been criticised based on three main aspects: first of all the lack of analytical tools for empirical validation, secondly the too prominent focus on niches in order to create change and thirdly a neglect of agency. This section will shortly touch upon these three points and indicate how this research aims to meet some of these challenges.

3.3.1 Lack of Analytical Tools for Empirical Validation

First of all, the MLP has descriptive power when it comes to three levels and the basic idea of structural change. However, when trying to turn these concepts into a more precise analytical framework as a researcher, the challenges and shortcomings of transition theories become more visible (Geels, 2011; Shove & Walker, 2007). Generally, all the different theories on socio-technical transitions have been criticised to some extent based on their ability to provide a clearly defined framework that is empirically applicable (Geels, 2011; Genus & Coles, 2008; Konefal, 2015; Shove & Walker, 2007; Smith et al., 2010). An extensive desk research on the different theories around transitions has resulted in the conclusion that a clear-cut framework to analyse transition pathways is not available (Geels & Schot, 2007; Geels, 2002, 2011; Genus & Coles, 2008; Holtz, 2011; René Kemp et al., 2007; Loorbach & van Raak, 2006; Nykvist & Whitmarsh, 2008; Schot & Geels, 2008; Shove & Walker, 2007). This is one of the main challenges when it comes to analysing transitions, mainly when it comes to the complexity and duration of transition processes. As shortly stated, the complexity of systems, multi-level processes and stakeholder interactions make it in reality difficult to clearly identify causes and effects over time. *"What looks like a regime shift at one level may be viewed merely as an incremental change in inputs for a wider regime at another level"* (Geels & Schot, 2007, p. 400). It is therefore very important to as a researcher of transitions to clearly demarcate the scope of a research and acknowledge its limitations. This research tries to do this by zooming in one two aspects of the transition spectrum, which are drivers of change (landscape-level and niche-level) and the governance capacity to scale-up transitional change (regime-level), within a city context. By limiting the scope of the research and combining the theoretical concepts, this research is able to construct an analytical framework to make transition concepts more graspable and to guide empirical validation. The analytical framework will be presented in section 3.5.

3.3.2 Too Prominent Focus on Niches

Secondly, transition processes have revolved largely around the capacity of niche networks to drive change through learning and experimentation (Caniëls & Romijn, 2008b; Rene Kemp et al., 1998; Loorbach & van Raak, 2006; Schot & Geels, 2008). Due to the more clearly defined concept of a niche, their role within socio-technical transitions has been more extensively emphasised. However, the role of the landscape level in triggering transitional change has generally been less clear and needs further investigation (Morone et al., in press). As a transition is often the result of a combination of pressures from both levels, it is valuable to study both niche pressures and landscape developments in the same context, instead of isolating one of them from the analysis. This approach has therefore also been applied in section 3.2. Furthermore, transition theories are rather clear on what the regime level is in abstract, but not on what that implies in practice (Geels, 2011; Shove & Walker, 2007; Verbong & Geels, 2007). The regime level will therefore play a more prominent role in the next section, related to the neglect of agency and the aspect of scaling-up in section 3.4. This research has in the end included all three levels in the analysis, by zooming in on the landscape and niche level for driving a potential socio-technical transition (section 3.2) and on the regime level when it comes to the scale-up potential (section 3.4).

3.3.3 Neglect of Agency

Thirdly, transition theories and in this context mainly the MLP have been criticised for often neglecting the role of agency within transitional processes (Geels, 2011; Konefal, 2015; Markard et al., 2012; Smith et al., 2005). According to Smith et al. (2005, p. 1503) *"agency is the ability to take action and make a difference over a course of events"*. It refers in other words to the adaptive or governance capacity of a regime to deal with incoming pressures. As shown in section 3.3, transitions are not automatically a result of certain pressures, but also require a certain agency or capacity to turn pressures into fruitful change (Konefal, 2015). Shove and Walker (2007) also argue that this is often a missing link within transition studies and should further be explored. An explanation can be found in the fact that it is still very difficult to systematically reveal what factors play a role within a possible socio-technical transition. By including the role of governance (section 3.3) within the analysis of scaling-up, this research is making an attempt to investigate this rather underexposed theme.

So, in order to adhere to the previously explained shortcomings, this research has first of all tried to turn the descriptive power of transition concept into a more analytical one. The drafted analytical framework in the following section 3.5 will be the last step in concluding this chapter and in showing how the different theoretical concepts can actually be of use to empirical validation. By taking the MLP division between landscape, regime and niche, specific drivers and corresponding indicators of a potential socio-technical transition have been identified. In this way, the analytical framework has also been able to address the issue of a too prominent focus on niches. Both landscape developments and niche pressures are included in this research and will be individually assessed to be able to show their influence on driving a potential transition. Lastly, the neglect of agency will be addressed by moving beyond landscape and niche drivers and additionally zooming in on the process of scaling-up and the more specific role of governance capacity.

3.4 Scaling-up a Socio-Technical Transition

The sub-question that will be central in this question is: 'what factors assist in scaling-up a transition process according to theory?' This question is posed in order to go beyond the initial question on what drives a potential socio-technical transition, but to also shine light on the ability of a system to govern that triggered transitional change (Konefal, 2015; Smith et al., 2005; Van den Bosch & Rotmans, 2008). Only then a niche experiment has the potential to move beyond its protected environment and actually create structural change. This process can be expressed in the concept of scaling-up, which can be defined as *"the translation or societal embedding of sustainable niche practices in the regime"* (Van den Bosch & Rotmans, 2008, p. 11). According to (van Doren, Driessen, Runhaar, & Giezen, 2016, p. 3) scaling-up is about a process *"where information from one scale is transferred to another, thereby reaching a higher level of scale and a greater impact".* They make a conceptual distinction between a horizontal and a vertical dimension of scaling-up, in which the first generally refers to a scale-up in scale and the latter to a scale-up in institutional impact. It has been hypothesised that both processes influence each other and are both needed in order to facilitate structural change(van Doren et al., 2016). The scale-up potential of a socio-technical transition is highly dependent on the capacity of a regime to cope and adapt to triggered change (Smith et al., 2005, p. 1502). The capacity of a city to scale-up is within this research defined as 'governance capacity' and will be further investigated in this section. Governance and more specifically governance capacity are however not well-defined concepts within transition theories and studies have often been criticised for this neglect (Geels, 2011; Shove & Walker, 2007; Smith et al., 2005). In order to arrive at an answer to the previously stated sub-question, this section will look beyond transition theories and will try to build on a more comprehensive definition of governance capacity.

3.4.1 Governance Capacity

Generally, governance refers to *"to the complex processes and interactions that constitute patterns of rule"* within multi-stakeholder (state, market and civil-society) networks (Bevir, 2011, p. 2). With that, governance largely plays a role in guiding actions to maintain or create a desired environment. It has increasingly become an important realm within sustainable development and more specifically an important part of guiding or scaling-up socio-technical transitions (Lange et al., 2013). As introduced however, the concept of governance has not been used in a very coherent and structured way within transition studies. As a response to that criticism, transition researchers have tried to further investigate the role of governance by modifying the concept to the purpose of several research topics (Cash, 2016; Coenen, Suurs, & van Sandick, 2010; Loorbach, 2010; Marsden, 2013; Smith et al., 2005; van den Bosch & Rotmans, 2008). On the one hand, governance is referred to as an iterative and long-term process in TM (Loorbach et al., 2010; Loorbach, 2010; Roorda et al., 2014). On the other hand, more specific attention has been devoted to concepts like power and agency in transition pathways (F. Avelino & Rotmans, 2009; Geels & Schot, 2007; Geels, 2011; Konefal, 2015; Smith et al., 2005). Despite the fact that researchers touch upon the subject of governance, a clear analytical framework is still lacking within transition studies. Especially when building further on the multi-level distinction between the landscape, regime and niche level, it become visible that regimes are not well defined and that clear indicators for governance capacity are not provided. A possible explanation could be found in the complexity of transition processes over time and the challenge to clearly define the level and boundaries of a regime in reality (Geels, 2011; Shove & Walker, 2007). However, when searching for definitions of governance capacity within other frameworks related to institutional adaptive capacity or climate change adaptation, valuable overlap with and additions to transition theories can be found. In order to arrive at a clear definition of governance capacity and its role in in scaling-up a socio-technical transition, this research will therefore further build on some of these concepts.

First of all, governance capacity could be related to the concept of (institutional) adaptive capacity, which has been more broadly used within studies on socio-ecological systems and resilience (Folke, Hahn, Olsson, & Norberg, 2005; Foxon et al., 2009; Gupta et al., 2010). Gupta et al. (2010, p. 461) define institutional adaptive capacity *"as the inherent characteristics of institutions that empower social actors to respond to short and long-term impacts either through planned measures or through allowing and encouraging creative responses from society"*. They have come up with an extensive and useful framework for analysing this capacity along certain dimensions and criteria. The main criteria formulated by Gupta et al. (2010) are; room for a variety in problems, actors, levels and solutions; room for learning, room for individual action, room for leadership, the availability of resources and fair decision-making. These criteria are also highly related to the governance capacity framework formulated by Mees and Driessen (2011, p. 253) in the context of urban climate change adaptation; existing of a legal, managerial, political, resource and learning pillar. Also Van Doren et al. (2016, p. 7-11) have recently constructed a helpful analytical framework in the context of scaling-up low-carbon urban development, in which indicators have been classified along; *"measures, operational arrangements, policy context, market context, socio-cultural context and the natural- and build-context".* Ford and King (2015) talk more specifically about the concept adaptation readiness, which refers to not only the hypothetical ability of a system to adapt, but also to the willingness or readiness of a system to use that ability. In other words, it moves beyond adaptation potential, towards the probability that adaptation actually occurs. Based on a large amount of research, Ford and King (2015) have designed an analytical framework to assess adaptation readiness consisting of six main factors. According to these authors, the readiness of a system to adapt or in other words to govern systematic change, is determined by; political leadership, public support, institutional organisation, decision-making in the form of stakeholder inclusion, availability of scientific knowledge

and lastly, funding for all adaptation processes. De Wildt-Liesveld, Bunders and Regeer (2015, p. 158) focus more on the concept of adaptive capacity on the niche level, in which they argue that the concepts of *"diversity of actors", "knowledge generation"* and *"alignment*" are key, of which the latter mainly refers to scaling-up niche experiments and aligning them with the institutional setting within the regime.

When connecting these criteria and indicators on adaptive and governance capacity to transition theories, it can be seen that overlap and valuable additions can be found. When for example looking at the scaling up of transition experiments, Van den Bosch and Rotmans (2008, p. 49) have formulated process guidelines that involve a strategic *"allocation of resources", "reflection on barriers and opportunities", "learning-processes", "feedback-mechanism", " inclusion of change agents"* and *"management guarantees"* (Van den Bosch & Rotmans, 2008, p. 50-51). Konefal (2015, p. 613) sees transition more as a result of multi-stakeholder initiatives (MSIs) in which he investigates the role of governance along *"membership selection, decision-making procedures and access to resources".* Highly related to this classification are the conditions provided by Smith et al. (2005), who mention membership or stakeholder inclusion, resource distribution and the management of expectation as the three main conditions for affecting change. Furthermore, Avelino and Rotmans (2009) talk about governance in terms of power and show that power plays a role in all phases and levels of transitions, which is already nested in the hierarchical division between landscape, regime and niche level. According to them a transition could be managed through *"empowerment and leadership",* for which the conditions can be found in *"access to resources, strategies to mobilize them, skills to apply these strategies and the willingness to do so"* (Avelino & Rotmans, 2009, p. 563).
Furthermore, Wallis (2015) points out that systemic changes or socio-technical transitions are best viewed from a systemic governance perspective, based on social learning and adaptation.

In order to gain more clarity in this large amount of criteria and indicators for governance capacity and scaling-up, it has been helpful to map and cluster all of them to see where they overlap (Avelino & Rotmans, 2009; De Wildt-Liesveld et al., 2015; Ford & King, 2015; Gupta et al., 2010; Konefal, 2015; Mees & Driessen, 2011; Smith et al., 2005; Van den Bosch & Rotmans, 2008; Wallis, 2015). In doing so, the governance capacity of a regime in this research could be divided into three main independent variables: which is the degree of awareness, the degree of willingness and the degree of power, each sub-divided into two indicators (figure 10 and section 3.5). The degree of awareness, refers to the awareness of regime actors on the problem and possible solutions, which can be expressed in two indicators; which is firstly the access to knowledge and secondly the process of learning. Furthermore, the degree of willingness expresses the willingness of regime actors to act according to their awareness. When looking at the previously cited literature, the degree of willingness could be expressed in firstly the inclusion of stakeholders and secondly in political leadership. Thirdly, the degree of power refers to the actual ability of regime actors to act and is mainly associated with resources and strategies. The degree of power can be divided in first of all the access to financial and legislative resources and secondly in the formulation of long-term strategies.

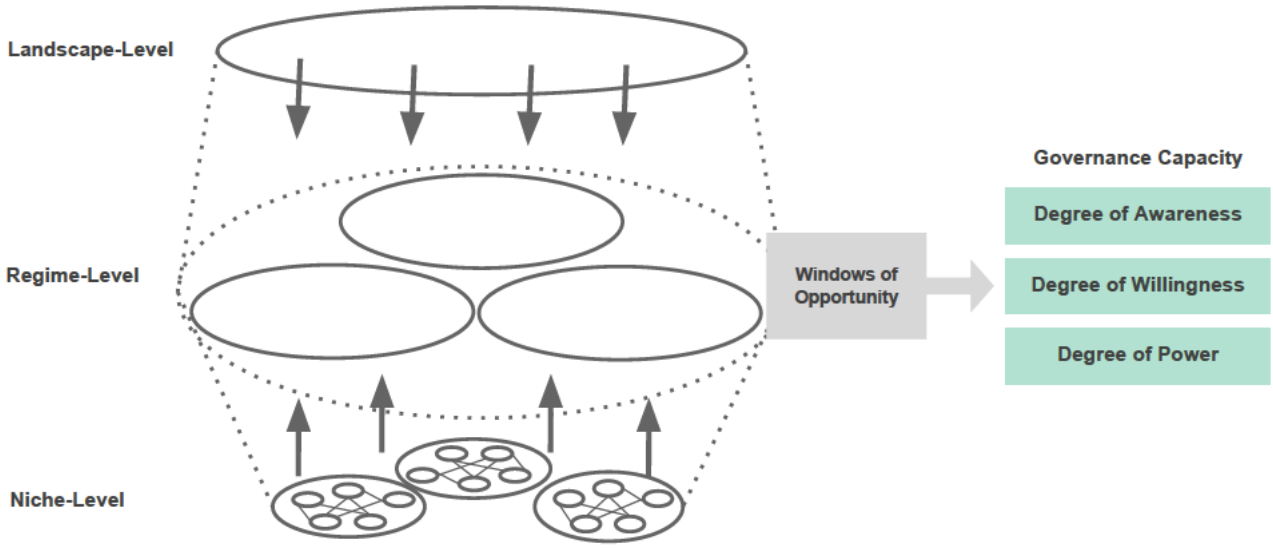

Figure 10: Governance Capacity

Overall it can be argued that there is a lot of overlap between niche mechanisms and the role of governance on the regime level, which makes it difficult to clearly distinguish in theory what the essential differences are. It can for example be seen that the role of knowledge and resources is both theorised to be important within the protected niche environment as within the established regime. Within this research the governance capacity of a regime has been separately formulated, in order to explain how a potential socio-technical transition could be scaled-up. It is hypothesised that a strong governance capacity on the regime level, assists in coping with niche pressures and landscape developments and in facilitating structural change. In this way, the role of e.g. knowledge, resources or cooperation can have different functions, including different actors on different levels. Before giving a more extensive overview of these theoretical choices in the analytical framework in section 3.5, it is important to shortly reflect on some shortcomings within theory. As explained, transition theories are still in their early stages of development and despite their growing popularity, they have also been criticised on several accounts. This research does not aim to provide an extensive overview of all the debates around transition theories. However, as it is largely building upon this research field and is acknowledging its value, it would be ignorant to not shortly touch upon some possible shortcomings.

3.5 Analytical Framework

The complexity of socio-technical transitions has by now been addressed and the scope of this research has mainly been defined along the MLP, by focusing on drivers of change (landscape- and niche-level) and the role of governance capacity (regime-level). In Figure 11, the previously provided information has been shortly visualised, in which the green shaded areas are the points of focus within this research. This final section aims to structure and cluster some of the earlier explained concepts in order to provide an analytical framework for landscape developments, niche pressures & governance capacity, (De Haan & Rotmans, 2011; Driel & Schot, 2005; Geels & Schot, 2007; Geels, 2011; Lopolito et al., 2011; Morone et al., in press; Nykvist & Whitmarsh, 2008; Smith et al., 2010). In this way, the analytical framework is the final answer to the two sub-questions:

1.2 What drivers of transitional change can be found in theory? (Table 2)

2.1 What factors assist in scaling-up a transition process according to theory? (Table 3)

Table 2 and table 3 show the analytical framework that will guide the empirical analysis in chapter 5 and 6 and has been divided into independent variables, hypotheses, indicators and methods. Both the independent variables, hypotheses and indicators have been derived from literature, however they have been modified to the purposed of this research. Especially landscape developments have been chosen based on the research topic of UA within the urban context. Frist of all, table 2 is divided into the landscape- and regime-level and provides an answer to the sub-questions: What factors drive a potential socio-technical transition according to theory?

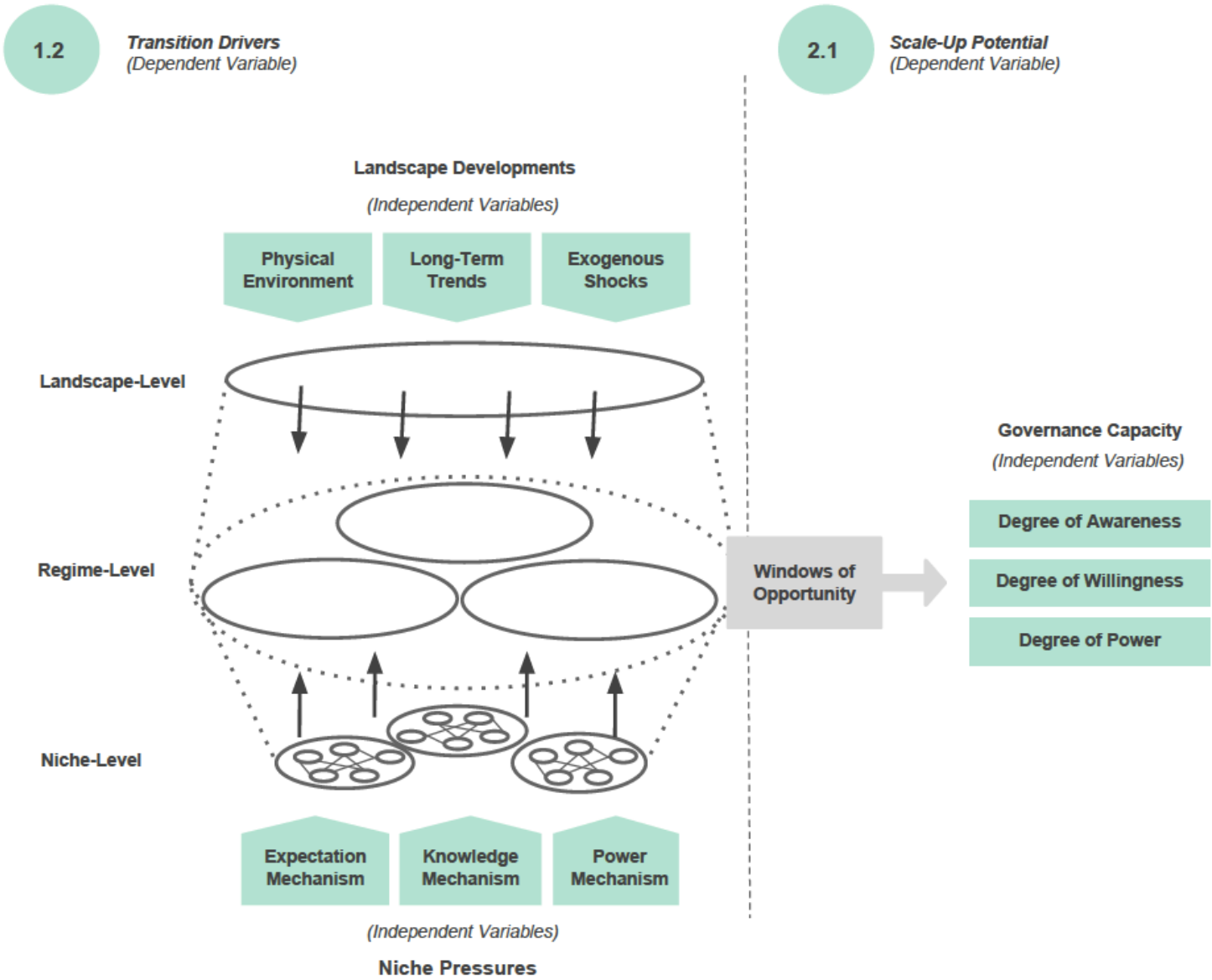

Figure 11: Visual Representation of Analytical Framework

TRANSITION DRIVERS (Dependent Variable)			
LANDSCAPE – Landscape Developments			
Independent Variables	**Hypotheses**	**Indicators**	**Methods**
Physical Environment (De Haan & Rotmans, 2011; Driel & Schot, 2005; Geels & Schot, 2007; Morone et al., in press; Smith et al., 2005)	The physical environment refers to the relatively fixed or very slowly changing environment of a socio-technical system. Examples can be found in climatic conditions and the rather fixed availability of natural resources, like land. In the case of urban agriculture it is hypothesised that a low and decreasing availability of arable land and climate change could create stress within an established regime.	**Availability of Arable Land** (% Of Total Land Area)	Desk Research, Statistical Data
		Climate Zone (Cold, Temperate, Sub-Tropic, Tropical)	Desk Research, Statistical Data
Long-Term Trends (De Haan & Rotmans, 2011; Driel & Schot, 2005; Geels & Schot, 2007; Morone et al., in press; Smith et al., 2005)	Long-term trends are external processes that find themselves in between the physical environment and exogenous shocks when it comes to the speed on which they occur. Long-term trends are able to slowly alter the structures, cultures and practices of a system (e.g. demographics). In the case of urban agriculture it is hypothesised that the following could create stress within an established regime; a high urban population, high urban population density, high urban population growth, low GDP per capita, low food security, high food import and a low self-sufficiency when it comes to water and energy.	**Urban Population** (Number and %)	Desk Research, Statistical Data
		Urban Population Density (People per km2)	Desk Research, Statistical Data
		Urban population Growth (% Per Year)	Desk Research, Statistical Data
		GDP per capita, PPP (Current International $)	Desk Research, Statistical Data
		Food Security Index (Index 0-100)	Desk Research, Statistical Data
		Food Import (% Total Food Consumed)	Desk Research, Statistical Data
		Water Self-Sufficiency (%)	Desk Research, Statistical Data
		Energy Self-Sufficiency (%)	Desk Research, Statistical Data

Exogenous Shocks (De Haan & Rotmans, 2011; Driel & Schot, 2005; Geels & Schot, 2007; Morone et al., in press; Smith et al., 2005)	Exogenous shocks refer to unforeseen and sudden occurrences that impact a socio-technical system (e.g. oil-crisis, political crisis, war). It is hypothesised that a shock could create stress within an established regime	**Experienced Exogenous Shocks** (No/Yes, which ones?)	Desk Research + Semi-structured Interview, Qualitative Data
NICHE – Niche Pressures			
Independent Variables	**Hypotheses**	**Indicators**	**Methods**
The Expectation Mechanism (Geels, 2011; Lopolito et al., 2011)	The expectation mechanism refers to the articulation of shared expectations and visions within a niche network and to a shared awareness on the socio-technical advantages of the niche innovation. It is hypothesised that a clear articulation of expectations and visions together with a high degree of awareness are able to create stress within an established regime	**Articulation of Expectations & Visions** (Inconsistent, Rather Inconsistent, Rather Consistent, Consistent)	Semi-structured Interview, Qualitative Data
		Awareness on Socio-Technical Advantages (Low, Medium, High)	Semi-structured Interview, Qualitative Data
The Knowledge Mechanism (Geels, 2011; Lopolito et al., 2011)	The knowledge mechanism refers to the knowledge that is needed to create a stable niche innovation that is able to compete with the existing regime. Within the niche network it is therefore important to gather knowledge through processes of learning-by-doing (generate knowledge through experiments) and learning-by-interacting (exchange knowledge within the network). It is hypothesised that a high degree of learning-by-doing together with a high degree of learning-by-interacting is able to create stress within an established regime	**Learning-by-Doing (Knowledge Generation by Experimentation)** (Low, Medium, High)	Semi-structured Interview, Qualitative Data
		Learning-by-Interacting (Knowledge Exchange) (Low, Medium, High)	Semi-structured Interview, Qualitative Data
The Power Mechanism (Geels, 2011; Lopolito et al., 2011)	The power mechanism refers first of all to the essential support of powerful actors within the niche network in order to mobilize resources and secondly to the degree of financial resource cooperation, as solely one actor cannot push the niche innovation forward. It is hypothesised that the support of powerful actors and a high degree of financial resource cooperation within the niche network is able to create stress within an established regime	**Support of Powerful Actors** (Low, Medium, High)	Semi-structured Interview, Qualitative Data
		Financial Resource-Cooperation (Low, Medium, High)	Semi-structured Interview, Qualitative Data

Table 2: Analytical Framework: Driving a Socio-Technical Transition

Table 3 represents the regime-level and provides an answer to the sub-question: what factors assist in scaling-up a potential socio-technical transition according to theory?

SCALE-UP POTENTIAL (Dependent Variable)			
REGIME – Governance Capacity			
Independent Variables	**Hypotheses**	**Indicators**	**Methods**
The Degree of Awareness	The degree of awareness refers to the access to knowledge and learning processes on the regime level. It is hypothesised that an easy access to knowledge and the presence of learning processes within the regime creates a high degree of awareness on a problem and its possible solutions. It is in other words hypothesised that it leads to awareness on the necessity to structurally change.	**Access to Knowledge** (Difficult, Rather Difficult, Rather Easy, Easy)	Semi-structured Interview, Qualitative Data
		Learning Processes (Low, Medium, High)	Semi-structured Interview, Qualitative Data
The Degree of Willingness	The degree of willingness refers to the extent to which regime actors have the will to act in line with their awareness and depends on the inclusion of stakeholders and the support of powerful actors. It is hypothesised that a broad inclusion of stakeholders and the presence of political leadership will lead to a high degree of willingness on the regime level to structurally change.	**Inclusion of Stakeholders** (Limited, Medium, Broad)	Semi-structured Interview, Qualitative Data
		Political Leadership (Low, Medium, High)	Semi-structured Interview, Qualitative Data
The Degree of Power	The degree of power refers to financial and legislative resources and secondly to the formulation of long-term strategies on the regime level. Together they are an indication of the actual ability of regime actors enable structurally change. It is hypothesised that adequate financial and legislative resources together with the presence of long-term strategies lead to a high degree of power on the regime level to structurally change	**Financial and Legislative Resources** (Low, Medium, High)	Desk Research + Semi-structured Interview, Qualitative Data
		Formulation of Long-Term Strategies (No/Yes, which ones?)	Desk Research + Semi-structured Interview, Qualitative Data

Table 3: Analytical Framework: Scaling-Up a Socio-Technical Transition

It is important to emphasise that the designed framework is not a blueprint of all the possible factors driving transitions, but is a simplified picture of reality, in which a lot of different processes will occur at the same time. However, it can be helpful in predicting certain mechanisms that enable a transition within the context of UA and the WEF nexus. Table 2 and 3 should be seen as guidelines when conducting the case studies analysis, further explained in chapter 4. They are helpful in structuring interview-questions and demarcating the scope of the research. However, this does not mean that other conditions that might arise during the analysis will not be included within the results of this research. With that, this research also tests the usefulness of such a framework within an empirical-setting. The following chapter will further elaborated on the methods that will be used in order to test this framework. Overall, the purpose of this chapter has been to look for ways in which theory can be helpful in guiding an empirical analysis. However, every decision made by a researcher could be inevitably biased in some ways (Shove & Walker, 2007). Being aware of the theoretical limitations can be an advantage, as it keeps the mind of the researcher more open to other possibilities and conditions that might arise in practice. The analytical framework has tried to grasp some of the mains theoretical concepts and should purely be seen as a possible framework to identify factors assist in driving and scaling-up a potential socio-technical transition.

4. METHODS

This chapter will elaborate on the methods that will be used to conduct this research and will exists of a research strategy, case study selection and data collection, including desk research, an explanation of the semi-structured interview set-up and interviewees.

4.1 Research Strategy

As the first three chapters might have shown, potential socio-technical transitions and are very complex and the field of vertical-, controlled- and resource-integrated-UA is highly interdisciplinary. This degree of complexity also leads to difficulties when conducting scientific research. According to Verschuren and Doorewaard (2010), a research strategy should therefore make the choice of a researcher between breadth and depth in his or her research clear. Choosing a specific scope and acknowledging the possible limitations a certain method are therefore necessary in order to guarantee the feasibility of the research (O'Neill et al., 2013).

As O'Neill et al. (2013) state, choices regarding the methodology have to be based on the nature of the research questions and objective in order to properly address the problem driving the research. The problem setting in chapter 1 shows that the field of UA is cross-boundary, touching upon several disciplines, sectors and stakeholders over time. Even though the global need for UA might be visible, the possible transition towards UA on a local level is highly complex and context-dependent. As stated this research will therefore be an in-depth study that is diagnostic and explanatory in nature. In order to make a useful, realistic, feasible, clear and informative research contribution; certain demarcations have been made, which have been justified throughout the previous chapters (Verschuren & Doorewaard, 2010). First of all this research has chosen to narrow down the scope of a potential socio-technical transition, by mainly focusing on drivers of change and the role of governance capacity to scale-up this change. Furthermore, this research focuses on a specific definition vertical-, controlled- and resource-integrated UA, as explained in chapter 2, which forms the foundation for the case study selection. In order to reach the research objective, mainly qualitative research methods will be used. Qualitative research methods are interpretive and context-specific in nature, opposed to the more mathematical and statistical methods of quantitative research (Yin, 2009).

One of the most used qualitative methods is a case study method, which will also be applied in this research. By conducting two case studies on vertical-, controlled- and resource-integrated-UA, one in the urban contexts of Linköping in Sweden and one in the city of Singapore, this research will be able to provide a context-specific answer to the research questions. Context specifics are highly relevant in identifying transition-drivers and it is important to emphasise that the two case studies do not aim at producing generalizable claims. The choice for a case study method can be justified based on criteria formulated by Yin (2009), which in this case are the explanatory research questions, the fact that contextual factors are important and cannot easily be excluded and the focus on information that is contemporary. Flyvbjerg (2006, p. 2, 25) also emphasizes this importance of *"context-dependent knowledge and experience"* as *"good studies should be read as narratives in their entirety".* By conducting an in-depth case study, a researcher is more likely to get feedback from the social context or objects involved (Shell, 1992; Yin, 2009). With this in mind, a researcher should be careful in assuming a verification of hypotheses derived from theory and should be aware that each research context could generate unique feedback from the social context it is conducted in (Flyvbjerg, 2006). It is therefore important to be aware of and transparent about the potential limitations of the research and the pitfalls of choosing a certain research method.

Both case studies will be analysed based on the previously drafted analytical framework by making use of desk research and semi-structured interviews with relevant public and private actors within the two urban contexts. The identification of relevant actors and the use of semi-structured interviews as a research method will be feasible, as this research will be conducted along an internship at Plantagon International. Due to a limited time-span, resource-constraints and the extensiveness of the research field, this research is forced to take a rather small-scale approach and start with two single case studies. Further research within multiple contexts is however encouraged.

4.2 Case Study Selection & Description

This section will provide a description and justification of the two case studies of vertical-, controlled- and resource-integrated-UA. This research will be based on a comparative case study analysis of two cases based on a hierarchic method (Verschuren & Doorewaard, 2010). This means that they will be individually analysed, but compared within the synthesis in chapter 7. The case studies are mainly explanatory in nature, as they try to find a context-specific answer to the two main research-questions. However, throughout the qualitative analysis the hypotheses of the analytical framework will be tested. Overall, these two case studies will be able to; generate feedback on the previously constructed framework, provide in-depth and context-specific information that could be of practical relevance and perhaps provide new insides into theory. However, two case studies would generally be too limited for making any generalisable claims as explained in section 4.4 (Flyvbjerg, 2006; Verschuren & Doorewaard, 2010).

Two niche environments of vertical-, controlled- and resource-integrated-UA have been chosen as case studies, one in the city of Linköping in Sweden and one in the city-state of Singapore. The first case study will be aimed at 'The Linköping Project' developed by Plantagon in the city of Linköping in Sweden. The second case study will focus on the niche environment of Plantagon and Sky Greens in Singapore. Both niches are furthermore embedded in a regime- and landscape-level. As a complete in-depth study of all three (niche, regime and landscape) levels in each urban context would require extensive elaboration and research, this research will limit itself to providing a short background on the niche in each case study. Appendix II additionally provides some background on the regime- (in this case city) and landscape- (in this case national) level in each case study. The aim of this section and appendix II is solely to provide some context on the two niche environments and the chosen regime and landscape level, so that the case studies in chapter 5 and 6 can be best understood.

4.2.1 Case Study 1: The Linköping Project, Plantagon - Linköping

The Linköping Project is the first example of a vertical, controlled and resource-integrated UA-system that Plantagon is building worldwide. As introduced, the Swedish-American Plantagon International is a global leader when it comes to innovative solutions for local food systems. It is furthermore the first example of a Companization model, which is driven on CSR-values and combines a company structure with a non-profit organisation. Its role has been previously defined in the preface, as this research is combined with an internship at Plantagon's Headquarters in Stockholm. The Linköping Project is based on a greenhouse and real estate construction for vertical-, controlled- and resource-integrated UA. The project has been initiated in the city of Linköping, in cooperation with the municipality-owned utility company Tekniska Verken (Tekniska Verken, 2015a). The construction of the Linköping Project has been officially initiated in 2009 and approved by the city of Linköping in 2012. Currently, the project is however still in an early building-phase, as Plantagon is trying to secure all the needed resources and is aiming to complete the project by 2018[3]. The total costs of the project are estimated around 35 million ($), of which around 600.000 ($) is currently already invested in the project location. The project consists of a multi-functional greenhouse design and will be around 60

[3] Interview 1 & 2

meters high and consist of 16-stories (figure 12) (HortiDaily, 2014). This greenhouse design is furthermore integrated with real estate purposes like office spaces and a restaurant called 'Urban Farmers Lounge' (Plantagon International et al., n.d.). By combining food production with real estate purposes, costs can be accounted for in different ways. As the name indicates, the vertical greenhouse design by Plantagon makes use of the vertical dimension in order to create more growing-space on a relative small amount of square meters. As Plantagon International (2011, p. 13) indicates, *"with a ground footprint of 10,000 m^2, a vertical greenhouse equals 100,000 m^2 of cultivated land"*. The Linköping project has around 12.000 m^2 build-up area, of which around 4.000 m^2 are assigned to the greenhouse and around 8.000 m^2 for the commercial office spaces[4].

Figure 12: Multi-functional Greenhouse Design Linköping (Plantagon International, n.d.-a)

The greenhouse will be used for horticulture, in which mainly bok choy, mizuna and beans will be grown. Crops will be grown in a closed glass system, in order to regulate the use of water, light, airflows and natural fertilizers and reduce the risk of diseases and need for pesticides. In general the greenhouse is designed around a helix conveyor system that aims at making as much use of the natural incoming light as possible and compensate further with LED-lightning. Seeds are sowed within pots that are extendable throughout the growing process of the plants and these pots are put into trays (Plantagon International, n.d.-b, n.d.-f). The trays regulate the irrigation patterns for the plans, with a nutrient-rich water solution. It is important to emphasise that the plants are not grown in soil, but in a combination of ebb-and-flood hydroponics and pumice particles, a volcanic stone. Plantagon

[4] Interview 1

holds certain patents on these conveying systems as well as on the method of growing plants (Plantagon International, n.d.-f; Plantagon International et al., n.d.). Furthermore, the project has been based on a resource-integrated approach, which Plantagon has called industrial symbiosis (Figure 13). Resources will be integrated and recycled as much a possible. This will happen first of all, between the multifunctional greenhouse, the biogas facility and the power plant of Tekniska Verken (water and energy); and secondly between the greenhouse and the office spaces (CO_2 and oxygen).

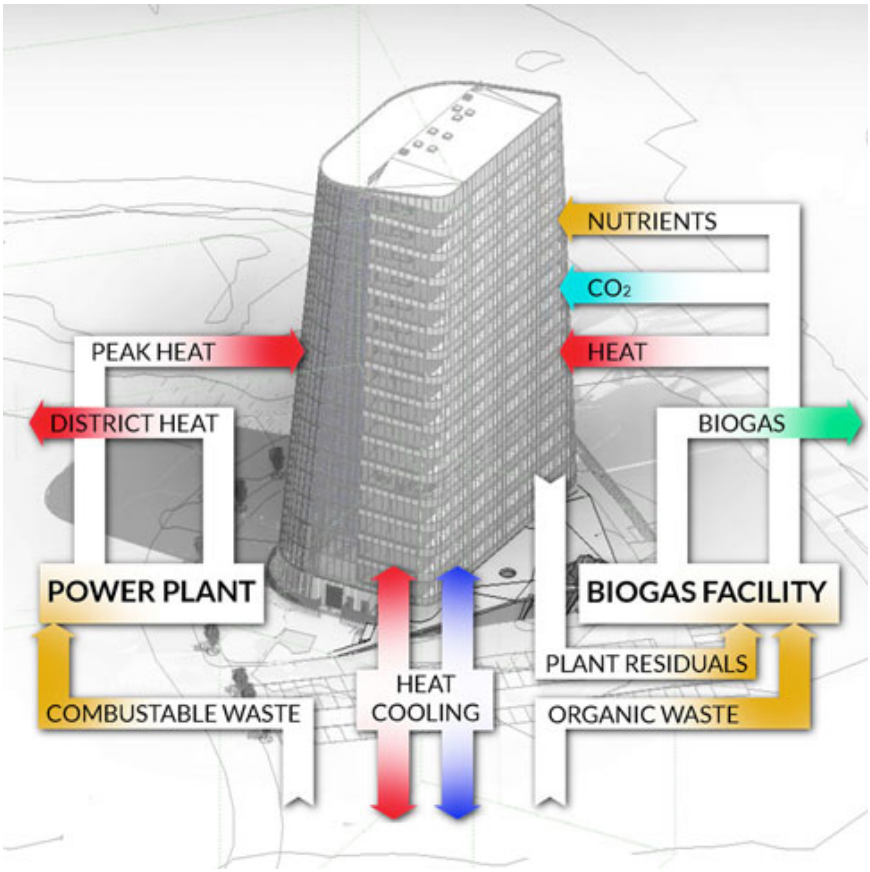

Figure 13: Overview of Industrial Symbiosis In Linköping (Plantagon International, n.d.-a)

Since 2008, Plantagon has been building a broad network of actors around UA, within Linköping itself and a global context. In 2013, the Companization also organised an Urban Agriculture Summit in Linköping to share their knowledge and vision on UA within a broader network (GUA SUMMIT, 2013a, 2013b). Based on their responsibility for the execution of the project and their role as a main facilitator for partnerships on UA within Linkoping, Plantagon could be seen as a prominent niche actor driving vertical-, controlled- and resource-integrated-UA. Appendix II additionally provides a background on the regime- and landscape-level in the context of Linköping.

4.2.2 Case Study 2: Sky Greens & Plantagon - Singapore

The second niche environment that is central within this research is vertical-, controlled- and resource-integrated UA in Singapore. This case study cannot so much be named after a project, but refers to the broader niche network around this form of UA, in which mainly Plantagon and Sky Greens have been identified as important niche actors (Plantagon International, n.d.-a; Sky Greens, 2014a). Within Singapore the concept of UA has been growing over the last years, in which the

concept of vertical farming has been increasingly established[5]. The niche network in Singapore is however not as limited to one specific project and group of actors as described in Linköping. As food security and urban development are both high up on the agenda, a variety of actors have devoted themselves to explore the new possibilities of UA. With currently *"more than 80 plots with fruits, herbs and vegetables"* it can be said that that UA in its broadest sense is booming within Singapore (Wee, 2015). Within Singapore, this variety of actors and projects is ranging from small-scale rooftop- and urban-gardening towards larger indoor vertical farms. (Edible Garden City, n.d.; Panasonic Singapore, 2014; Pao, 2014; Plantagon International, n.d.-f; Sky Greens, 2014a; Wee, 2015). Within this research, two main actors related to vertical, controlled and resource-integrated environment have been included, namely Sky Greens and Plantagon.

First of all, Sky Greens can be seen as one of the first commercial experimentation with UA in Singapore and described itself as *"a low carbon, hydraulic driven vertical farm for safe, fresh and delicious vegetables"* (Sky Greens, 2014a). Its founder, Jack Ng, has developed the company from its personal investments since 2009 by experimenting with prototypes and green-tech solutions for growing food within a vertical setting. Due to the financial and technical capacities of the founder, the government of Singapore has granted Sky Greens a relatively long land lease of 20 years in order to develop the vertical farming construction of around 36 million (SING$). Sky Greens, in collaboration with the Agri-Food & Veterinary Authority of Singapore (AVA), has been awarded for its work with an award in R&D of the Ministry of National Development (MND) in 2011, a showcase at the World Cities Summit in 2012, a Singapore Sustainability Award in 2014 and as one of the winners of the INDEX Design Award in 2015(Sky Greens, 2014a). The system of Sky Greens consists of an aluminium and steel structures of revolving tiers, in which vegetables are grown in soil up to 9 meters high (figure 14) (Sky Greens, 2014c). In this way, Sky Greens provides a vertical system that is ten times more productive per unit of land area (Sky Greens, 2014c). The 1000 vertical towers approximately produce around 800 kg of leafy vegetables per day (Lim, 2015) The company brands itself based on a relatively low water and energy use due to the natural sunlight, hydro-power, flooding-systems and the recycling of rainwater (Sky Greens, 2014c). Despite its commitment to the conditions for vertical-, controlled- and resource-integrated-UA, Sky Greens is still encountering some challenges when it comes to maintaining a fully closed-environment and a high yield when it comes to growing crops within soil without the use of harmful pesticides[6]. As Sky Greens is rather constrained to calculating all their costs into the price of the vegetables, they have not been able to embrace all technological innovations around UA yet. Sky Greens currently sell its vegetables to local supermarkets through one of Singapore's main retailers, FairPrice, for around 0,5 or 1 $ more than the market-price (NTUC FairPrice Online, 2016; Sky Greens, 2014b).

[5] Interview 13
[6] Interview 12

Figure 14: Sky Greens Vertical Farming Structure (Sky Greens, 2014a)

Secondly, Plantagon is aiming to build a second project in Singapore, based on the same kind of UA-system as described before in the case of Linköping. In Singapore, the vertical-, controlled- and resource-integrated system will however not be a new stand-alone building, but will most likely be integrated as a façade to an existing building (of 2000m^2 and around 8 million $). In 2014, Plantagon joined forces with Nanyang Technical University (NTU) to further develop UA in Singapore and signed a Master Research Collaboration Agreement under a joint development company named Plantagon Global Pte Ltd, largely owned by Plantagon and partly owned by NTU. Based on this agreement, NTU has provided and assigned a space for Plantagon to experiment and develop a vertical-, controlled- and resource-integrated-UA in Singapore. NTU has furthermore devoted 10.000 of research hours to this project and emerging niche[7]. The UA-system will most likely grow leafy vegetables and be based on a cultivation method of hydroponics, aeroponics or aquaponics, due to their resource-efficiency (mostly low water-use) and their capacity to regulate nutrient solutions and root zones[8]. Especially aeroponics can be valuable within vertical farming, due to its resource-efficiency when used in multiple tiers and its lightweight when it comes to construction material. These aspects all contribute to a more productive and cost-effective UA system, according to prof. Lee Sing Kong from NTU[9]. For the further development of a project, Plantagon is currently in a phase securing the necessary financial partnerships to start the project[10].

Appendix II additionally provides a background on the regime- and landscape-level in the context of Singapore.

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[7] Interview 9 & 13
[8] Interview 14
[9] Idem
[10] Interview 13

4.3 Data Collection

4.3.1 Desk Research

Initially, has been collected through an extensive desk research, making use of databases like Scopus and Google Scholar by using the key words as: *'urban agriculture', 'urban food systems', urban sustainability, 'vertical farming', 'closed environment agriculture', 'socio-technical transitions', 'transition theory', 'transition management', 'multi-level-perspective', 'water-energy-food-nexus', 'industrial symbiosis', 'Linköping and Plantagon, 'Singapore food security', 'Sky Greens', 'Singapore urban environment' etc.* Next to academic databases, relevant websites and reports of companies, organisations and governments have been consulted. Throughout the research, the referencing style is APA 6th edition and Mendeley has been used as the main referencing tool.

4.3.2 Semi-structured Interviews

The semi-structured interviews have been conducted along the analytical framework drafted in chapter 3. Interview questions have initially been formulated based on the indicators of landscape developments, niche pressures and governance capacity and can be found in appendix III. To provide a more logical interview structure, the order of the questions has been modified. As it regards a semi-structured interview, the provided questions have mainly been guiding the interview but also left room for an open discussion. Overall, interviewees have been informed about the purpose of the interview, have been asked for permission to record the interview and have been ask if he or she would like to be updated about the results of the research. Interviews related to the Linköping case have mostly been conducted in person, whereas interviews for the Singapore case have been conducted over phone or Skype, due to logistical reasons.

A list of interviewees has been identified with the help of Plantagon, based on their involvement with UA in each context (table 4 and 5 on page 54 and 55). Relevant actors have further ben identified throughout the conduction of the interviews. Overall, it is important to emphasise that the list of interviewees could always be longer or more complete, but has here mainly been chosen based on the relevance of the actors and their willingness to participate in the research. As the qualitative data from the interviews is based on personal communication instead of existing data sources, they will not be included in the references list. Next to the use of APA as the main reference style, interviews will therefore be cited by means of footnotes. In order to avoid long footnotes, interviews have been given a reference number as can be seen in table 4 and 5. A more extensive description of the role and position of each interviewee can be found in appendix IV.

4.4 Scoring of Indicators

In order to use all the qualitative data in a consistent and comparable way, each indicator in the analytical framework of this research has been assigned with a type of scoring, as shown in table 2 and 3. Qualitative indicators have for example been expressed in several degrees, like 'Low, Medium, High', 'Limited, Medium, Broad' or 'Lacking, Rather Inconsistent, Rather Consistent, Consistent'. This choice has been made in order to make judgements within the case study analyses, based on the formulated hypotheses and experiences of involved actors. When it comes to transition drivers and the scale-up potential, degrees like; high, consistent, easy, broad and adequate are representing a more 'desired' situation, compared to low, inconsistent, difficult, limited and inadequate. The scoring of the indicators is a methodological choice and could be seen as rather subjective. However, the aim is to indicate differences in the strength or presence of indicators, in order to make statements about the influence of landscape developments, niche pressures and the degrees of governance capacity. As most indicators are not quantifiable, but are based on the perceptions of involved actors, the

scoring of each indicator has been based on and assigned with the help of the date derived through qualitative interviews. It is important to emphasise that this scoring is solely a method for assessment and should be understood in the context of this research. It does not proclaim to be the only or most objective way to structure all the gathered data.

4.5 Reliability & Generalisability

As Golafshani (2003, p. 603) has argued, reliability is a tricky concept within qualitative research, as it is most measurable and commonly used within quantitative analyses, but generally relates to how *"credible and defensible"* a research result is. This research is first of all trying to guarantee its reliability by building upon existing theoretical concepts, which has led to the construction of an analytical framework. This framework has been divided into dependent variables, independent variables, hypotheses, indicators and corresponding data collection methods. The framework will furthermore be applied in two case studies, each in a similar and structured way. The derived results can therefore be traced back to the used framework and the used methods of data collection, which are desk research and the use of semi-structured interviews. Conclusions that will be drawn in chapter 7 should only be seen as valid within the scope and case study contexts of this research. This research acknowledges that in order to make any generalisable claims outside of these two case studies, further research based on the same approach would be necessary.

INTERVIEWEE	REPRESENTING	POSITION	DATE	METHOD	REFERENCE
Hans Hassle	**Plantagon International & Association**	Founder; General Secretary	02/06/2016	Personal Communication, Stockholm	Interview 1
Paul Lindvall	**Municipality Linköping**	Deputy Chairman of the City Board	24/05/2016	Personal Communication, Linköping	Interview 2
Stefan Jakobsson	**Tekniska Verken**	Manager Business Development	24/05/2016	Personal Interview Linköping	Interview 3
Mats Hellström	**Plantagon International & Matskonsult**	Senior Advisor Plantagon Trade & Agriculture	04/04/2016	Personal Communication, Stockholm	Interview 4
Thomas Malmer	**Plantagon International, Percipia**	Senior Advisor Plantagon on Academia & R&D	25/04/2016	Personal Communication, Stockholm	Interview 5
Jan de Wilt	**Innovatie Agro & Natuur, Plantagon International Association**	Programme Manager; Honorary Board Member Plantagon Association	23/05/2016	Personal Communication, Skype	Interview 6
Alessio Boco	**SWECO**	Chief Architect & Engineer	12/05/2016	Personal Communication together with Basitaan Vinkestijn, Stockholm	Interview 7
Bastiaan Vinkestijn	**SWECO**	Architect	12/05/2016	Personal Communication together with Alessio Boco, Stockholm	Interview 7
Johan Mattsson	**SSAB**	Key Segment Manager Agriculture	30/03/2016	Personal Communication, Stockholm	Interview 8

Table 4: List of Interviewees - Linköping

INTERVIEWEE	REPRESENTING	POSITION	DATE	METHOD	REFERENCE
Shrikant Ramakrishnan	**Plantagon International**	Global Business Development Director	13/05/2016	Personal Communication, Stockholm	Interview 9
Elyssa Ludher	**Centre for Livable Cities (CLC) - Part of Ministry of National Development**	Senior Assistant Director	17/05/2016	Personal Communication, Skype	Interview 10
Alfred Ng	**City Developments Limited (CDL)**	Project Manager	23/05/2016	Personal Communication, Skype	Interview 11
Roshe Wong	**Sky Greens**	Business Development Manager	26/05/2016	Personal Communication, Skype	Interview 12
Prof. Tjin Swee Chuan	**Nanyang Technological University (NTU)**	Director (Projects) President's Office; Co-Director of The Photonics Institute (TPI); Associate Chair (Research) in the School of Electrical and Electronic Engineering	23/05/2016	Personal Communication, together with Prof. Chen Wei Ning, Skype	Interview 13
Prof. Chen Wei Ning, William	**Nanyang Technological University (NTU)**	Tenured Full Professors, School of Chemical and Biomedical Engineering; Director of the Food Science & Technology Programme	23/05/2016	Personal Communication, together with Prof. Tjin Swee Chuan, Skype	Interview 13
Prof Lee Sing Kong	**Nanyang Technological University (NTU)**	Vice President (Education Strategies) as well as Vice President (Alumni and Advancement) at Nanyang Technological University	25/05/2016	Personal Communication, Skype	Interview 14

Table 5: List of Interviewees - Singapore

5. CASE STUDY ANALYSIS 1 THE LINKÖPING PROJECT, PLANTAGON – LINKÖPING

The previous four chapters have together formed the foundation for the empirical analysis of two case studies. As introduced, the city of Linköping in Sweden and the city-state Singapore will be investigated around the niche of vertical-, controlled- and resource-integrated-UA and its transition potential. Both cases are facilitating a form of vertical-, controlled- and resource-integrated-UA, while dealing with different drivers of change and governance settings. The case of Linköping (chapter 5) and Singapore (chapter 6) will be individually assessed along the same framework and will be shortly compared in the synthesis. This chapter is focused on The Linköping Project led by Plantagon, as explained in chapter 4, and aims to answer the following sub-questions.

1.3 What drives vertical-, controlled- and resource-integrated-UA in the context of Linköping?
2.2 What is the capacity of the city of Linköping to scale-up vertical-, controlled- and resource-integrated-UA?

First of all, sub-question 1.3 will be answered by applying the analytical framework of landscape developments and niche pressures around vertical-, controlled- and resource-integrated-UA in Linköping. Secondly, sub-question 2.2 will be answered by analysing the governance capacity on the regime level in the case study of Linköping. Chapter 3 has argued why the governance capacity plays a role in the scale-up potential of a transition and how this could be assessed within the context of this research. In the end, this chapter aims to contribute to a better understanding of driving and scaling-up a potential socio-technical transition around UA, by providing an in-depth analysis of Linköping

5.1 Landscape Developments

As explained in chapter 3, the landscape refers to the exogenous context in which a socio-technical system is based over a longer period of time (Geels & Schot, 2007; Geels, 2002; Morone et al., in press; Nykvist & Whitmarsh, 2008). Landscape developments that have been identified in theory are clustered in the physical environment, long-term trends and exogenous shocks. These three independent variables and their corresponding indicators will be assessed in the case of Linköping. In doing so, this research aims to gain more insight into the landscape developments that are driving the emergence of vertical-, controlled- and resource-integrated-UA in Linköping. Table 6 shows an overview of the results.

LANDSCAPE DEVELOPMENTS		
Independent Variables	**Indicators**	**Overall**
Physical Environment	**Availability of Arable Land (Sweden)** (% Of Total Land Area / Hectare Per Person)	6,4% / 0.27
	Climate (Linköping) (Cold, Temperate, Sub-Tropic, Tropical)	Temperate
Long-term Trends	**Urban Population (Linköping)** (Number)	151.881
	Urban Population Density (Linköping) (People per km2)	96 per km^2
	Urban population Growth (Linköping) (% Per Year)	1,1%
	GDP per capita, PPP (Sweden) (Current International $)	$ 45.297
	Food Security Index (Sweden) (Index 0-100)	81.3
	Food Import (Sweden) (% Total Food Consumed)	20%
	Water Self-Sufficiency (Sweden) (%)	100%
	Energy Self-Sufficiency (Sweden) (%)	71%
Exogenous Shocks	**Experienced Exogenous Shocks (Sweden)** (Yes/No)	No

Table 6: Results - Landscape Developments Linköping

(FAO Economic and Social Development Department, 2001; A.Y. Hoekstra, 2003; The Economist Intelligence Unit, 2016; The World Bank Group, 2016b, 2016c; Urbistat, 2014)

5.1.1 Physical Environment

Availability of Arable Land

Sweden is one of the larger countries in Europe, with a landmass of 447.420 km^2 stretching from the border with Denmark in the South, over the Arctic Circle in the North. Currently, 6,4 % of its total surface is arable, of which most of it is located in the southern part of the country due to the climate and vegetation. Furthermore, 53% of the country is covered by forest, 12 % by rocks and mountains and 9% by water (river & lakes) (Swedish Institue, 2016c). Sweden is overall not coping with a scarcity in arable land, which is furthermore reflected in its demographics and food production that will be explained in the following section. Linköping is, as most cities in Sweden, located in the southern part of the country and with that largely surrounded by agricultural land. Overall, the availability of arable land will not likely cause any stress within the setting of Linköping.

Climate Zone

Being situated in the Northern part of Europe, Sweden both has both a temperate and a cold climatic zone. However, its arable land in the South of the country is characterised by a temperate climate, which is generally favourable for growing temperate vegetables and keeping livestock. Agriculture in temperate climates is season-bound and with that the concept of indoor farming becomes more appealing near a city like Linköping, than in tropic zones (Climate-Zone, 2016).

5.1.2 Long-term Trends

Urban Population, Density & Growth

Overall, Sweden is a country with a large urban population, as 85% of its 9.6 million inhabitants live in cities. Linköping has a relatively small population of 151.881 inhabitants, with an urban population density of 96 per km^2. It is the 6th biggest city within Sweden and experiencing a yearly growth of around 1,1 % (Linköping Municipality, 2015a, 2015b; Swedish Institue, 2016c; Urbistat, 2014). Overall, the urban population, density and growth of Linköping are not experienced as problems for the further development of the city and its resource security[11].

GDP per capita

Within a century, Sweden has developed from a country with a long agricultural and traditional history into a service-based and wealthy nation (ICLD & SKL International, 2011). With a current GDP per capita (PPP in international $) of around $ 45.297, Sweden is nowadays one of the wealthier nations in the world. Due a high GDP per capita, it could be stated that Swedes are relatively resilient when it comes to their finances and therefore less likely to experience stress on the regime level.

Food, Water & Energy

Sweden has a food security index of 81.3, which ranks them the 10th most food secure place in the world (The Economist Intelligence Unit, 2016). Sweden has an open economy that is generally revolving around import and exports worldwide(OEC, 2013b). When it comes to food, Sweden however only imports 20% and produces 80% within its own borders (FAO Economic and Social Development Department, 2001). Within the network of Linköping, it has been indicated that food security is often experienced as something that is self-evident. The availability of and access to food is rarely debated within Sweden and Linköping in itself[12]. Next to the lack of stress when it comes to food security, there have also not been any concerns or awareness expressed when it comes to the environmental footprint of food.

With around 100.000 lakes, Sweden is furthermore abundant in water and 100% self-sufficient when it comes to their water supply (Hoekstra, 2003). Water management in Sweden is allocated to the municipal level and within Linköping, the municipality-owned utility company Tekniska Verken is therefore in charge of its water supply. All water used in Linköping is locally derived from the River Stångån and Motala Ström and purified by Tekniska Verken to supply clean drinking water. Also most wastewater and rainwater is captured and recycled within the municipality(Tekniska Verken, 2015b).

Thirdly, Sweden is also not very vulnerable when it comes to the external supply of energy. The country is 71% self-sufficient when it comes to energy, in which there is a strong aim to move towards renewable resources (IEA, 2013). Since the 1970s, Sweden already reduced its dependency on oil from 75% to currently only 20% (Swedish Institue, 2016a). Currently, 52% of Sweden its energy consumption comes from renewable sources, of which 95% of that is generated through hydropower (Swedish Institue, 2016b). Within Linköping, Tekniska Verken is furthermore involved in the development of biogas as a source for heating and vehicle fuel (Tekniska Verken, 2015b). Overall, Linköping is not experiencing any stressful long-term developments when it comes to the security of food, water and energy.

[11] Interview 1-8
[12] Idem

5.1.3 Exogenous Shocks

No exogenous shocks have been experiences within Linköping. As stated before, there is currently no debate on the vulnerabilities regarding food or other resource-securities[13].

In conclusion, Linköping is located within a region of Sweden that is characterised by an abundance of arable land and a temperate climate. It is a relatively sparse populated area, but still the 6th largest city of Sweden. As hypothesised, its abundance of land and a relatively low urban population, density and growth (in numbers) are unlikely to cause any stress within the city. High-income levels together with a high security and local supply of food, water and energy, are furthermore preventing any stress from long-term developments. It has furthermore been emphasised that the city of Linköping has not experienced any exogenous shocks that might have put pressures on the existing structures of the city. The only driver from a Swedish landscape perspective in Linköping to push vertical-, controlled- and resource-integrated-UA, would be the advantages of growing crops all-year-round.

5.2 Niche Pressures

As stated in chapter 3, a niche refers to a new and rather isolated space within a socio-technical system that is fundamentally different than the established functioning of the regime. Within a niche, a network of actors aims to change the status quo, by driving systemic change in a certain area (Caniëls & Romijn, 2008a; Geels, 2002; Rene Kemp et al., 1998; Nykvist & Whitmarsh, 2008). The three mechanisms through which niches have the potential to drive systemic change have been identified within theory, which are the expectation-, the knowledge- and the power-mechanism. All three independent variables with their corresponding indicators will be assessed in the case of Linköping. In doing so, this research aims to gain more insight into the niche pressures that are driving the emergence of vertical-, controlled- and resource-integrated-UA in Linköping. Table 7 provides an overview of the main results.

NICHE PRESSURES		
Independent Variables	**Indicators**	**Overall**
The Expectation Mechanism	**Articulation of Expectations & Visions** (Lacking, Rather Inconsistent, Rather Consistent, Consistent)	Rather Inconsistent
	Awareness on Socio-Technical Advantages (Low, Medium, High)	High
The Knowledge Mechanism	**Learning-by-Doing** (Knowledge Generation through Experimentation) (Low, Medium, High)	Medium
	Learning-by-Interacting (Knowledge Exchange) (Low, Medium, High)	High
The Power Mechanism	**Support of Powerful Actors** (Low, Medium, High)	Medium
	Financial Resource-Cooperation (Low, Medium, High)	Low

Table 7: Results - Niche Pressures Linköping

[13] Interview 1-8

5.2.1 The Expectation Mechanism

Articulation of Expectations & Visions

The ways in which expectations and visions on the UA project in Linköping are articulated within the network are rather inconsistent. However, it can be stated that the expectations around the project generally show more coherency than the underlying visions.

The most common expectation is that the project will function as a showcase or in other words demonstration plan for UA and resource-integrated systems in a global perspective[14]. As the need for UA in Linköping is not very high from a landscape-perspective, it is expected that the project will mainly be relevant to show the technology and possibilities of a vertical-, controlled- and resource-integrated-UA system. It is expected to become an example of innovation and to attract interested parties from all over the world, who are actually dealing with stressful landscape developments that are putting pressures on the provisioning of food and availability of resources. In this way, there appears to be quite a shared expectation of the project in Linköping as a functional prototype of UA, in order to address markets for export.

Yet, when considering the expectations around the duration and process of the project, there appears to be more divisions within the network[15]. As the project has been initiated in 2009 and officially started in 2012, combined with a rather large branding campaign and therefore media attention, some actors would have expected the project to be up and running at this point in time[16] Due to some delays in the process that will be discussed further throughout this analysis, some actors have expressed their doubts about the economic and technical feasibility of the UA system. Most actors have pointed out that they expect a higher trust within this UA system as soon as a first functioning building will be constructed, a moment most of them are still waiting for[17]. Hans Hassle, one of Plantagon's founders and the current General Secretary of the Plantagon Association, confirms this divide in expectations, but also explains where he thinks that is coming from. Most people will only associate the official construction of a building with a 'proof-of-concept', as from that moment on the UA system will become visible and real[18]. It is assumed that as long as there is no visible functioning prototype, the technology around vertical-, controlled- and resource-integrated-UA is not proven and therefore not relating to reality. However, Hans Hassle raises the question "when can we say a concept or technology is really proven?" and indicates that the answer provided by most actors is a more psychological than a rational one. The commitment of Plantagon to UA is based on a longer process, in which they have generally expressed no doubts about the technical capacities of constructing the greenhouse[19].

For Plantagon other expectations play a role, than for involved actors like the Municipality of Linköping or Tekniska Verken. Being aware of the trust that a demonstration plant in Linköping could create internationally on their work around UA, their expectations reach beyond this city. It is expected that the project in Linköping will set other UA projects in motion, in those cities in the world that are dealing with more direct pressures of urbanisation and resource security. Once that happens, Plantagon is expected and required to grow in its knowledge, resources and staff, in order to deliver and facilitate projects worldwide. Plantagon has pointed out that for them it is not about having one

[14] Interviews 1-8
[15] Interview 2, 3, 5, 6 & 8
[16] Interview 2, 3, 5, 6 & 8
[17] Interview 2, 3, 4, 5, 6, 7 & 8
[18] Interview 1
[19] Idem

UA project up and running, but it is generally about the experimentation with innovation and technology in order to arrive at a system that works and is scalable in different settings. In this way, Plantagon does not share the expectation that the scalability and sustainability of UA in this form is proven once the Linköping project is completed. They argue it is important to test UA solutions in different urban and climatic contexts over a longer period of time (at least 3 years). They furthermore expect a need for future research when it comes to the life-cycle-assessment of the buildings, the growing of different types of crops and local distribution possibilities[20]. These are articulated expectations that are not all shared or acknowledged by other actors within the network.

These expectations can be related to the underlying visions hold by different actors on what UA means to them, both from a professional as well as a personal point of view. Within Linköping most actors share the vision that UA should mainly be understood in a resource-integrated way[21]. It has been pointed out that UA is able to use multiple resources like water, energy and waste in a more efficient way. Furthermore, there is a shared vision on the fact that UA should not be seen as a sector that is competing with traditional farming, but one that is able to complementary and collaborative[22].

Overall, it has been emphasised that UA within Linköping is mainly pursued for its potential synergies and contribution to sustainability, not for its core definition, which is the provisioning of food[23]. Especially for the city of Linköping, which aims to live up to its slogan *"where ideas become reality",* UA is seen as one component of the city's image around innovation and resource-efficiency[24]. The municipality owned utility company Tekniska Verken has for example mainly become an important partner for Plantagon when it comes to the connection of the building to the grid and the possibilities for exchanging heat and CO_2 within a resource-efficient system[25]. This explains a sometimes-lacking vision on UA, as its food provisioning quality has not been the main reason for actors to get involved in this newly emerging field. As emphasised by multiple actors, the Linköping project is able to provide unique selling points that are able to enhance the sustainability branding of businesses and the government[26]. It is interesting to notice that most actors do not perceive food as the main driver behind this project[27].

On the other hand, there are actors who hold a more long-term vision on UA, specifically related to its ability of bringing food closer to the growing urban world population[28]. Plantagon has been pointed out as the main actor who has envisions the Linköping project as a first step in feeding cities world-wide and addressing the more global problem-setting described in chapter 1[29]. With that, Plantagon goes behind solely resource-efficiency, city planning or CSR, but addresses an envisioned long-term and global trend[30]. As Alessio Boco and Bastiaan Vinkestijn from Sweco have also pointed out: *"UA should be seen as a part of the natural evolution of cities. We now arrived at a moment in time in which we are not only required to adapt our environment, but also able to design it. We should use that ability to think about how we want our societies and systems to look like"*[31]. In this way, the project in Linköping is envisioned as a perfect means towards more sustainable, liveable and

[20] Idem
[21] Interview 1-8
[22] Interview 1-8
[23] Interview 2, 3, 4, 5, 6 & 8
[24] Interview 2 & 3
[25] Interview 3
[26] Interview 1, 2, 3 & 8
[27] Interview 2, 3, 4, 5 & 8
[28] Interview 1, 5, 6, 7 & 8
[29] Interview 1-8
[30] Interview 1
[31] Interview 7

symbiotic urban environments[32]. As Thomas Malmer and Mats Hellström have also pointed out, UA should be defined within a more holistic context of societal and city development[33]. Within Sweden and more specifically Linköping, UA would probably never be viewed from a food security perspective[34].

The main challenges within the articulation of expectation and visions could be found in the diversity of actors involved and the relatively new field of UA. Plantagon explains that is has been rather easy to inspire people and get them excited about the concept of UA. However, when it comes down to the actual implementation and financial investments needed for the UA project in Linköping, a different approach has proven necessary. Initially, their strategy has been to communicate the ideals and technical innovation behind UA. However, as Hans Hassle has pointed out *"markets are in essence not designed around sustainability and despite our sometimes personal disappointment in that, we need to use the principles of the market in order to show that sustainability can actually be competitive and do better. Until markets and legislation change in favour of sustainability, idealism is unfortunately not enough"*[35]. Now, Plantagon is aiming to adapt their communication strategies more to the actor that they are addressing. By not only emphasising food production, but also packaging an UA project in such a way that it offers a unique selling point for potential investors (e.g. including office spaces or housing), Plantagon is able to address a broader audience and create different business models. Plantagon is perceived as a pioneer within the UA market, which is a market that still needs to be created and with that brings a lot of uncertainties and risks. According to Hans Hassle it is about not being afraid of taking on the risks as an early movers within a newly emerging market. "*We might be a great success or we might be a great failure, but at Plantagon we do not want to wait for the safer business option, we want to be the early mover"*[36].

Awareness on Socio-Technical Advantages

The awareness on the socio-technical advantages of the UA within Linköping is generally high within the niche network. Most actors involved in the project have stated to be aware of the socio-technical advantages of UA and emphasise the importance of interdisciplinary thinking[37]. Plantagon has mainly based is expertise on years of research, feasibility studies and experts within certain fields, from horticulture, towards architecture and engineering[38]. With that Plantagon has tried to set up partnerships in order to gather all the necessary knowledge around vertical-, controlled- and resource-integrated-UA[39]. As Alessio Boco and Basitaan Vinkestijn from Sweco have emphasised that education plays a major role within UA and the Linköping project. Also from an architectural or engineering perspective, it is not only about creating an aesthetic and functioning construction, but also about combining the building with education and awareness[40]. As this form of UA has involved a lot of new knowledge for most actors, they have had to learn and gain expertise over time, often outside of their original personal and professional background[41]. However, at this point in time that has led to a high awareness on the socio-technical advantages, but also disadvantages of UA within different settings and in this case Linköping. As Paul Lindvall has pointed out, this has also led to changes within the original design of the UA in Linköping over time, as the awareness on the

[32] Interview 1, 4, 5, 6, 7 & 8
[33] Interview 4 & 5
[34] Idem
[35] Interview 1
[36] Idem
[37] Interview 1, 4, 5, 6 & 7
[38] Interview 1 & 7
[39] Interview 5
[40] Interview 7
[41] Interview 1, 2, 3, 4, 5, 7 & 8

possibilities and constraints of UA within Linköping has been growing within Plantagon[42]. There are actors within the project that would in theory need a less interdisciplinary mind-set, as their role is limited to a specific part of the building. Examples can be found in SSAB as a steel-supplier or Tekniska Verken as mainly a utility company[43]. However, actors have still emphasised that they do not feel there is a lot of knowledge or research lacking around UA and they feel confident about the technology.

5.2.2 The Knowledge Mechanism

Learning-by-Doing

Learning-by-doing refers to the degree of knowledge generation through experimentation with technology. Within Linköping this degree is medium as experimentation is indicated as important within knowledge generation, but does not play a very prominent role. Overall, actors have pointed towards the importance of smaller test rigs or experimentation plants within Linköping, before the construction of the large-scale vertical farm. The reason that actors would like to see more experimentation is mostly related to creating awareness on and interest in UA through education. The role of experimentation would in that sense contribute in making this form of UA visible and understandable[44].

Until now, this form of learning-by-doing has been relatively low within Linköping itself. On the other hand experimentation is present to a high degree for Plantagon when it comes to testing certain technologies and learning about growing plants in different systems[45]. Alessio Boco and Basitaan Vinkestijn have pointed out that a lot of basic literature on UA is still missing, both in horticulture, as well as in architecture and engineering. This had made experimentation key, as there is no existing literature or similar project to fall back on and learn from[46]. As architects, they have challenged themselves to understand all aspects of *"the puzzle"* by integrating different disciplines, conducting lightning analyses and even designing new software to calculate all aspects of the UA construction. Despite this large role of experimentation within Sweco and Plantagon itself, the degree of experimentation is medium. This is because it has mainly played a role within early feasibility studies and the Plantagon office in Stockholm, not so much yet in Linköping itself.

Learning-by-Interacting

Learning-by interacting refers to degree of knowledge generation through exchange of information and interaction between actors. Most actors have indicated to have an open mind-set towards sharing their knowledge and learning from others and this type of knowledge generation is therefore high within the network. The UA project in Linköping has been involving a lot of new knowledge for most actors involved[47]. As stated before, there is generally a high awareness on the interdisciplinary character of UA and a willingness to share information among experts[48]. Especially the architecture and engineering team at Sweco have played a large role in bringing different disciplines together and getting involved with R&D in areas that normally would be outside of their job description[49]. For them challenges were mainly found in creating a transparent and aesthetic building, while considering other factors as solar insolation, the greenhouse effect of glass, climate conditions and plant growth. This

[42] Interview 2
[43] Interview 3 & 8
[44] Interview 4, 5, 7 & 8
[45] Interview 1, 5 & 7
[46] Interview 7
[47] Interview 1, 2, 4, 5, 6 & 7
[48] Interview 1, 2, 4, 5, 6, 7 & 8
[49] Interview 1 & 7

process has been highly characterised by 'learning-by-interacting'. Another example of knowledge exchange is the organisation of the Urban Agriculture Summit by Plantagon in 2013, in which all stakeholders were brought together in Linköping to arrive at a more integrated vision on the project and UA in general[50].

Plantagon has stated that they are highly dependent on the expertise of others, but that their facilitating character in bringing the right people together could be seen as their strength. According to Hans Hassle it is not necessary for every person within a team to know all the details from every field, but it is about trusting each other's expertise and exchanging information. Within Plantagon there is generally one expert for each aspect of UA, from plant growth, to engineering, to strategy and business development. The companization furthermore works with senior advisors, of which Mats Hellström and Thomas Malmer are examples[51]. However, Plantagon is for its staff largely dependent on people who are not internally employed, like the team at Sweco. This has been indicated as a challenge once the Linköping project is being constructed and the involvement of the company in UA projects will grow. When it comes to finding the right team and partnerships, *"it has been a lesson to put a team together not only based on competences, but rather on values"*[52]. By taking values and intrinsic motivation into consideration, people are often more open to learning new things and exchanging their knowledge with others. Overall, the process of learning-by-interaction can be perceived as high with the Linköping project.

5.2.3 The Power Mechanism

Support of Powerful Actors

Within the niche environment of UA in Linköping it could be stated that there is a medium support of powerful actors. Powerful actors have been identified based on the experiences within the network and on the extent to which these actors have the ability to drive UA forward. Overall, Plantagon has been identified as the most important partnership or actor by all interviewees[53]. In this way Plantagon is perceived as the niche actor with the most expertise and partnerships when it comes to UA within Linköping. Plantagon likes to see itself as well as a pioneer and leader when it comes to UA, but emphasises their valuable partnership with others, when it comes to architecture, engineering and research & development in a broader sense.

On the other hand, the project has also been facilitated with the help of Tekniska Verken and the consent of the Municipality of Linköping. Initially, Tekniska Verken has been perceived as one of the main powerful actors within UA in Linköping, as it reached out to Plantagon in 2009 for the initiation of a vertical greenhouse as part of their system. At that moment in time, Hans Hassle explains, Plantagon was currently in the middle of its feasibility studies and was encountering some challenges with the energy aspects of the greenhouse. Their challenges led to a discussion if their concept was worth pursuing in the light of its technical and economic feasibility[54]. The fact that Tekniska Verken reached out to Plantagon at a crucial moment in time and offered relatively cheap access to heating, CO_2 and other resources, has been a major driver for bringing the project to Linköping. As Hans Hassle has stated, the city of Linköping has not been a logical choice form a food security or UA perspective, but it was the city in Sweden that was the most open and facilitating towards the project[55].

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[50] Interview 1 & 2
[51] Interview 4 & 5
[52] Interview 1
[53] Interview 2-8
[54] Interview 1
[55] Idem

Business Developer at Tekniska Verken, Stefan Jakobsson however explains that their own technologies and the Plantagon project have evolved a lot since 2009[56]. At this moment in time, the initially proposed resource-integration with Tekniska Verken is therefore being debated. Recent research has shown that the CO_2 produced by the biogas plant of Tekniska Verken appears to be not clean enough for plant-growth and would need to be filtered when used in the vertical greenhouse, which is relatively expensive. Furthermore, due to internal improvements in resource-efficiency at Tekniska Verken, the company does not have so much excess heat as it used to have[57]. Also Plantagon has learned that the use of LED lightning will actually produce a lot of excess heat itself and have been researching the possibilities of a heat storing system underground[58]. These developments over the last years have created a different relationship between Plantagon and Tekniska Verken than was initially imagined. This makes Tekniska Verken mainly a powerful actor for the initiation of UA in Linköping, but a less prominent one for the further development of the project[59] However, a relationship between the two companies will continue to exist due to the fact that Tekniska Verken owns all water and energy utilities in the city and the project will be build within the area of Tekniska Verken its biogas- and waste-disposal plant[60].

At this point, it has namely been stated that Plantagon is not so much encountering technological challenges anymore, but mainly a challenge to deliver projects that are viable and therefore relatively simple (to avoid too high investment and maintenance costs)[61]. Financial resources have therefore been repeatedly indicated as a condition for being a powerful actor within vertical-, controlled- and resource-integrated-UA[62]. According to Thomas Malmer, every company or project needs three things to be successful, which is financial resources, a market and leadership. According to him, Plantagon is still experiences challenges in all three aspects, but mainly excels in leadership and lacks mostly in financial resources[63]. Currently, Plantagon is still at a stage within their project in which financial investments need to be secured before the building can actually be constructed. Financial partners play such a large role due to the relatively high costs of this form of UA (±millions). Within this process, UA cannot just rest upon its socio-technical advantages, but also needs to provide a strong business case for potential investors. Therefore, the most valuable potential investment partners for Plantagon appear to be real estate companies and investment banks. By addressing real estate in combination with UA, Plantagon has now been able to design a vertical, controlled and resource-integrated greenhouse with possible office spaces or private housing[64]. A stand-alone greenhouse concept has proven not to be economically viable from solely the vegetable production and therefore Plantagon has designed a system that can serve multiple purposes. However, UA as a newly innovation remains risky and requires a long-term perspective from investors, which is often missing. The support of powerful financial actors is therefore currently seen as one of the most crucial but also difficult steps for Plantagon, which also leads to the following section.

Financial Resource-Cooperation

Financial resource-cooperation around UA in Linköping is low, due to the fact that it is mainly seen as a high-profile business investment around sustainability, innovation and resource-efficiency. Actors have expressed that the financial responsibility mainly lays at Plantagon and that they are the ones

[56] Interview 3
[57] Idem
[58] Interview 1, 3 & 7
[59] Interview 1, 3, 5 & 7
[60] Interview 3
[61] Interview 7
[62] Interview 1-8
[63] Interview 5
[64] Interview 1

who should be able to secure that aspect of the project[65]. One of the main underexposed aspects of UA that has been addressed, is therefore the economic viability and market potential of UA. Despite the fact that most parts of the technology and social benefits are stated to be clear, it is argued that UA needs to be economically viable in order for it to sustain itself. As vertical-, controlled- and resource-integrated UA is Linköping is driven by the private sector, its viability is mainly based on business.

Within Linköping there are currently no financial incentives from the government or private partnerships purely on a financial basis for the construction of the building. Some actors have expressed the willingness to resource-cooperation from a personal motivation for UA, but this has not been able to result in concrete agreements. For example, Johan Mattsson has indicated that he would personally like to create more financial support within SSAB for Plantagon if he could. However also he is tied to the financial conditions and investment opportunities of his company, in which UA does not play a prominent role[66].

As Thomas Malmer has explained, there has only been some financial resource-cooperation within the niche environment when it comes to R&D. In the earlier stages of UA in Linköping a research cooperation was set up with the SP Technical Research Institute of Sweden, which was aimed on creating a separate research institute on UA[67]. The reason why this cooperation did not result in the desired outcome can according to Thomas Malmer, be explained by existing divisions within research institutions. There is often no top-down management when it comes to the importance of research topics and research on UA is therefore very dependent on the willingness and interest of individual researchers. However, among established researchers there is often a high level of scepticism or conservatism towards UA as a new and interdisciplinary research field.

As stated in the previous section, the main challenge is still to ensure financial partnerships for the UA project in Linköping. According to Hans Hassle, the main barrier to financial partners is still the 'proof of concept', which related to the earlier explained differences in the articulation of expectations and visions. As he stated *"it is important to communicate our intrinsic motivation for UA, but at the end of the day it does comes down to the excel sheet for potential investors"*[68]. By learning from experience, Plantagon is now trying to move away from solely communicating the technology and aiming to translate its knowledge on UA in traditional business models and concepts. By putting things in a different logic, Plantagon is trying to find unique selling points for their potential partners so that they are able to increase the resource-cooperation and drive UA forward.

In conclusion, Linköping is overall experiences a variety of niche pressures that are driving vertical-, controlled- and resource-integrated-UA. However, not all niche mechanisms have been able to fully develop and be of use within Linköping at this point in time. The niche network within Linköping mainly has a strong knowledge mechanism, through which knowledge has been generated and learning processes have been stimulated between different actors. There is furthermore a high awareness on the socio-technical advantages of UA. However, expectations and visions on the project in Linköping are still articulated in a rather inconsistent way. Not all actors seem to share the same goal and vision behind UA. When it comes to the power mechanism, there is a medium support of powerful actors. Here actors have mainly emphasised that strong financial partnership for UA in Linköping are currently missing. This also related to the low level of financial resource-cooperation

[65] Interview 2, 3 & 5
[66] Interview 8
[67] Interview 5
[68] Interview 1

around UA in Linköping. UA project is by many actors seen as an interesting innovation and high-profile business investment, for which Plantagon is mainly responsible. There are currently no direct financial partnerships between niche actors in order to drive UA forward in Linköping.

5.3 Governance Capacity

The regime refers to the general structures, cultures and practices that define the "business-as-usual" of a certain socio-technical system, as explained in chapter 3 (De Haan & Rotmans, 2011; Geels, 2002; Loorbach & van Raak, 2006). In order to scale-up a socio-technical transition around UA, these structures, cultures and practices must be open to change. As explained in chapter 3, this scale-up potential is nested within the regime its governance capacity, which can be expressed in the degree of awareness, the degree of willingness and the degree of power. Each of these independent variables and their corresponding indicators will be assessed in the case of Linköping. By analysing the governance capacity, this section will be able to derive lessons on how the city of Linköping is capable of dealing with drivers of UA in order to scale it up. Table 8 provides an overview of the main results.

GOVERNANCE CAPACITY		
Independent Variables	**Indicators**	**Overall**
The Degree of Awareness	**Access to Knowledge** (Difficult, Rather Difficult, Rather Easy, Easy)	Rather Easy
	Learning Processes (Low, Medium, High)	Low
The Degree of Willingness	**Inclusion of Stakeholders** (Limited, Medium, Broad)	Medium
	Political Leadership (Low, Medium High)	Medium
The Degree of Power	**Financial and Legislative Resources** (Inadequate, Adequate)	Low
	Formulation of Long-Term Strategies (No/Yes)	No

Table 8: Results – Governance Capacity Linköping

5.3.1 The Degree of Awareness

Access to Knowledge

Overall, all actors have indicated that it has been relatively easy to access knowledge around UA, which could be related to the high degree of learning-by-interacting within the niche network as described before[69]. Overall, UA has involved a lot of new knowledge when it comes to its functioning of the system. However, not all actors have felt they needed all of this knowledge to play their part in the project, like SSAB and Tekniska Verken[70]. The interdisciplinary knowledge around UA has therefore stayed mainly within the direct niche network that is involved with the construction of the greenhouse[71]. As Mats Hellström has also indicated, the access to knowledge within the niche network is much higher than outside of it. Overall, there seems to be a division between an awareness on the technology of the vertical-, controlled- and resource-integrated-UA system and secondly the underlying problems and reasons for an initiation of UA. The latter appears to be largely missing within Linköping. This is not so much related to the fact that people are not allowed to access information about UA, but mainly stems from a lack of interest in and awareness on food within the city. This could be related to the previously described lack of stressful landscape tensions, which will also be discussed in the following section.

Learning Processes

Despite the fact that the access to knowledge is relatively easy, the learning processes around UA on the regime level in Linköping are low. As said, the UA project in Linköping has been more of a coincidence than a deliberate path chosen by Plantagon. Its role is mainly seen as an interesting innovation rather than a food-provisioning project, which is reflected in the learning processes around UA within the city. As both emphasised by Deputy Chairman of the City Board Paul Lindvall as well Stefan Jakobsson from Tekniska Verken, there is no big debate about food security within Linköping or even Sweden[72]. Thomas Malmer has confirmed this notion of a low awareness on the problems and possible solutions around UA within Linköping. He argues that a long-term vision and debate around UA is often missing, not only within academics but also on the government level[73].

The main reason for this can according to most actors be found in the structure and landscape context of Linköping in Sweden, in which farmland is abundant, food security is high and people are generally not 'forced' to reflect on the supply chain behind their food. Here a strong link can be found with a lack of stressful landscape developments, as described before. Furthermore, it is connected to the vision and expectation of UA as mainly a showcase of innovation and a potential export market. Most actors have indicated education and transparency as important measure for increasing the overall degree of awareness on UA[74]. Some of them also believe a smaller test right or constructed proto-type in Linköping could help raise a higher awareness on UA within the structures of society[75].
When looking at the awareness on the socio-technical advantages outside of the network, some actors have indicated more concerns. First of all, there has been a relatively low awareness on and interest in UA within the University of Linköping, something a lot of actors would like to see improved[76]. Hans Hassle believes the reason for this can also be found in the often still missing link between

[69] Interview 1-8
[70] Interview 2 & 8
[71] Interview 1, 4, 5 & 7
[72] Interview 2 & 3
[73] Interview 5
[74] Interview 4, 5, 6, 7 & 8
[75] Interview 5, 6 & 8
[76] Interview 1, 2, 4 & 5

university research and businesses. Another group within society that is rather unaware of the technological and social advantages of UA in Linköping according to some interviewees is the traditional farming sector[77]. It has been stated that especially an older generation of farmers would be less open to the idea of UA in Linköping, despite their useful knowledge when it comes to growing food. It has been stated as a challenge to overcome this conservatism and include traditional farmers within the UA sector. The low involvement of the university and farmers will furthermore be discussed under the degree of willingness. Furthermore, there are still knowledge gaps when it comes to the WEF-nexus related to UA in Linköping. As Jan de Wilt argues *"the challenge is still to create a win-win situation between actors and sector, in which collaboration benefits all from both a technological as well as a cost-perspective"*[78].

5.3.2 The Degree of Willingness

Inclusion of Stakeholders

Within Linköping there overall seems to be a medium inclusion of stakeholders within the field of UA. Solely related to the UA project of Plantagon, actors have stated that they feel the most necessary actors are included in the process[79]. However, when further asking about additional partnerships they would like to see established, multiple actors arose.

First of all, the University of Linköping has not been as involved in the field of UA and the project as the rest of the network would have liked. It has been argued that the university is mainly operating based on traditionally divided research fields, in which researchers are rather independent in choosing their expertise. In this way, they can also decide if they want to be involved with the field of UA in particular or not. Despite the university its focus on innovation and its generally strong relationship with the municipality in Linköping, it has been quite challenging to get them involved in the project. It has been speculated that reasons can be found in the lack of a top-down management and the newly emerging and interdisciplinary research field of UA. Established scientists are often already embedded in a certain research field and due to their reliance on publications and research grants, they are not always able or willing to make a radical shift in their research focus. Furthermore, there is an existing divide between the work methods and priorities within academia compared to business, which has also played a role in partnerships with universities according tot Hans Hassle from Plantagon[80]. A younger generation of researchers would perhaps be more open to start a career in this field or be open to interdisciplinary research between urban food, energy and water systems, but also between UA and engineering and architecture[81].

Secondly, the traditional farming sector and more specifically the farmers association in Sweden has been named as a valuable actor within UA. Most actors have explained that they would like to see traditional farmers more involved to show them that UA within Linköping is not aiming to compete with their agricultural products, but be an addition to the market through the cultivation of different products that usually are imported from far away. Furthermore, the agricultural sector holds a lot of expertise when it comes to the growing and harvesting of plants. This knowledge could be very valuable for UA in Linköping, where the main niche actors are not in essence 'growers' or horticulturalists[82].

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[77] Interview 4 & 8
[78] Interview 6
[79] Interview 1-8
[80] Interview 1
[81] Interview 1, 2 & 5
[82] Interview 4, 7 & 8

Furthermore, it has been indicated that financial partners are still desired in order to push the project forwards and scale UA up. Most of these financial partnerships are sought within the private sector. However, according to Jan de Wilt the local or national government could generally also play a financial role in UA, by creating the social and financial infrastructure for UA through incentives[83]. The reason why this does not seem to be a priority in Linköping, could again be related to the lack of stressful landscape developments. Actors have mainly pointed towards the important role of investment banks and real estate companies. As Hans Hassle has explained, the strategy of Plantagon on the long-term is to licence their technology and UA systems to real estate developers and cities. To start this process, we need initial investors who understand our long-term vision on UA, who see the business opportunities it can create and who is willing to take on the initial risk[84]. This is currently the main challenge confirmed by all actors and also related to the following section[85].

Political Leadership

Political leadership in Linköping can be perceived as medium. Despite the fact that UA is not a priority within the city of Linköping, there has been official support of the UA project. Paul Lindvall explains that Linköping as a city has a rather progressive character, upon which it formed it slogan *"where ideas become reality".* The project has been debated and approved at the time he was Chairman of the City Board and he has been one of the main actors to push the project forward from a political level[86]. However, the Green Party that was in the opposition at that time was the only actor who opposed the idea of such a large-scale UA project in Linköping. The main arguments where based on the fact that Linköping is surrounded by an abundance of farmland. The construction of a vertical farm would therefore not make sense in the setting of Linköping and Sweden overall. The opposition of the Green Party has caused some delays in the political and legislative processes when it comes to the approval of the building.

However, most actors have stated that one of the main reasons for bringing UA to Linköping has been the political openness and willingness to facilitate the UA project[87]. The strong involvement with innovation within Linköping has contributed to their willingness to take part in such a visionary project. It has furthermore been speculated that the showcase and export-potential of the UA system in Linköping will be able to boost the image of the city as a leader for innovation and resource-efficiency. To show their support, the municipality of Linköping has been part of a symbolic opening ceremony in 2012 at the site where the UA project will be constructed. The municipality has furthermore been involved with the Urban Agriculture Summit that has been organised by Plantagon in 2013 in Linköping. According to Paul Lindvall, this summit has been able to take a lot of doubts away on the UA project for politicians and local media. Overall, the political leadership has mainly been a symbolic one, which could be related to the low degree of financial and legislative resources in the following section.

5.3.3 The Degree of Power

Financial & Legislative Resources

It could be stated that the financial and legislative resources at the municipality level are low when it comes to UA. Overall, Linköping has a very strong economy within Sweden and therefore has the capacity to make large-scale investment. However, UA within Linköping is not perceived as a

[83] Interview 6
[84] Interview 1 & 7
[85] Interview 1-8
[86] Interview 2
[87] Interview 1, 3, 4, 5, 7 & 8

government issue, but more as a *"high-profile business investment"*[88]. Actors have stated that Plantagon is therefore caring the main responsibility for the financial aspects of the UA project[89]. Investments are therefore mainly pursued within the private sector. Even thought the Swedish national government is considering more financial incentives for start-ups and small-scale enterprises to help them accelerate, these are not specifically aimed at UA projects and have not been officialised yet[90]. In order to secure financial resources within Linköping from the private sector, Plantagon needs to be able to make a strong business case. One of the main challenges within Linköping is the aspect of renting out the office spaces integrated into the greenhouse for a competitive price[91].

When looking at the legislative resources within Linköping the same low commitment applies. There have been a few legislative barriers when it comes to pushing UA forward. First of all, the permits and planning approvals for the UA project by the Municipality in Linköping has been taken around three to four years, which has really slowed down the process[92]. Long bureaucratic processes when it comes to spatial planning and environmental legislation have been the main reasons for the delay in the project. A more specific issue that Plantagon in particular encountered within Linköping was the aspect of zoning within spatial planning. The municipality could not decide if the building would fall under the legislation belonging to industries or to office buildings, as it is an integrated building of both. This process took over a year and eventually resulted in the decisions to give Plantagon two different registration numbers on the same piece of land. Another dispute around the UA project in Linköping has been with representatives of a bird association in the region, who were worried about light pollution and the risk of birds flying into the construction. Both these issues have been resolved, but caused delays in the actual construction phase of the project over the last years. Hans Hassle has pointed out that there are in general a lot of mismatches, more so in a global context, when it comes to legislations on agriculture and city planning. These sectors have traditionally always been divided and are now coming together within UA projects. However, legislation has often not been adapted to this new trend and problems are encountered when it comes to definitions, land allocations and regulations[93]. This highly related to following section, which acknowledge the need for long-term strategies in order to scale UA up.

Formulation of Long-term Strategies

UA does in essence not play any role within the long-term strategies of the city of Linköping, or those that have been opposed on the city by the national government. Most actors have indicated that they believe these long-term strategies will not be formulated as long as there are no pressures when it comes to food security and resource availability (landscape developments)[94]. Mats Hellström has pointed out that there are currently discussions within governments and standardization committees in Sweden on how to frame UA within cities, in which a variety of terms like "smart", "symbiotic" and "sustainable" are debated[95]. Sweden is generally known for its leading role on innovation and its clean-tech industry. In that sense it mainly supports all projects or initiatives that contribute to that image in a broader context. However, UA is often not yet perceived as an important aspect to sustainable development and the future urban planning of city.

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88 Interview 2
89 Interview 2 & 3
90 Interview 4
91 Interview 1, 3, 7 & 8
92 Interview 1 & 5
93 Interview 1
94 Interview 1, 2, 3, 5, 7 & 8
95 Interview 4

As already cited, the slogan of Linköping *"where ideas become reality"* has been a way of embracing innovation and branding the city. From this perspective, Linköping is very open to the idea of UA and mainly in its opportunities when it comes to resource-integrations. Furthermore, the city of Linköping has the ambition to become carbon neutral by 2025 (Visit Linköping, 2016). However, Paul Lindvall indicated that the city is mainly focused on energy issues to achieve this goal. The issue of increasing local food production is generally not part of the city its vision and long-term strategies[96].

In conclusion, it could be stated that the governance capacity to scale-up UA in Linköping is rather limited. Within the city is has overall been rather easy to access knowledge within this newly emerging field, but learning processes around UA remain low. Here a link can between the degree of awareness and the previously described landscape developments. In the case of Linköping it seems that a lack of stressful landscape developments also leads to a lower awareness on the problems and possible solutions of UA. The degree of willingness to scale-up UA in Linköping is medium to high. It can be stated that the political leadership is high in Linköping, but is mainly expressed in symbolic support. For the city of Linköping, the UA project would mainly be an interesting addition to its image of innovation and resource-efficiency. Generally, all included actors are committed to the completion of the project, even though this might not be for the same reasons (section 5.1.4). However, there are still actors that have not been as willing to get involved with UA in Linkoping, among which are university actors, traditional farmers and financial investors. The limited governance capacity within Linköping is furthermore expressed in the low degree of power. As UA is not a main priority for the city of Linköping itself, there has been no specific attention for the legislative implications of a vertical-, controlled- and resource-integrated-UA project within the city. Within the city there has furthermore been no financial support for the project. Lastly, UA is also not part of any long-term strategies of the city of Linköping. Here also a strong link can be found between the formulation of long-term strategies and previously described landscape developments.

[96] Interview 2

5.4 Conclusion - Linköping

Sub-question 1.3:
What drives vertical-, controlled- and resource-integrated-UA in the context of Linköping?

Within Linköping, vertical-, controlled- and resource-integrated-UA seems to be mainly driven by niche pressures and more specifically by a strong knowledge mechanism. Plantagon has been identified as the main niche actor and is responsible for the concept and implementation of the Linköping Project. Plantagon has been founded based on the idea of CSR and its vision and mission are specifically aimed at providing a long-term solution for the underlying problems of food security, rapid urbanisation and environmental degradation (chapter 1). Years of research and feasibility studies, together with an interdisciplinary team of experts have facilitated the concept and technology for UA in a vertical, controlled and resource-integrated way. With that, the knowledge and expertise of Plantagon can be seen as the main driver behind the Linköping project. As Plantagon is based in Sweden, most of its expertise has also been developed within this same context. Together with companies like Sweco and Tekniska Verken, Plantagon has therefore been able to initiate a first prototype close to home. Especially a high degree of learning-by-interacting has been responsible for the development of the niche technology and network. This has furthermore led to a high awareness on the socio-technical advantages of vertical-, controlled- and resource-integrated-UA in theory and has for Plantagon been a main driver for pursuing this technology.

Secondly, vertical-, controlled- and resource-integrated-UA has been able to emerge in Linköping due to power mechanism in the initiation stage of a project by Plantagon. Due to the facilitating character of Tekniska Verken and the municipality of Linköping, Plantagon has been able to initiate their first project in Linköping. As explained, the choice for vertical-, controlled- and resource-integrated-UA in Linköping has been rather a coincidence than a very logical step. The circumstances have led to the choice of this city, but actors have expressed the project might as well have been initiated in another city if the situation allowed it. The power mechanism has not been as strong in the later stages of the project, but can be seen as a driver behind the initiation of a project. The main shared expectation of the project has been to create a first showcase of vertical-, controlled- and resource-integrated-UA in the world, in order to further develop and drive it forward.

Overall, Linköping is not dealing with any stressful landscape developments that in theory could drive vertical-, controlled- and resource-integrated-UA forward. It is surrounded by an abundance of land, is not dealing with any stressful demographic trends and is characterised by a high degree of food, water and energy security and self-sufficiency. The lack of stressful landscape developments is also reflected in the inconsistent articulation of visions and expectation on UA within the broader niche network and the low financial-resource cooperation. In conclusion, vertical-, controlled- and resource-integrated-UA in the city of Linköping is driven by the individual vision and mission of Plantagon based in Sweden, a strong knowledge mechanism and the coincidental role of powerful actors at the initiation stage of the project. However, the city of Linköping is not experiencing any stress from the landscape level that drives the need for this form of UA. The broader niche network is furthermore still characterised by inconsistent visions on and expectations of the Linköping Project and a low financial resource-cooperation. These drivers will assist in understanding the following sub-question.

Sub-question 2.2:
What is the capacity of the city of Linköping to scale-up vertical-, controlled- and resource- integrated UA?

Due to the relatively strong knowledge mechanism of the niche environment around vertical-, controlled- and resource- integrated-UA in Linköping, it has been rather easy to access knowledge around the technology and the project. Generally, it has been hypothesized that an easy access to knowledge, together with a high degree of learning process would lead to awareness on the need for structural change within a city. However, in Linköping it can be seen that despite the easy access to knowledge, learning processes are low. These low learning processes could be related to the fact that Linköping is not experiencing any stress from the landscape level. People generally do not see the need for structural change within the context of Linköping itself. As explained, the expectation of the project goes for niche actors like Plantagon, beyond the city of Linköping and serve a more long-term global goal of 'feeding the city'. However, within the city of Linköping the project is more seen as an interesting innovation when it comes to resource-efficiency and sustainability. So, due to the lack of stressful landscape developments and the inconsistency in visions and expectations on the niche level, the city of Linköping does not have a high degree of awareness to structurally change.

Secondly, the city is characterised by a medium degree of willingness when it comes to the governance capacity to scale up vertical-, controlled- and resource- integrated-UA. Building further on the previous section, political leadership is mainly symbolic. Furthermore, the degree of willingness could be improved by including more stakeholders in the process, like research actors, traditional farmers and strong financial partners.

Thirdly, the city of Linköping has a low capacity to scale up this form of UA when it comes to degree of power. Financial resources and legislation devoted to vertical-, controlled- and resource-integrated-UA are low and the city has not been involved in the formulation of any long-term strategies. The low degree of power could again be related to the lack of stressful landscape developments. It has been argues that the allocation of resources and the formulation of long-term strategies will mainly occur when a city is actually experiencing stress from the landscape level and becomes aware of its challenges related to urbanisation, food security and its other embedded resources.

Overall, it could be stated that the city of Linköping appears to have a low governance capacity to scale up vertical-, controlled- and resource- integrated-UA. The completion of the Linköping project seems to mainly rest upon the private- sector-driven niche network. It could be stated that without a higher degree of awareness, the city of Linköping is not likely to become willing and with increase its power to facilitate structural change. In conclusion, there seems to be a strong correlation between landscape developments and the scale-up potential of vertical-, controlled- and resource- integrated-UA. Furthermore, there seems to be a chronological order between the degree of awareness, willingness and power. Awareness lays the foundation for willingness, which again becomes vital for the allocation of resources and the formulation of long-term strategies. However this does not mean they automatically result from one another. The three degrees of governance capacity cannot easily be understood without each other and without the underlying pressures from the niche and landscape level.

6. CASE STUDY ANALYSIS 2 **SKY GREENS & PLANTAGON - SINGAPORE**

This chapter will follow the same structure as the previous chapter, in which the analytical framework has been applied within the context of Singapore. In doing so, this chapter aims to answer the following sub-questions:

1.3 What drives vertical-, controlled- and resource-integrated-UA in the context of Singapore?
2.2 What is the capacity of the city of Singapore to scale-up vertical-, controlled- and resource-integrated-UA?

In the end, this chapter also aims to contribute to a better understanding of driving and scaling-up a potential socio-technical transition around UA, by providing an in-depth analysis of the case study in Singapore.

6.1 Landscape Developments

As explained in chapter 3, the landscape refers to the exogenous context in which a socio-technical system is based over a longer period of time (Geels & Schot, 2007; Geels, 2002; Morone et al., in press; Nykvist & Whitmarsh, 2008). Landscape developments that have been identified in theory are clustered in the physical environment, long-term trends and exogenous shocks. These three independent variables and their corresponding indicators will be assessed in the case of Singapore. In doing so, this research aims to gain more insight into the landscape developments that are driving the emergence of vertical-, controlled- and resource-integrated-UA in Singapore. Table 9 provides an overview of the main results.

LANDSCAPE DEVELOPMENTS		
Independent Variables	**Indicators**	**Overall**
Physical Environment	**Availability of Arable Land** (% Of Total Land Area / Hectare Per Person)	0,8% / 0.00
	Climate Zone (Cold, Temperate, Sub-Tropic, Tropical)	Tropical
Long-term Trends	**Urban Population** (Number and %)	5.535.000
	Urban Population Density (People per km2)	7.697 per km^2
	Urban population Growth (% Per Year)	1.2 %
	Gross Domestic Product (GDP) **Per capita, PPP** (Current International $)	$ 82.763
	Food Security Index (Index 0-100)	88.2
	Food Import (% Total Food Consumed)	90%
	Water Self-Sufficiency **(Through Purification & Desalination)** (%)	40 %

	Energy Self-Sufficiency (%)	2%
Exogenous Shocks	**Experienced Exogenous Shocks** (Yes/No)	No

Table 9: Results - Landscape Developments Singapore (Agri-Food & Veterinary Authority of Singapore, 2016; IEA, 2013; OEC, 2013a; PUB, 2016; The Economist Intelligence Unit, 2016; The World Bank Group, 2016b, 2016c)

6.1.1 Physical Environment

Availability of Arable Land

Currently, only 0,8% of Singapore its in total 718 km^2 of land is arable. As Singapore has rapidly evolved over the last 50 years, most of its farmland has been phased out to facilitate roads, housing, transport and industries. These developments together with an already existing scarcity of land had led to the fact that Singapore is mostly urbanised and importing around 90% of all its food, which will be explained in the following sections (Ludher, 2016). There are furthermore very little opportunities for land reclamation, due to Singapore strategic port, busy shipping routes and the depth of the ocean floor[97]. Land allocation and planning is with that one of the main challenges for Singapore. Almost all land in Singapore is stated-owned and managed under the vision of *"limited land, unlimited space"*, which refers to its ambition to use the limited urban space as efficient as possible for all the national priorities (Singapore Land Authority, 2016; Urban Redevelopment Authority, 2016).

Climate Zone

Being situated near the equator, Singapore has a tropical climate with relatively warm temperatures and high rainfall patterns (Meteorological Service Singapore, n.d.) These climate conditions enable most available crops to grow all-year-round on land, which positively affects the availability of food when it comes to the region around Singapore and import from its neighbouring countries[98]. Despite its favourable climate, Singapore is not able to grow a lot of food due to its lack of arable land. A tropical zone would generally lead to a lower incentive for growing crops all-year-round in an indoor environment.

6.1.2 Long-term Trends

Urban Population, Density & Growth

Singapore currently has a total population of around 5.5 million people, who are all perceived to be urban citizens within a city-state. Singapore its high population and small land surface makes it one of the most densely populated areas in the world, with an urban population density of around 7.697 people per km^2. With an annual urban population growth of around 1.2%, Singapore is dealing with increasing population challenges when it comes to land allocation and resource security and with that more likely to experience stress on the regime-level.

GDP per capita

With an average yearly GDP per capita (PPP in international $) of $ 82.763, Singapore is one of the wealthiest countries and cities in the world. Due a high GDP per capita, it could be stated that Singaporeans are relatively resilient when it comes to their finances and therefore less likely to experience stress on the regime level.

Food, Water & Energy

[97] Interview 11 & 12
[98] Interview 10

Singapore is the third most food-secure country in the world, with a food security index of 83.9. At the same time, Singapore imports around 90% of all the food that its consumes. Since Singapore's independency in 1965, the city-state has been undergoing a large transformation from a rather rural and poor area into one of the most urban and wealthiest countries in the world. Up till 1975, Singapore did invest in its farms and reached almost full self-sufficiency when it came to the production of eggs, poultry and mainly pork (Ludher, 2016). However in the following decades, industrialisation and urbanisation were putting increasing pressures on existing farmland. As farms were located relatively close to the urban areas, problems occurred when it came to smell and waste-disposal issues, especially in pig-farms. This was one of the reasons that Singapore decided to implement higher standards on sanitation, safety and infrastructure within its farms. These strict regulations resulted in additional costs for farmers and due to the then highly competitive pork industry most farmers decided to leave Singapore and move their business to neighbouring countries[99]. Over time, farms were resettled or provided with compensation to make way for e.g. sufficient housing, industries and infrastructure. These trends have currently left only 1% of Singapore's surface available for agriculture of both food and non-food items, which is around 7km^2 (Figure 15) (Centre for Liveable Cities (CLC), 2014, 2015; Ludher, 2016). As stated, Singapore nowadays imports around 90% of all its food (Ludher, 2016; Teng & Escaler, 2010).

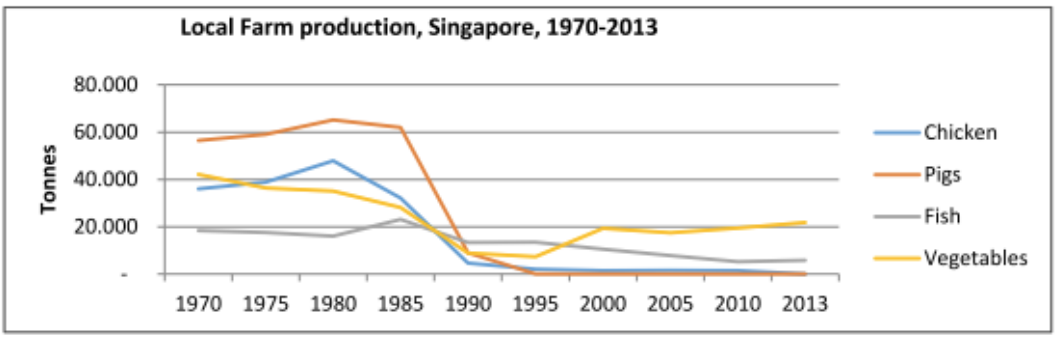

Figure 15: Local Farm Production Singapore 1970 – 2013 (Ludher, 2016)

Singapore has mainly been able to reach such a high food security-level through food-supply diversification strategies (Agri-Food and Veterinary Authority, 2015a; Ludher, 2016). This entails that for every food product that Singapore imports; it has established contracts with at least three suppliers in different countries. So, in the rare case that their main supplier is not able (e.g. due to climate changes, lower yields) or willing (e.g. due to political conflicts) to export a certain food product, Singapore has generally established two back-up suppliers to ensure its food security. By diversifying its food sources, Singapore has up till now always been able to limit its vulnerability to import-fluctuations[100].

This diversification in supply can also be found in Singapore's water management, which has developed into one of the most efficient policies worldwide. Through its so-called *"Four National Taps",* Singapore has been able to secure its water supply by catching local rainwater, by purifying wastewater (NEWater), by desalinating water and lastly by importing water from neighbours (PUB, 2016). Currently, Singapore is able to supply 40% of its water demand through only the purification and desalination of water and aims to increase this level to 80% in 2060 (Ministry of the Environment and Water Resources & Ministry of National Development, 2014; PUB, 2016). However water purification and desalination are both highly energy-intensive, as is food production. Singapore is

[99] Interview 10
[100] Interview 9-14

generally dealing with an energy scarcity, as currently only able to supply 2% of its own demand(IEA, 2013). It does not have any substantial natural reserves and due to its lack of land surface, strong winds and ocean currents, the opportunities for expanding renewable energy sources are limited (Ministry of the Environment and Water Resources & Ministry of National Development, 2009). Overall, Singapore is highly sensitive to landscape developments around its dependency on natural resources, of which the supply of food and energy are its biggest concerns.

6.1.3 Exogenous Shocks

Singapore is currently not experiencing any direct exogenous shocks[101]. However, there is a high awareness on Singapore's vulnerability to potential future shocks in for example food prices, imports and the availability of resources due to climate change[102]. As stated by Shrikant Ramakrishnan, *"almost everything that Singapore does is external and the city-state is aware of the possible risks resulting from that"*[103]. In times of the Nipah Virus in 1999 that largely affected all pork imports from Malaysia or in times of the global crisis of food prices in 2007-2008, Singapore was required to adapt (Ludher, 2016). Most actors have indicated that the government of Singapore has until now always been able to prevent sharp spikes in food prices and inflationary growth, mainly due to the earlier described diversification strategies[104]. However, throughout 2007 the prices of imported food still rose with around 12% in Singapore, due to global disturbances in the price of oil and availability of food. Even though these price-increases did not immediately create chaos in a rich and well-managed city-state like Singapore, it still showed the vulnerability of Singapore to exogenous shocks (Ludher, 2016). Within the network of Singapore, there seems to be a greater concern for global crises than region ones[105]. Overall, there seems to be a common understanding of Singapore its high dependency on trade and resources outside of its own borders and with that an awareness on the possible risk of future crisis.

In conclusion, Singapore is coping with several landscape developments that are able to create stress within the regime when it comes to availability of food and other embedded resources for its growing urban population. As hypothesized, a lack of arable land creates vulnerabilities within Singapore, as it has contributed to the disappearance of local farms, a high-dependency on imports and a continuous competition within land-use planning. Nowadays, its 718 km^2 is completely urbanised and Singapore is dealing with a high population number, density and growth. In its quest for maintaining a liveable and sustainable urban environment for its citizens, Singapore is aiming to increase its self-sufficiency in food, energy and water. As stated, the latter has been one of Singapore's main success stories, with a current self-sufficiency in water of 40% and working towards 80% in 2060. However, when it comes to food Singapore is still importing around 90% of everything consumed. Furthermore, it is currently only able to supply 2% of its own energy use. Due to Singapore's high GDP and well-managed import system within a tropical region, the city-state has up till now been able to limit vulnerabilities and stress within the regime. However, all these landscape developments have been mentioned as current worries and drivers behind UA, as a means to increase local production and resource-efficiency in Singapore[106].

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[101] Interview 9-14
[102] Interview 12 & 14
[103] Interview 9
[104] Interview 10-13
[105] Interview 11 & 13
[106] Interview 9-14

6.2 Niche Pressures

A niche refers to a new and rather isolated space within a socio-technical system that is fundamentally different than the established functioning of the regime. Within a niche, a network of actors aims to change the status quo, by driving systemic change in a certain area, as stated in chapter 3 (Caniëls & Romijn, 2008a; Geels, 2002; Rene Kemp et al., 1998; Nykvist & Whitmarsh, 2008). The three mechanisms through which niches have the potential to drive system change have been identified within theory, which are the expectation-, the knowledge- and the power-mechanism. All three independent variables with their corresponding indicators will be assessed in the case of Singapore. In doing so, this research aims to gain more insight into the niche pressures that are driving the emergence of vertical-, controlled- and resource-integrated-UA in Singapore. Table 10 shows an overview of the main results.

NICHE PRESSURES		
Independent Variables	**Indicators**	**Overall**
The Expectation Mechanism	**Articulation of Expectations & Visions** (Lacking, Rather Inconsistent, Rather Consistent, Consistent)	Consistent
	Awareness on Socio-Technical Advantages (Low, Medium, High)	Medium
The Knowledge Mechanism	**Learning-by-Doing** (Knowledge Generation through Experimentation) (Low, Medium, High)	High
	Learning-by-Interacting (Knowledge Exchange) (Low, Medium, High)	High
The Power Mechanism	**Support of Powerful Actors Financial Resource-Cooperation** (Low, Medium, High)	Medium
	Financial Resource-Cooperation (Low, Medium, High)	Medium

Table 10: Results – Niche Pressures Singapore

6.2.1 The Expectation Mechanism

Articulation of Expectations & Visions

Within Singapore it could be stated that the expectations of and visions on UA are articulated in a consistent way[107]. All actors seem to be aware of the previously described landscape developments, which seem to be directly linked to their expectations of and visions on this newly emerging field. UA is mainly perceived as a measure for increasing local food production and food security, against the background of a rapidly growing urban population. Next to being a measure for increasing local food production, UA is also perceived valuable in creating a more efficient, cooler and greener urban landscape[108]. As Singapore is currently only producing 10% of its own food supply and existing farmland is under a lot of pressure, there is an expectation that the strong reliance on import could create vulnerabilities or stress within the city. There exists a common worry about the affordability and nutrition of food, in the case that Singapore will not be able to secure the import of certain basic food products anymore on the long run. This worry is not so much based on Singapore its own financial

[107] Interview 9-14
[108] Interview 13

capacity to buy food, but on possible events around crises, resource scarcities and climate change that could negatively influence the export of food from their main suppliers. As prof. Lee Sing Kong emphasises "money does not mean anything, when there is no available food to buy"[109].

The articulation of expectations and visions around UA is for most actors also based on a historical perspective on Singapore's development[110]. Singapore developed rapidly from a rural region into one of the most densely populated and urban nations in the world. In order to facilitate a strong economic and urban development in Singapore, farmland had to make way for housing, infrastructures and industries. Due to the strategic location and strong position of its port, Singapore has always been able to still access relatively cheap food and sustain a high food security through imports. It has furthermore always learned to use the urban space in a smart way. For most actors, UA is therefore seen as a logic step for Singapore to explore.

Symbiosis and resource-integration is an inherent part of the vision on UA in Singapore. According to Shrikant Ramakrishnan from Plantagon, the awareness on closing resource-loops has always existed in traditional farming and is shared among generations. Especially in combination with a relatively high awareness on the scarcity of national land-, water- and energy- resources, resource-integration becomes an evident part of UA in Singapore. Furthermore, UA within Singapore has been mainly envisioned within a vertical setting. This can be explained both due to a lack of arable land and a lack of rooftop space. As Elyssa Ludher has explained, rooftop spaces are often already competing with other purposed like water storage, solar panels and mostly air-conditioning. This is why an indoor vertical farm would be less competitive and more productive in scale within the context of Singapore[111]. The government of Singapore has furthermore identified three main food groups in which it therefore wants to become more self-sustaining, which are eggs, fish and vegetables. In all of these three items there is a potential to go vertical within Singapore and that is where UA becomes important[112]. Within the network there is an expectation that Singapore could perhaps reach 30% self-sufficiency of food within the next decade, which is perceived as a great leap forward[113]. At least all actors have the expectation that UA will grow rapidly within Singapore over the next decades, as the city will aim to be a hub for innovation and an *"urban-farming-living-lab"*[114].

When it comes to the type of crops that are grown, actors acknowledge the importance of vegetables that are normally not produced locally and imported from all over the world in order the compete with local prices and reduce food miles. Another aspect to consider is the UA advantage of growing crops all-year-round, which is not so much an issue for countries within the tropical regions, as it is for those in the temperate one. Singapore focuses on perishable and basic food items that cannot be preserved for a very long time and are important for Singapore its food security, like eggs, fish and vegetables[115]. When it comes to the concept of vertical-, controlled- and resource-integrated-UA, the controlled-aspects is the most debated within Singapore. Its advantages and disadvantages are weighed in the light of energy use and cooling costs, but also when it comes to food safety, disease control and productivity [116]. Overall, "w*e have to adopt the most appropriate UA system that uses the lowest amount of resources and provides best productivity"*[117].

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[109] Interview 14
[110] Interview 10, 11, 12, 13 & 14
[111] Interview 10
[112] Interview 10
[113] Interview 9 & 10
[114] Interview 10
[115] Interview 10, 12, 13 & 14
[116] Interview 9-14
[117] Interview 14

Overall, all actors emphasise the importance of economic viability and competitiveness as conditions for UA. They argue that UA will only be able to be successful as long as it can compete with the prices of imported foods[118]. Higher prices could only be justified to a certain extent by the use of branding on competitive advantages when it comes to taste, safety and the environment[119]. As Roshe Wong has pointed out, *"once there is a commercialised model, an idea will become reality",* which is a notion shared by all actors on UA[120]. A stronger connection between the economic viability and the technology is expected to push UA forward.

Awareness on Socio-Technical Advantages

The awareness on the socio-technical advantages around UA in Singapore could be described at medium. When it comes to the social advantages of UA for Singapore and its citizens a high awareness has been expressed, which can also be seen in the previously described visions and expectations. However, when it comes to the technical advantages of different UA systems, some uncertainties seem to remain. While, some actors are rather confident about the technical aspects of UA and believe the advantages are measurable and objective, there are also actors who emphasise that more research is needed on aspects of energy use, plant growth and economic viability [121].

Frist of all, Alfred Ng from CDL has pointed out that the technical advantages of UA within a controlled environment do not apply in tropical zones as they do in the temperate zones. Building a closed greenhouse within a tropical environment like Singapore would require a lot of additional cooling, resulting in higher energy costs[122]. However, without a closed environment, plant growth can easily fluctuate due to a lack of pest control. With that, the niche network around UA in Singapore is still researching the most efficient UA solution in Singapore that at the same time is economically viable. Another doubt of is related to the fact that very few vertical farming structures are actually in place or achieved the potential that they have initially projected[123]. Especially when it comes to vertical farming within a controlled and resource-integrated environment, the challenge becomes even greater. The concern of economic viability seems to be returning in most perspectives on UA and is perceived to be the main barrier for companies and governments to invest in the technology. The costs for vertical-, controlled- and resource-integrated-UA in Singapore are rather implicit until an actual system will be built and operated[124]. This point will be further addressed in the following sections. Thirdly, Roshe Wong from Sky Greens has pointed out that there are still some knowledge gaps when it comes to the biological knowhow and growing processes of plants[125]. Within UA, agricultural or horticultural expertise is of great value when it comes to the right cultivation methods, nutrient formulas and disease control for different plants. However, as Singapore is in essence not a traditional growing country and has lost a lot of its farmland over the last 50 years, there are no decades of expertise to dependent on[126]. The importance of knowledge-exchange and learning form best practices all around the world has therefore been emphasised extensively, which related to the following section[127].

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118 Interview 9-14
119 Interview 12 & 14
120 Interview 9-14
121 Interview 9-14
122 Interview 11
123 Interview 10
124 Interview 13
125 Interview 12
126 Idem
127 Interview 9-14

6.2.2 The Knowledge Mechanism

Learning-by-Doing

As said, learning-by-doing refers to the degree of knowledge generation through experimentation with technology. Within Singapore this degree is high, as experimentation plays an important role within knowledge generation. Singapore promotes itself as a 'living-lab' for innovation and welcomes private initiatives that want to use the urban space of Singapore to test new ideas[128]. Also when it comes to UA, Elyssa Ludher explains that the city basically wants to facilitate an environment in which companies and individuals can experiment, learn and grow. Singapore could in that way be seen as a proto-typing space. However, it is important to emphasise that this is still an on-going process for Singapore and not something that is fully in place[129].

All actors acknowledge the importance of having up-and-running examples in place, in order to drive knowledge and awareness on UA forward[130]. When it comes to generating knowledge on UA through experimentation, actors have pointed to the importance of climate conditions, plant growth and water- and energy-use[131]. Here, the NTU also plays a big role when it comes to research and the development of UA systems[132]. Experimentation does not only develop new proto-types and systems, but also enables existing UA projects to improve and become more efficient along the way[133]. As Roshe Wong from Sky Greens points out, it is important to test and develop prototypes to arrive at a more commercial and scalable business model[134]. These processes can often take a lot of time (up to years) as expressed by both Sky Green and Plantagon[135].

Learning-by-Interacting

Learning-by interacting refers to degree of knowledge generation through exchange of information and interaction between actors. Most actors have indicated to have an open mind-set towards sharing their knowledge and learning from others and this type of knowledge generation is therefore high within Singapore. As Shrikant Ramakrishnan from Plantagon explains, there is no reason for not sharing knowledge and hampering good competition. Knowledge exchange is of essence to the development of new technologies and *"by sharing our expertise we have also been able to take on a more advisory role within meetings and committees on a government level"*[136]. Furthermore, knowledge exchange can be found in the involvement of NTU as one of the main research actors within the upcoming field of UA and its specific technological insights when it comes to farming within a vertical-, controlled- and resource-integrated environment. As stated, also the goal of the CLC as a government actor is *"to distil, create and share knowledge on liveable and sustainable cities"* (Government of Singapore, 2016a). This exchange of knowledge and learning from best practices is often trans-boundary and happens more in an international context.

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128 Interview 9, 10, 13 & 14
129 Interview 10
130 Interview 9-14
131 Interview 11, 12, 13 & 14
132 Interview 13 & 14
133 Interview 14
134 Interview 12
135 Interview 9 & 12
136 Interview 9

6.2.3 The Power Mechanism

Support of Powerful Actors

Within the niche environment of UA in Singapore it could be stated that there is a medium support of powerful actors. Powerful actors have been identified based on the experiences within the network and on the extent to which these actors have the ability to drive UA. Initially, a lot of different actors have been described as 'powerful', ranging from research actors, (e.g. NTU), towards government departments (e.g. MND & AVA) and for example Plantagon as a private actor[137]. Shrikant Ramakrishnan from Plantagon has stated that research (both on technology as well as on market structures and cultures) is the most crucial link for a newly emerging field like UA. He states that a business model that is build upon research will therefore always be valid[138]. Other actors have pointed towards the importance of collaboration, instead of the support of one or a few powerful actors. As vertical-, controlled- and resource-integrated-UA would require resources, like land, water, energy, buildings and infrastructure; a strong collaboration is needed between all involved actors and sectors. UA needs to build on partnerships between the government, businesses and researchers in order to fully investigate its most desirable setting[139]. On the one hand the MND and AVA have the most expertise and influence when it comes to setting long-term strategies for the city of Singapore. On the other hand, research is needed to develop efficient and productive UA technologies, while businesses are required to build, own and operate the UA systems[140].

However, it has been pointed out that in order for this collaboration to grow, initial investors or 'pioneers' within the field of UA are needed[141]. Without actors who are willing to take on the initial risks of a new technology and market, innovation is not likely to occur. Therefore private actors like Plantagon or Sky Greens can be see as pioneers that carry a certain responsibility for creating the foundations for a viable growing environment[142]. In order to make this initial investment possible and create an up-and-running example of vertical-, controlled- and resource-integrated-UA, not only research, but also finances are important. In order to secure these finances the involvement of strong investors or real estate actors are perceived as crucial. Currently, the involvement of such actors is not very high yet, which had led to the medium support of powerful actors[143]. This role of financial cooperation will further be addressed in the following section.

Financial Resource-cooperation

There is a medium level of financial resource-cooperation around UA in Singapore. Financial resource-cooperation is generally perceived as important within innovation, but not as the main priority or end-goal[144]. It is needed to develop a first example of vertical-, controlled- and resource-integrated-UA in order to proof its technology, justify its costs and with that create a viable market. As Shrikant Ramakrishnan from Plantagon has emphasises *"finances are mainly a current need to arrive at a tipping-point, not an ever-existing problem"* [145]. Especially with the emergence of impact-investment banks, actors envision less financial difficulties for UA in the near future[146]. However, at this point in time, it could be stated that financial resource-cooperation is not optimal yet[147].

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137 Interview 9-14
138 Interview 9
139 Interview 10
140 Interview 10, 11 & 12
141 Interview 12 & 14
142 Interview 9, 12 & 14
143 Interview 9, 10, 11, 13 & 14
144 Interview 9
145 Idem
146 Interview 9, 13 & 14
147 Interview 9-14

Overall, there are two main principles and also challenges for UA in Singapore, which are first of all low investments costs and secondly a high productivity[148]. These principles are according to most actors based on the fact that Singapore currently has a relatively cheap access to food imports. In order for UA to compete with conventional food structures and prices, the costs per vegetables cannot be too high. Especially when it comes to leafy greens, most of them are currently imported from Singapore its neighbour Malaysia. This make competition even more difficult compared to vegetables that are transported and imported from the other side of the world[149]. This is according to most only achieved through high productivity and relatively low costs[150]. Plantagon on the other hand offers the option of combining housing or office spaces with a vertical greenhouse, so that not all investment costs would have to be calculated in the price of the vegetable[151]. Generally, it has been stated that there is a continuous challenge between high-tech vertical, closed and resource-integrated systems that are financially intensive, but highly productive; and those systems that are less technologically advanced, but therefore also less efficient and productive. This has not only been seen as an operational challenge, but also as one in research[152].

Prof. Tjin Swee Chuan and prof. Cheng Wei Ning from NTU have pointed out that the university is acknowledging the need for financial resources in developing such innovations and is actually trying to provide some seed money in order to stimulate collaborative research. However, because the start-up costs for vertical-, controlled- and resource-integrated-UA are so high (±millions), additional government funding is often required. In this case, initiatives are highly dependent on the individual willingness of faculty members to comes together and develop a solid interdisciplinary research program. Researchers are often quite independent and it has been proven difficult to prioritise such research efforts[153].

In conclusion, Singapore is experiencing rather high niche pressures around vertical-, controlled- and resource-integrated-UA. First of all, expectation and visions are articulated in a consistent way. These expectations and visions can largely be related to the previously described stressful landscape developments. The awareness on the advantages of UA from a social perspective is rather high, but actors have emphasised that some technical aspects of UA are still under research. Especially the tropical climate of Singapore and the economic viability of certain technologies play a role. Within Singapore, there seems to be a strong knowledge mechanism in which learning is both stimulated through experimentation and the exchange of knowledge between actors and fields. The power mechanism within the niche network is not as strong as desired yet. The support of powerful financial actors is still seen as vital to further drive UA within Singapore. This also related to the financial resource cooperation within Singapore. Within the niche network in Singapore there seems to be a persisting challenge to create a vertical-, controlled- and resource-integrated-UA system that is both low in investment-costs, but at the same time high in efficiency and productivity.

[148] Interview 14
[149] Interview 12
[150] Interview 10-14
[151] Interview 9 & 12
[152] Interview 12, 13 & 14
[153] Interview 13

6.3 Governance Capacity

The regime refers to the general structures, cultures and practices that define the "business-as-usual" of a certain socio-technical system, as explained in chapter 3 (De Haan & Rotmans, 2011; Geels, 2002; Loorbach & van Raak, 2006). In order to scale-up a socio-technical transition around UA, these structures, cultures and practices must be open to change. As explained in chapter 3, this scale-up potential is nested within the regime its governance capacity. According to theory, the governance capacity of a city can be expressed in the degree of awareness, the degree of willingness and the degree of power. Each of these independent variables and their corresponding indicators will be assessed in the case of Singapore. By analysing the governance capacity, this section will be able to derive lessons on how the city of Singapore is capable of dealing with drivers of UA in order to scale it up. Table 10 provides an overview of the main results.

GOVERNANCE CAPACITY		
Independent Variables	**Indicators**	**Overall**
The Degree of Awareness	**Access to Knowledge** (Difficult, Rather Difficult, Rather Easy, Easy)	Easy
	Learning Processes (Low, Medium, High)	Medium
The Degree of Willingness	**Inclusion of Stakeholders** (Limited, Medium, Broad)	Broad
	Political Leadership (Low, Medium, High)	High
The Degree of Power	**Financial and Legislative Resources** (Low, Medium, High)	Medium
	Formulation of Long-Term Strategies (No/Yes)	Yes

Table 10: Results – Governance Capacity Singapore

6.3.1 The Degree of Awareness

Access to Knowledge

Overall, all actors have indicated that it has been easy to access knowledge around UA, which could be related to the high degree of learning-by-interacting within the niche network as described before. There is a high cooperation between government departments, universities, research institutes and private actors, which has made it easy for actors to access and exchange knowledge[154]. The government of Singapore is furthermore known for facilitating role when it comes to innovation and its humble attitude when it comes to learning from best practices in an international context[155]. From a cultural perspective, "leaders often get their space" within Singapore, which means that subject-expertise opens doors and initiates collaboration[156]. This statement both related to private actors like Plantagon, as well as to research actors like NTU[157].

Learning Processes

Learning processes around UA on the regime level in Singapore are medium. Overall, Singapore is nowadays quite aware of the general problems and possible solutions around UA, especially on a

[154] Interview 9-14
[155] Interview 9 & 10
[156] Interview 9
[157] Interview 9, 13 & 14

government level. Within the government these learning processes seem to be based on historical learning, research and the sharing of best-practices world-wide. As Singapore is well aware of the earlier described landscape developments, the government has been very progressive on issues of food, resource security and urban development[158]. Despite its relatively high awareness on the possibilities of UA, the government of Singapore seems to be mainly struggling with land allocation purposes due to a high scarcity of and strong competition over land[159]. Learning processes could furthermore be increased when it comes to an interdisciplinary approach towards UA and its relationship with other resource scarcities, like energy and water. As Shrikant Ramakrishnan from Plantagon has explained *"we are trying to show a system that can produce food, reduce and recycle water and energy, while being part of the urban infrastructure"*[160].

Within society, there also seems to be a growing demand for safe and good quality food, for which people are willing to pay a relatively higher price. With that there is a higher interest for food that is grown locally, within a trusted environment. However, prof. Lee Sing Kong points out that the price of food is very important within Singapore and that a price of 15% above the average price-level will maximum be feasible for UA[161]. The environmental footprint of food furthermore plays a low role within Singapore. As Elyssa Ludher explains, it is a given within Singapore that almost all food products are imported and therefore include 'food-miles'[162]. For the average citizen, it is therefore very difficult to see imported food as a problem. Locally grown foods are mostly appealing to Singaporeans, as they trust the control and safety around food in their own country more than in those of their neighbours[163]. When it comes to the employment aspects around UA, there is still a challenge to change people's mind-sets about agriculture. As traditional farmland is declining and most of Singaporeans work within the service sector of urban environment, the agricultural sector is unfortunately often not being associated with an appealing life-style[164]. Questions therefore arise on who will be maintaining the UA systems and harvest their crops, once they are up-and-running[165]. With this in mind, multiple actors are wondering if UA is able to face these labour challenges, remove biases and gain public support[166].

6.3.2 The Degree of Willingness

Inclusion of Stakeholders

Within Singapore there seems to be a broad inclusion of stakeholders within the field of UA. Stakeholders can be found both in the public as well as the private realm, in which government officials as well as universities and business are playing a role. When asking actors about additional partnerships they would like to see established, no immediate gaps in stakeholder inclusion arose[167].
In other words, it has been perceived that the currently involved actors together have the potential to scale-up UA within Singapore. However, one of the remaining issues when it comes to stakeholder inclusion is as well the aspect of financial investment in UA. Some actors would like to see more government incentives, while other emphasise that the financial investments should come from the business environment[168]. In order to secure finances, niche actors like Plantagon, would like to see

158 Interview 10
159 Interview 11
160 Interview 9
161 Interview 14
162 Interview 10
163 Idem
164 Idem
165 Interview 11
166 Interview 10, 11, 12 & 13
167 Interview 9-14
168 Idem

more involvement of for example real estate companies or investment-banks. However, their inclusion is also dependent on the technological developments and business models around UA in Singapore, as explained before[169].

Some actors might not be of essence for the scale-up potential of UA Singapore, but have been mentioned as a valuable future partner. First of all, local farmers in Singapore could be seen as interesting partners when it comes to the future adaptation of and employment in UA. Not all traditional farmers are open to new ways of growing food, but in Singapore there is generally a high awareness among farmers on the need for innovation within agriculture[170]. As prof. Tjin Swee Chuan and prof. Cheng Wei Ning have emphasised, it would be interesting to set up concrete projects with local farmers to learn from their 'growing-expertise and to educate them on the new possibilities around UA[171]. Another possible group for future collaboration would be construction contractors, according to Shrikant Ramakrishnan from Plantagon[172]. Especially when it comes to the actual construction process of a vertical-, controlled- and resource-integrated-UA, there is a level of intelligence yet to be optimised. Construction contractors would be able to share their practical expertise when it comes to the construction of a building, which is a relationship similar to learning from farmers about how to grow plants in the best way[173]. Community actors have only been mentioned when it comes to speculation on the perceptions of citizens towards this new form of food production, but have not been indicated as crucial actors at this point in time[174].

Political Leadership

Political leadership around UA in Singapore is stated to be high. At the government level there are a lot of different departments who are involved with resource security and increasing local production in order to increase Singapore its self-sufficiency level and create a more sustainable urban environment (Agri-Food and Veterinary Authority, 2013b, 2015a, 2015b, 2016; Government of Singapore, 2016a; Ludher, 2016; Ministry of National Development, 2011, 2013; Ministry of the Environment and Water Resources & Ministry of National Development, 2014). In this way, UA is not only something that is emerging with technology and science, but a newly emerging field in which legislators are also involved[175].

As stated, there is generally a high awareness on the future challenges for Singapore when it comes to resource security and urbanization trends. Due to the government's centralized system, it has been able to address most of these challenges within its strategies, further explain the degree of power section. The high political willingness to develop sustainably and adopt new innovation has created a rather progressive, but also humble mindset [176]. The government of Singapore is very open to learn from private companies, universities and other cities who are dealing with similar pressures[177]. The political leadership in Singapore is furthermore expressed on the formulation of long-term strategies, which will be discussed in the following section.

Despite the high political leadership when it comes to agenda setting, Singapore deliberately relies on the private sector for creating new markets and driving innovation. As said, Singapore aims to be a living-lab for innovation and UA, but mainly facilitates this by creating an open business environment,

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[169] Interview 9 & 13
[170] Interview 10 & 12
[171] Interview 13
[172] Interview 9
[173] Idem
[174] Interview 10, 11, 12 & 14
[175] Interview 13
[176] Interview 9
[177] Interview 9 & 10

not by providing financial policy incentives[178]. Sustainability and innovation should according to Singapore not only be based on good ideals, but also be economically viable. According to prof. Tjin Swee Chuan and prof. Cheng Wei Ning, Singapore holds the political and cultural vision that society should not be supported by crutches, but should be taught to be independent. According to them *"this hardship within Singapore can be seen as a way to groom society to accept and adopt, in order to create a society with a greater resilience and perseverance. It is a philosophy of policy that is not wrong, but sometimes impede the start of new initiatives"*[179]. This aspect of financial power relates to the following section, the degree of power.

6.3.3 The Degree of Power

Financial & Legislative Resources

It could be stated that the financial and legislative resources within Singapore available for UA are medium. Overall, Singapore has a very strong economy, with a capacity to make large-scale investment[180]. Despite its centralized and powerful government, Singapore is in favour of an open-market economy[181]. A high reliance on the private sector and an open market makes sure that the chance a new innovation will be adopted will largely depend on its price. For new technologies and innovations it is therefore often challenging to compete with already existing structures and prices[182]. Despite the fact that Singapore does not have a lot of policy incentives or tax reductions, it does provide certain funds for green technology and productivity in food production (Agri-Food and Veterinary Authority, 2013a; National Environment Agency of Singapore, 2016). As long as an innovation is able to positively contribute to the urban environment of Singapore and can provide a scalable business model, government funds are often available[183]. An example of financial support towards local production can be found in the Agriculture Productivity Fund (APF) of around 63 million Singaporeans dollars, which has been established in 2009 in order to boost productivity and the use of new technologies within local farms.

However, when it comes to vertical-, controlled- and resource-integrated-UA in particular, some general difficulties in obtaining financial resources have been indicated. In any business case, questions are raised around the investment costs, the return on investment, the payback time and the possible risks involved. In this case of UA, costs are often very high (±millions), which will only be paid back over a relatively longer period of time. Also risks are often associated with agriculture, when it comes to productivity, disease control and changing consumer patterns[184]. Due to the infancy of UA, it has been very challenging so far to find enough financial investors that are willing to take on the risk. Most actors have acknowledged that a sound business model is currently the most important challenge to scale-up UA, in which there if unfortunately not always room enough for ideals and long-term visions[185]. According to prof. Tjin Swee Chuan and prof. Cheng Wei Ning, it is in essence about finding the right technology that works and that can be economically and environmentally viable within the city of Singapore.

When looking at the legislative environment within Singapore, most actors have repeatedly mentioned the issue of land tenure contracts[186]. As stated, most land in Singapore in owned by the government

[178] Interview 11, 12 & 13
[179] Interview 13
[180] Interview 9-14
[181] Interview 11 & 14
[182] Interview 9, 11, 12 13 & 14
[183] Interview 10
[184] Interview 9-14
[185] Interview 11, 13 & 14
[186] Interview 10-14

and therefore leased out for a certain amount of time (Singapore Land Authority, 2016). Furthermore, the Urban Redevelopment Authority (2016) is in charge of all land-planning in Singapore and has the authorization to decide what happens with the space within the city[187]. Land is generally expensive at it is leased under market rates and without subsidies. For those who lease land, it is therefore important that all their investments will pay back within the duration of their lease-contract[188]. As Elyssa Ludher has explained, land tenure contracts sometimes create difficulties for individuals or companies to make large-scale investments, especially within the agricultural sector or when it comes to expensive UA systems[189]. However, the insecurity around leasing land is an issue that is known within the Singaporean government and this currently being addressed, by making land tenure contracts by definition longer (20 years)[190].

Roshe Wong from Sky Greens emphasises another current challenges for UA within Singapore, which is a structural problem in the type of fertilizers and pesticides that can be bought and used in Singapore[191]. Due to the very small agricultural market in Singapore, some of the better and newly developed pesticides and fertilisers are not registered and therefore not sold within Singapore. This has created certain challenges in productivity when farming with soil. However, for UA systems with for example hydroponics or aeroponics, this would not form a problem.

To give example of stimulating legislation, Alfred Ng from CDL has pointed towards the BCA Green Mark Scheme that has been initiated in 2005 in Singapore. This scheme is aimed at stimulating sustainability within the building sector and ranks projects and buildings based on their environmentally friendly aspects. As stated by the Building and Construction Authority (2016) it *"provides a meaningful differentiation of buildings in the real estate market. It is a benchmarking scheme which incorporates internationally recognized best practices in environmental design and performance".* Such schemes could actually push UA forward, as UA could play a valuable role in the making buildings greener[192]. Furthermore, Plantagon is already providing an UA design that combines a vertical, controlled and resource-integrated greenhouse with the possibility for office space or housing[193].

Formulation of Long-term Strategies

UA does play a role within the long-term strategies of the city of Singapore. Especially the vertical dimension of growing food, combined with possible synergies between water and energy systems, is extremely interesting for Singapore. The demand for water, energy and food will continue to rise and Singapore is acknowledging the importance of dealing with these issues within the urban environment in order to sustain a liveable environment for its citizens. Especially when it comes to food, Singapore is aiming to be less dependent on only a few supplying countries, as rising food prices and security issues are able to put pressures on Singapore's food-import (Teng & Escaler, 2010). Singapore is therefore increasingly prioritising resource efficiency, self-sufficiency and a greening of the city, aiming to be an example of how a *"densely populated city in the tropics can grow in an environmentally friendly manner"*(Ministry of the Environment and Water Resources & Ministry of National Development, 2009, p. 33). As furthermore stated by the government in the Sustainable Singapore Blueprint 2015, *"given our dense urban landscape, we need to look skywards in our quest to go greener"* (Ministry of the Environment and Water Resources & Ministry of National Development, 2014, p. 38).

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187 Interview 11
188 Interview 10-12
189 Interview 10, 11 & 12
190 Interview 10
191 Interview 12
192 Interview 11
193 Interview 9

In 2013 the Singaporean government also drafted a 'Food Security Roadmap', together with other actors among which Plantagon was one[194]. Within this roadmap, an increase in local production has been formulated as one of the core strategies (Agri-Food and Veterinary Authority, 2013b; Ludher, 2016). Next to goals on increasing the productivity and supply of local produce of eggs, fish and vegetables, the consumption of local products is also being promoted (Agri-Food & Veterinary Authority, 2015; Agri-Food and Veterinary Authority, 2015b; Ludher, 2016). The aim of Singapore to become more self-sufficient is already reflected in the country its water policy and its target to in 2060 supply 80% of Singapore its water demand through the recycling and desalination of water (PUB, 2016). Most actors see food as the next priority up on the agenda for Singapore[195]. Overall, there exists no doubt within the network that Singapore is aware of its challenges and has formulated long-term strategies to tackle those[196]. According to some actors, the main policy challenge with regards to vertical-, controlled- and resource-integrated-UA will be the implementation of a systematic approach in which the traditionally divided silos of e.g. land planning, water and energy, will be integrated and managed in a holistic way[197].

In conclusion, there seems to be rather strong governance capacity within Singapore to scale-up vertical-, controlled- and resource-integrated-UA. The degree of awareness on the problems and possible solutions around UA within Singapore seems rather high. Mainly on the technological and economic aspects of UA within Singapore, there still seems to be room for learning. Furthermore, there is a high degree of willingness within the city of Singapore to scale-up UA, both supported by a broad inclusion of stakeholders, as well as high level of political leadership. This is also partly reflected in the degree of power, in which long-term strategies have been formulated around UA and resource security and efficiency issues. In the case of Singapore, the formulation of long-term strategies seems to be linked to certain stressful landscape developments. Mainly, when it comes to financial and legislative resources, Singapore is still encountering some challenges.

6.4 Conclusion Singapore

Sub-question 1.3:
What drives vertical-, controlled- and resource-integrated-UA in the context of Singapore?

First of all, vertical-, controlled- and resource-integrated-UA in Singapore seems to be mainly driven by landscape developments. The city of Singapore is experiencing several stressful developments when it comes to the availability of arable land, urbanisation trends and the availability and self-sufficiency when it comes to food and other resources like energy and water. The fact that Singapore is one of the most food secure places in the world is mainly due to their very structured and diversified import systems. However, increasing concerns have been expressed when it comes to the long-term access to perishable food items (mainly vegetables, eggs and fish) through import and Singapore its vulnerability to potential global crisis. The stressful landscape in which Singapore is embedded has created challenges when it comes the allocation of land, resource securities and sustainable development. All actors have expressed a high awareness of these landscape developments, which is furthermore reflected within the niche network.

[194] Idem
[195] Interview 9, 10, 12 & 13
[196] Interview 9-14
[197] Interview 9, 10 & 13

Secondly, within the niche network in Singapore expectations and visions are articulated in a consistent way, which all seem to be based on the landscape challenges. As stated, vertical-, controlled- and resource-integrated-UA is being explored as a potential solution for increasing local food production in a resource-efficient way. UA is mainly seen as a form of food provisioning, but is also explored for its potential to create a more liveable and sustainable urban environments, through for example cooling and greening. The shared visions on and expectations of UA within Singapore could also be related to a shared historical perspective on the development of the city. Most niche actors have expressed awareness on the development of Singapore from a rural and poor region into one of the most urban and wealthy nations in the world and are sharing a vision on the long-term sustainable development of Singapore as a liveable urban space. Despite an expressed desire for more research on this form of UA when it comes to its technological benefits and economic viability, the expectation mechanism can also be seen as a strong driver in the context of Singapore.

Furthermore, vertical-, controlled- and resource-integrated-UA seems to be driven by a strong knowledge mechanism within the niche network. Knowledge is easily shared with others and the importance of experimentation is central, also expressed in the notion of Singapore as a 'living lab for innovation'. Niche actors like Sky Greens, but also NTU and Plantagon, have emphasised the importance of developing prototypes, before being able to arrive at a fully developed system that is productive, economically viable and scalable. There seems to be a high degree of learning-by-doing and learning-by-interacting to arrive at the most suitable form of vertical-, controlled- and resource-integrated-UA for the context of Singapore. Next to the knowledge mechanism there is a medium role for the power mechanism. Its has been pointed out that the niche network is not so much looking the support of one specific powerful actor, but is more emphasising the need for a strong collaboration between both businesses, research actors and governmental bodies. However, when it comes to financial resource-cooperation in Singapore, the niche network is currently experiencing some challenges. Openness to financial cooperation has been expressed, but under the conditions of low risks, high productivity and economic viability, which are being researched at the moment. Overall, vertical-, controlled- and resource-integrated-UA in the city of Singapore is mainly driven by stressful landscape developments, in combination with the strong knowledge mechanism of niche actors and a consistent articulation of expectations and visions. These drivers will assist in a better understanding of the scale-up potential of this form of UA in Singapore.

Sub-question 2.2:
What is the capacity of the city of Singapore to scale-up vertical-, controlled- and resource-integrated UA?

When it first of all comes to degree of awareness within the city of Singapore, it can be concluded that this is relatively high. Knowledge around the underlying problems and possible solutions is easy to access and in combination with the stressful landscape developments have led to a high awareness on the future challenges for Singapore as a city within the context of this research. This has not only been concluded from the qualitative interviews, but has also shown in the accessibility of information on government websites and reports throughout the desk research. The related learning process are medium, mainly because actors have expressed a need for more research and education when it comes to the most suitable technology, the economic viability and the cooperation between sectors when it comes to vertical-, controlled- and resource- integrated-UA. Despite a very high awareness on the social-technical advantages of this form of UA within the direct niche network, it has furthermore been expressed that the average Singaporean is mainly occupied with the safety and affordability of their food. When it comes to the environmental footprint of food and the actual social acceptance of UA, awareness could still be improved.

Secondly, Singapore appears to have a high degree of willingness when it comes to structural change. This willingness could again be related to the previously explained awareness and underlying landscape. Overall there is a broad inclusion of stakeholders and at the government level the political leadership is high. Even though Singapore is strongly focused at stimulating innovation through the market and private sector, there is a broad support for further developing vertical-, controlled- and resource- integrated-UA. Government funding or long-term land tenure contracts are often available, as long as an innovative project can proof its productivity, economic viability and value to the sustainable development of the city-state. This high degree of political leadership is interlinked with the degree of power.

The degree of power in Singapore is mainly high when it comes the formulation of long-term strategies. Within Singapore, the awareness and willingness to change are actually transformed into long-term visions and political actions when it comes to increasing the local supply of food. UA as a local food provisioning solution can also be seen as part of the food security roadmap in Singapore. Sustainable development and the security of resources like water, energy and food are all high up on the government's agenda and the fact that Singapore is a city-state makes urban development the main focus of the national government. However, when it comes to the availability of financial and legislative resources, challenges still remain. As explained, despite Singapore's centralized and wealthy government, the city-state believes in the power of the free market. In this way, Singapore does not want to heavily subsidise sectors and attaches a lot of value to the economic viability of innovation in order to sustain itself on the long-term. On the other land, the allocation of land is strongly regulated by the government through land tenure contracts. There is a shared realisation that in order for vertical-, controlled- and resource- integrated-UA to become viable and scale up, longer lease-periods of land would be required to justify high investments.

Overall, it could be stated that the city of Singapore appears to have a high governance capacity to scale up vertical-, controlled- and resource- integrated-UA. All three degrees of governance capacity are present within Singapore, but improvements could mainly be found in learning processes and the allocation of resources. Also in the case of Singapore, willingness seems to be built on a preceded awareness and the degree of power seems to follow on those two. However, the scale-up potential and related governance capacity around vertical-, controlled- and resource- integrated-UA in Singapore seems to be largely influenced by stressful landscape development.

7. SYNTHESIS, CONCLUSION & DISCUSSION

7.1 Synthesis & Conclusion

The previous chapters together form the foundation for answering the two main research questions that have been posed in chapter 1. A short overview of each research question is provided in table 11 and 12, which will be further explained in this section.

7.1.1 Transition Drivers

Question 1	**What explains the emergence of vertical-, controlled- and resource-integrated-UA and could assist in driving a potential socio-technical transition, based on the contexts of Linköping and Singapore?**
Hypotheses	*As hypothesised throughout this research, landscape developments and niche pressures are in theory perceived as transition drivers, as they are able to explain the emergence of niche environments and create stress within an established regime. Stressful landscape developments can be found in the physical environment, long-term trends and exogenous shocks, while niche pressures are able to create stress on the regime-level through a high expectation-, knowledge- and power-mechanism.*
Main Conclusions	• **Landscape developments are essential (Influence on articulation of expectations & visions);** • **Main niche pressures are found in the knowledge mechanism;** • **Role of economic viability (underexposed in theory).**

Table 11: Summary Research Question 1

The emergence of vertical-, controlled- and resource-integrated-UA and its potential to drive transitional change could be explained along different lines. The two case study analyses in the previous chapters have shown that the drivers of this form of UA strongly differ in each urban context, but have led to the following synthesis and conclusions.

Landscape Developments shape Expectations & Visions
First of all, the emergence of vertical-, controlled- and resource-integrated UA as a niche environment seems to be directly related to landscape developments. The level of scarcity and stress when it comes to e.g. land, water, food and energy, but also urbanisation trends, seems to largely shape a niche environment. Especially when it comes to the expectation mechanism, the articulation of expectations and visions seem to be highly related to level of stress experienced by the landscape level. As explained in chapter 2, this type of UA is in essence build upon the interconnectedness of water, energy and food. In the context of Singapore, where landscape developments are most stressful, this interconnectedness is more clearly articulated and emphasised by all actors than in the context of Linköping. As shown, the Linköping project is not being driven by stressful landscape developments, but has mainly emerged as a business initiative to create a prototype for vertical-, controlled- and resource-integrated-UA in a global context. Due to the absence of any significant tensions on the defined landscape level in the context of Linköping, the expectations and visions

around vertical-, controlled- and resource-integrated-UA in Linköping have not been articulated in a consistent way. The diversity of stakeholders together with a lack of shared stress from the landscape level has resulted in very individual and contrasting perspectives on what vertical-, controlled- and resource-integrated-UA is envisioned to be and expected to achieve. For some actors in Linköping, the actual provisioning of food plays almost no role within their perception of this form of UA. Visions vary from being solely an interesting technology of resource-efficiency (mainly energy) or a way of branding sustainability, towards the more global goal of feeding cities in a global context. Expectations are furthermore varying when it comes to the duration, the scale and the impact of the Linköping project. Those niche actors who do hold a more holistic vision on vertical-, controlled- and resource-integrated-UA when it comes to feeding cities, like Plantagon, often have a more global vision on and expectation of the niche environment. The Linköping Project could be seen as a niche that is being driven in a certain urban context, but is actually aimed at other places in the world that are more vulnerable to stressful landscape developments.

Singapore on the other hand is such an urban context that is dealing with a lot of stressful landscape, like a rapidly growing urban population, a lack of arable land and a high vulnerability to the external supply of resources (mostly food and energy). The stress that Singapore is experiencing from the landscape level is also reflected within the related niche environment. In Singapore it can be stated that the visions and expectations on vertical-, controlled- and resource-integrated-UA are articulated in a consistent way, with a broader understanding of all actors how food relates to its embedded resources. UA is envisioned as a possible solution for increasing local food production in a resource-efficient way and is expected to grow significantly in Singapore over the next decades. This consistency could be related to shared stresses from the landscape level, which result in a sense of urgency and a collective challenge. Based on the context of Linköping and Singapore it could therefore be stated that landscape developments mainly have a large influence on the consistency of expectations and visions around UA, which influences the strength of the expectation mechanism of niches. In these two case studies, this has proven to play a large role in the emergence of vertical-, controlled- and resource-integrated-UA and its potential to drive transitional change.

Niche Knowledge

Furthermore, the emergence of vertical-, controlled- and resource-integrated-UA and its transition potential is mainly driven by the knowledge mechanism of niche networks, which mainly relates to learning processes and knowledge generation around the involved technologies. The two case studies have shown that this form of UA requires expertise and cannot exist without research, experimentation and continuous interdisciplinary learning. The role of knowledge and learning especially plays a vital role in the interdisciplinary character of this form of UA, in which technology, agriculture, architecture and knowledge of several resource-systems is combined. Both in the case of Plantagon as well as Sky Greens, the private financial investments of the founders have initially facilitated this knowledge generation and allowed both actors to devote resources to R&D and established valuable partnerships. Currently, Plantagon is for example perceived as one of the main pioneers when it comes to systemic-thinking and technical expertise in vertical-, controlled- and resource-integrated-UA, due to its valuable partnerships and gathered expertise. Sky Greens is on the other hand a pioneer when it comes to the first operationalized proto-type of a vertical farm. Both in the context of Linköping as well as in Singapore, knowledge generation and exchange have been indicates as essential components for the development of vertical-, controlled- and resource-integrated-UA. Both cases have therefore shown that the pressure of niches when it comes vertical-, controlled- and resource-integrated-UA are mainly found in their knowledge mechanism.

Role of Economic Viability

Lastly, vertical-, controlled- and resource-integrated-UA has not emerged based on its economic viability, but it has been perceived as an important factor for driving a potential socio-technical transition. Next to the social advantages and technical possibilities, all actors have expressed a concern about the market potential and costs of vertical-, controlled- and resource-integrated-UA. This could first of all be explained by the high costs for the construction of this form of UA (±millions) and its required integration with the infrastructure of a city. Furthermore, this focus on economic viability could be related to the fact that both niches are largely driven by the private sector, for who UA is a business investment, not a subsidised project. Financial resource cooperation will in reality most likely occur when vertical-, controlled- and resource-integrated-UA is supported by a strong business case and can sustain itself on the long-term. In order for UA to become a viable business model, start-up expenses must be justified and all costs must be calculated in the price of the grown vegetable. In Singapore, Sky Greens has been able to operationalize a functioning vertical farm due to the financial commitments of its founder, but needs to keep its technological investments relatively low in order to maintain economic viability through affordable vegetables. On the hand, Plantagon builds on a business case that combines vertical-, controlled- and resource-integrated-UA with the possibilities for office space or housing, for which mainly real estate actors are approaches as potential financial partners. In this way the investment costs are not all calculated in the prices of the vegetables, but are combined with real estate purposes. However, like any new technology time is needed to arrive at a point in which it can compete with the price-levels of established systems. It has been pointed out that a first prototype or showcase is highly important to stimulate trust and financial partnerships, but to complete a first working prototype this same trust and financial investment is needed. This issues leads to a continuous struggle between developing and proofing a technology on the one hand and being limited by the start-up costs of innovation on the other.

The power mechanism of niches as a driver behind vertical-, controlled- and resource-integrated-UA has therefore been strongly debated. Especially the definition of what is perceived as powerful seems to change over time. In the case of Linköping, the support of Tekniska Verken has mainly given power to the niche through the facilitation of a project-location and the possibility for resource-integration (energy). Without the role of this power mechanism in the initiation-phase of the Linköping Project, the niche might not have been developed within the context of Linköping. However, at this stage in both niche environments it shows that powerful actors are mainly financial ones. Due to the high investment cost, its interdisciplinary character and the large scale of this form of UA, strong financial partnerships have been identified as the main necessity and at the same time challenge. It has been stated that financial partnerships seem most likely to occur when technological insecurities are low, market potential is high and long-term-visions are present. Unfortunately, it has been difficult to find this combination in both cases. In the context of Linköping for example, there seems to be a high awareness on the technology, but a lack of shared and long-term visions on the project and doubts about the market potential. In Singapore on the other hand the long-term visions and market potential seems higher, but doubts are still expressed about the risks of the technology and the return on investment when it comes to the issue of short-term land tenure contracts. Financial resource-cooperation seems with that one of the most vital, but currently least strong indicator of the power mechanism within the context of this research. So, the emergence of vertical-, controlled- and resource-integrated-UA is initially not build on its economic viability, but this has been pointed out as an important driver of a potential socio-technical transition in both cases.

In conclusion, landscape developments are essential drivers to understand the emergence of vertical-, controlled- and resource-integrated-UA and the articulation of expectations and visions within the niche network. From both cases it could be concluded that a lack of stressful landscape developments seems to cause higher inconsistency in expectation and visions within the niche

network, due to the absence of shared stress. At the same time, more coherent visions and expectations are formulated when landscape developments are creating stress and with that awareness, which will also play a role within the next research question. From a niche perspective, the knowledge mechanism seems to be the strongest driver of vertical-, controlled- and resource-integrated-UA in both contexts. Lastly, the economic viability of both niches has stated to be an essential driver for potential transitional change, but is currently still the biggest challenge. As vertical-, controlled- and resource-integrated-UA in these two niche environments is largely driven by the public sector, there seems to be a strong emphasis on finding a viable business model and being competitive with existing markets. It has been argued that these aspects are not easy to achieve for an innovation that has not been established or fully 'proven' yet, without strong financial resource-cooperation. So, to shine more lights on the potential to scale up vertical-, controlled- and resource-integrated-UA, the second research question becomes important.

7.1.2 Lessons for Scaling-up

Question 2	**What lessons could be derived for scaling-up this process in both cities?**
Hypotheses	*As hypothesised throughout this research, the potential of a socio-technical system to scale-up a triggered transition process could be expressed in the concept of governance capacity. A high degree of awareness, willingness and power on the regime-level to structurally change will together result in a high governance capacity to scale-up a transition process.*
Main Conclusions	- **Awareness comes before willingness, which comes before power;** - **Strong correlation between stress from landscape developments and governance capacity;** - **Driven by private sector.**

Table 12: Summary Research Question 2

In order to answer this question, this research has initially looked at factors that assist in scaling-up a potential socio-technical transition according to theory. Chapter 3 has investigated this sub-question and led to the construction of an analytical framework on the concept of governance capacity. In the previous chapters this capacity to scale-up vertical-, controlled- and resource-integrated-UA has been assessed within two case studies, now leading up to an answer on this second research question.

Awareness

First of all, the degree of awareness seems to play an important initial step in leading up to a degree of willingness and power within the governance capacity of a city. A correlation can initially be found between the degree of awareness on the necessity to structurally change and the willingness to do so. When awareness on the underlying problems and solutions is high, due to a high access to knowledge and learning processes, it seems more likely that a city is also willing to change. On the other hand, it does not seem probable that a socio-technical system would be characterised by a high degree of willingness, while having no awareness on why or how to change. The same correlation also seems valid for the degree of power within a regime. As hypothesised, a high availability of financial and legislative resources together with the formulation of long-term strategies should be able to give a regime the power to structurally change. These two aspects will likely not be present, without a preceding awareness and willingness. In this way, a high degree of power also seems to rest upon a high awareness and willingness. A lesson that could be learned is that the degree of awareness initially plays an important role within the strength of the governance capacity and should be addressed before aiming to strengthening other aspects. To point towards the case of Linköping, low learning processes are identified when it comes to the degree of awareness on the possibilities and

need for vertical-, controlled- and resource-integrated UA, which is especially reflected in a low degree of power. On the contrary, Singapore is characterised by a higher degree of awareness, which also reflects in the degree of willingness and power.

As awareness has been defined by an access to knowledge and learning process, it would be expected that they stimulate each other. However, both case studies have shown that an easy access to knowledge does not automatically result in learning processes on the regime level. Awareness and more specifically learning processes also seem to be influenced by the previously defined landscape developments. The more stress a system encounters from the landscape level, the more likely it seems that the degree of awareness will be high. It is however important to emphasise that there is a difference between awareness on the technological expertise of a niche environment and the awareness on the underlying problems and possible solutions. The latter is perceived as most important in facilitating a higher degree of willingness and power. Another lesson that could be derived is that niche actors could try to increase the degree of awareness within a regime, by understanding its landscape level and providing education on the need and possibilities for structural change. Understanding the correlation between awareness, willingness and power could further more provide lessons on what the priority is for a certain system in improving its governance capacity. In Linköping it could for example be seen that the governance capacity could initially be strengthened when it comes to degree of awareness and stakeholder inclusion. In Singapore on the other hand priorities can be found in the allocation more financial resources and making legislation easier, when it comes to for example the issues of land allocation and land tenure contracts.

Willingness

As explained, the willingness of a regime to structurally change has been expressed in the inclusion of stakeholders and political leadership. As hypothesised, a broad inclusion of stakeholders could on the one hand express the support of a variety of actors within society. On the other hand, political leadership shows the willingness of the established government to embrace a niche environment and structurally change. Even though these two analyses are not able to make generalisable claims, a correlation can be found between a medium inclusion of stakeholders and a medium degree of political leadership in Linköping; and between a broad inclusion of stakeholder and a high degree of political leadership in Singapore. However, it is not clear if and what indicator leads to the other and if the two indicators particularly need each other. One the one hand, a broad inclusion of stakeholders would generally imply an inclusion of the government. On the other, political leadership does not always seem dependent on a broad inclusion of stakeholders. Especially not when a niche environment is driven by the private sector instead of the community. Further research would be valuable on the influence of these two indicators and their suitability for expressing a degree of willingness.

Both analyses have pointed towards another explanation for a higher degree of willingness. Again, both the inclusion of stakeholders and political leadership seem stronger in a system that is experiencing stress from the regime level. This furthermore has to do with the previous conclusion that landscape development strongly influence awareness and that awareness seems to be the foundation for the rest of the governance capacity within a regime. In Linköping it can for example be concluded that it has been challenging to get stakeholders like the university, local farmers and financial investors on board, mainly due to a lack of urgency and awareness on the underlying problems. This low degree of willingness is for example also reflected in the fact that university actors in Linköping have not been willing to participate in the purpose of this research. Furthermore, the political leadership in Linköping is rather symbolic compared to Singapore. Singapore furthermore shows a broader inclusion of stakeholders who are aware of landscape stresses. A lesson that could be derived is that a high degree of willingness seems difficult to achieve without awareness on

stressful landscape developments. Niches could again play a role in addressing these landscape stresses specifically for different types of stakeholders, in order to help them understand their role in the potential transition process.

Power

Lastly, stressful landscape developments also seem to have a large influence on the degree of power within the governance capacity. A system that is encountering stressful landscape development, like Singapore, seems to have a stronger governance capacity than Linköping who is not experiencing these. In this way, there seems to be a less strong connection between niche pressures and the governance capacity. Both cases shown that despite the fact niche networks hold a strong knowledge mechanism, this does not mean that learning processes on the regime level are automatically high. Especially when it comes to the formulation of long-term strategies and the allocation of resources, landscape developments appear to play a major role. Long-term strategies on the policy agenda are usually only developed when an issue is seen as an important aspect for the future development and stability of a system. The formulation of long-term strategies within policy could furthermore function as a reference point for innovations and result in responsibility and accountability. In the case of Singapore for example, policy strategies on increasing local food supplies legitimise upcoming innovation and niches around UA. The context of Linköping on the other hand shows that the absence of stressful landscape developments has led to low learning processes around UA and a low degree of power when it comes to the allocation of financial resources, legislation and strategies. Based on these two case studies, it does not seem likely that a regime would hold a high degree of power, when it does not encounter any stress from the landscape level and has not initially build up an awareness and willingness to change around that.

A lesson for scaling-up vertical-, controlled- and resource-integrated-UA could, very straight-forward, be to focus on those regimes that actually experience stress from the landscape level for which UA is aiming to be a potential solution. It is important for a niche to see in which landscape its knowledge is most valuable and to use that knowledge to increase awareness, learning processes and stakeholder inclusion. In this was the to allocation of financial resources, legislation and long-term strategies could be stimulated. This could furthermore assist in identifying potential markets for UA. As explained, the geographical location of the Linköping project has rather been a coincidence, than a strategic choice when it comes to the need and market for vertical-, controlled- and resource-integrated-UA. On the contrary, Singapore could be seen as an ideal setting for this type of UA to develop further. However, for those cities that are not directly experiencing landscape-stress within their own national setting, perhaps a different level of analysis is needed. Especially when it comes to the environmental footprint of globalised food structures and the unequal distribution of environmental degradation and resource-scarcities, a more holistic and international perspective would ideally be needed. In this way, regional stressful landscape developments become less of an individual issue, but more a global and shared concern. The communication of such a global message however requires long-term visions, which has proven to be a major challenge.

Overall, all these conclusions could be debatable, as they rest solely upon two contemporary and context-specific cases. It is therefore valuable to discuss some aspects of the theoretical and methodological decisions that have been made throughout this research.

7.2 Discussion

It is important to acknowledge that the previous explained results are to a certain extent biased to choices and interpretations that have been made throughout this research. In order to put the conclusions in a more critical daylight, it is therefore valuable to consider some points of discussion. These will also provide some recommendations for future research.

7.2.1 Perception of UA

Chapter 1 has started this research by presenting UA as a potential alternative for the provisioning of food, which could furthermore address underlying problems related to urbanisation, environmental impacts and resource-scarcities. This research has furthermore based its analysis on a newly emerging and rather large-scale version of UA, furthermore building upon the principles of the WEF-nexus. With that, the WEF-nexus has mainly played a role in the definition and design of UA in this research. However, throughout the analyses it has become clearer that UA, in this setting and contexts, is not always perceived as anticipated at the start of this research. Vertical-, controlled- and resource integrated-UA in Linköping is mainly seen as an interesting innovation and addition to the city's leading role when it comes to resource-efficiency. In Singapore it is mostly perceived valuable in the light of urbanisation trends, a lack of arable land and resource-security issues. However, both cases have shown that the environmental footprint of food or environmental impacts of conventional food structures compared to UA, do not play a major role in current discussions. Despite some actors who do hold a more global and long-term vision on feeding cities, the evolvement of this form of UA has proven to be less idealistic in reality. Especially when it comes to a lack of stress from the landscape level, this form of UA is mostly dealing with challenges around technical feasibility and economic viability in order to compete with conventional food structures. In order to better understand the actual perception of UA in different contexts, a recommendation for future research could be the inclusion of a discourse analysis. This discussion point could also be related to the type of actors that are currently involved in vertical-, controlled- and resource-integrated-UA, as further explained.

7.2.2 Inclusion of Actors

Vertical-, controlled- and resource-integrated-UA seems to be highly driven by actors of the private sector, who believe in the potential of this upcoming market and who have the technological expertise to develop a system. Despite support from the government level, private actors seem to hold most of the responsibility for the development of these UA systems. This has partly led to the conclusion that economic viability and market potential appear to play major roles in the scale-up potential of vertical-, controlled- and resource-integrated-UA. This discussion point has resulted from the two case studies, but has received little attention within theory. Furthermore, the level of resource-cooperation seems highly influenced by the nature of a niche, when it comes to division between state-, market- and community-actors. Especially the financial responsibility could potentially shift when more actors within society, like the state, could share the initiative for vertical-, controlled- and resource-integrated-UA.

The importance of different actors has also become debatable when it comes to scaling-up a potential socio-technical transition around vertical-, controlled- and resource-integrated UA. As indicated, private sector actors mostly drive the niche environment, but the inclusion of the established government is required when it comes to the governance capacity of a city to scale up the niche innovation. Both case studies have shown a very limited role for community actors within the driving and scaling-up vertical-, controlled- and resource-integrated-UA. The actor-triangles of the interviewees in appendix IV confirm that vertical-, controlled- and resource-integrated-UA is mainly

initiated by private actors, with the support of government agencies and some third sector actors like the university. It could perhaps be stated that the selection of interviewees in this research could have led to biased conclusions. However, community actors have not been identified as crucial throughout the identification of possible interviewees and the actual qualitative analyses. The role the community has only been mentioned within the context of Singapore, when it comes to the eventual distribution of the vegetables and the perception of citizens towards such a new for of food production. The inclusion of community actors or a more extensive stakeholder analysis could be interesting for future research (Runhaar, Dieperink, & Driessen, 2006). However, when a prominent for the private sector seems inevitable, research could also be devoted to more specific business analyses.

7.2.3 Analytical Approach

As this research has taken on a MLP on transitions, the main level of analysis has resulted in the landscape-, regime- and niche-level. These three levels have been popular in theory and have provided a lense for analysing transitions that speaks to the imagination (Geels & Schot, 2007; Geels, 2002; Konefal, 2015; Smith et al., 2005, 2010; Van den Bosch & Rotmans, 2008). The three levels have initially been useful in identifying the process of structural change and have given descriptive power driving and scaling-up a potential socio-technical transition, as explained in chapter 3. However, throughout the process of this research it has proven rather difficult to identify and isolate these three levels in reality. Especially when it comes to the regime level, there are very limited tools within transition theories to define what a regime actually is and where it boundaries are (Geels, 2011; Verbong & Geels, 2007). The theoretical and methodological choices for choosing a level of analysis have played a large role in defining a regime, a niche and landscape. Also Genus and Coles (2008, p. 1441-1442) have pointed out that especially the MLP lacks in clear tools for empirical validation, leaving researchers with a lot of room for individual interpretation when it comes to; *"the operationalisation of variables, case study selections, case study information, transition start- and end-points and the role of technology versus social and cultural change".* This also applies for the choices made in this research, in which vertical-, controlled- and resource-integrated UA has been defined as a niche, nested within a regime on the city-level, furthermore embedded in a national landscape. However, UA as a niche could also have been defined on the global level, due to the international character and trans-boundary influence of niche actors. This would perhaps have led to other conclusions, but would also have made the identification of a landscape and a regime almost impossible from a researcher's perspective. Furthermore, the gathering of context-specific data would be impeded, which would lead to a less informative, clear and feasible research project. On the other hand, this research could have zoomed in on the influence of a particular UA project on a specific sector, like agriculture, spatial planning or infrastructure. Overall, the level of analysis has been one of the main challenges within this research and has largely influenced the formulation of conclusions.

Additionally, the usefulness and validity of the analytical framework drafted in chapter 3 could be discussed. Especially the justification for choosing certain indicators and their underlying hypotheses were not always easy to find within existing literature. Extensive reading, comparing and reasoning has finally led to a graspable analytical framework of the three different levels of analysis, which has divided the focus of this research into the transitions processes of driving and scaling-up. The different levels, independent variables and indicators have mainly been useful in guiding this research and formulating semi-structured interview-questions. Nonetheless, it could be stated that a strong focus on the analytical framework with specific indicators has also led to a rather forced way of looking at empirical data. In an attempt to devote the same amount of attention to each mechanism, degree or indicator throughout the analysis, some interviews might have been too structured. When reflecting on the process afterwards, these are all learning processes of conducting a research project. As already indicated, it has not been easy to define what a regime, landscape and niche

actually means in in practice (Geels, 2011; Genus & Coles, 2008; Konefal, 2015; George Papachristos et al., 2013). Overall, the practical usefulness of the level of analysis and the analytical framework could best be tested, by applying the same approach in multiple contexts, which could be a recommendation for future research.

7.3 Scientific & Social Relevance

The conclusions and discussion points are together able to show the scientific and social relevance of this research. First of all, this research has been scientifically relevant by addressing the underexposed theme of food on the urban agenda and by adding to research on the interconnectedness of food with its embedded resources like water and energy (FAO, 2011, 2014; Haysom, 2015; T. Marsden & Morley, 2014; Terry Marsden, 2014; Morley et al., 2014; Smajgl et al., 2016; Wiskerke, 2015). It has furthermore provided a more specific definition of UA that is in line with the underlying research problems it aims to address. By investigating the niche of vertical-, controlled- and resource-integrated-UA in two specific contexts it has furthermore provided insights into the potential for transitional change and governance capacity. These insights have been based on an analytical framework that has added to the existing body of literature by combining transition theories with governance concepts in order to come to a more specific focus on the transition processes of driving and scaling-up. It has been able to provide an operationalisation of the landscape developments, niche pressures and governance capacity, including hypotheses, indicators and corresponding research methods; which is something that has not existed in this combination before in theory (Geels & Schot, 2007; Geels, 2011; Konefal, 2015; Shove & Walker, 2007; Smith et al., 2005, 2010; Verbong & Geels, 2007). Furthermore, this research has devoted more attention to landscape developments, which has proven to be play a large role within the two case studies. Within theory, the role of the landscape level has been rather underexposed and niches have often received a more prominent role (Coenen et al., 2010; Rene Kemp et al., 1998; Lopolito et al., 2011; Morone et al., in press; Nykvist & Whitmarsh, 2008). This analysis has shown that the nature and power of niches cannot fully be understood without analysing the landscape in which it is embedded and that landscape development are of essence to the degree of governance capacity. In this way, this research has not only been able to apply theoretical concepts and indicators in practice, but has also provided more specific insights in the relationship between them. It has furthermore pointed towards the relevance of different indicators, like economic viability or market potential. However, the actual scientific relevance of the analytical framework can only be properly assessed when it would be applied in multiple contexts. Due to the limited availability of resource and time when it comes to the feasibility of this master thesis, only two in-depth case study analyses have been conducted. It would therefore be desired if the framework could be applied more often within future research, in order to learn from practice and improve its empirical validation. The analytical framework could also be applied is other cases of vertical-, controlled- and resource-integrated-UA or within a totally different field in which transitional change is desired. In that case, mainly the indicators of landscape developments need some adjustments for the right context.

The social relevance of this research can mainly be found in the context-specific feedback on vertical-, controlled- and resource-integrated-UA. By first of all defining UA in a vertical-, controlled- and resource-integrated environment, the relevance of the WEF-nexus has become more graspable and the large-scale potential of UA clearer (Despommier, 2010; Eigenbrod & Gruda, 2015; FAO, 2014; Hoff, 2011; Leck et al., 2015; Smajgl et al., 2016; Villarroel Walker et al., 2014). This research has not only used and added to theories, but has also tried to explain real-life examples and processes around vertical-, controlled- and resource-integrated-UA. The analytical framework could be seen as a practical tool for assessing drivers of transitional change and the role of a system's governance capacity in that. Any system (e.g. a sector, a city or a company) that is encountering some form of

transition stress could use this framework in order to better understand the drivers behind it and the governance capacity to deal with it. Also niche actors, like Plantagon or Sky Greens, could derive practical lessons from applying the framework in specific contexts. As most initiatives around this form of UA are still under development, this research is relevant in understanding opportunities and barriers at this moment in time. This could assist in guiding future processes when it comes to the actual implementation of such UA-systems and its practical integration with urban infrastructures. Here, the concept of the WEF-nexus will also be able to play a more prominent practical role (Hoff, 2011; Leck et al., 2015). However, as previously stated, the framework still requires further validation before strong conclusions or recommendation could be derived from it.

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Appendix I - Glossary

Urban Agriculture (UA)
Urban agriculture can generally be defined as the growing and processing of agricultural products within the boundaries of a city or metropolis, using all resources from within and distributing to the same urban area (Mougeot, 2005).

Water-Energy-Food (WEF) Nexus
The WEF Nexus is an approach that acknowledges the scarcity and interconnectedness of natural resources and aims to look for ways in which different resource systems can complement each other and become more efficient. The WEF nexus is focused on creating synergies between water, energy and food systems and is aimed at integrating this perspective in the design and governance of resource-systems (Bizikova, Roy, Swanson, Venema, & McCandless, 2013; Hoff, 2011; Leck, Conway, Bradshaw, & Rees, 2015; Rasul & Sharma, 2015; Scott, Kurian, & Wescoat Jr., 2015; Smajgl, Ward, & Pluschke, 2016; Yillia, in press.).

Socio-Technical Transition
A socio-technical transition refers to the structural or fundamental change of a socio-technical system, which generates new ways of functioning within that same system. A socio-technical system could be defined along different sectors and levels (e.g. a city or a resource-system), but is characterised by certain path-dependencies that define the established structures, cultures and practices within that system. Structural or transitional change often includes multi-level and multi-stakeholder interactions over a longer period of time (De Haan & Rotmans, 2011; Geels & Schot, 2007; Geels, 2002; Loorbach & van Raak, 2006; Markard et al., 2012; Murphy, 2015; Roorda et al., 2014; Smith et al., 2010).

Governance
Governance generally refers to *"to the complex processes and interactions that constitute patterns of rule"* within multi-stakeholder (state, market and civil-society) networks (Bevir, 2011, p. 2). It could more specifically be defined as all processes that *"make a purposeful effort to guide, steer, control, or manage sectors or facets of societies"* (Lange, Driessen, Sauer, Bornemann, & Burger, 2013, p. 406).

Scaling-Up
Scaling-up can be defined as a process *"where information from one scale is transferred to another, thereby reaching a higher level of scale and a greater impact"* (van Doren, Driessen, Runhaar, & Giezen, 2016, p. 3). In the light of transitions, it refers to *"the translation or societal embedding of sustainable niche practices in the regime"* (Van den Bosch & Rotmans, 2008, p. 11). It is aimed at creating impact both in scale as well as in institutional structures.

Appendix II – Regime & Landscape Backgrounds

Caste Study 1: The Linköping Project, Plantagon - Linköping

Regime Background

To further analyse this niche, the city of Linköping is chosen as the regime level (figure 16). Linköping is a city consisting of around 150.000 inhabitants in the eastern part of Sweden and is with that the fifth largest city of the country (Linköping Municipality, 2015b). It is a relatively small, but growing city, known for its focus on science, innovation and expertise in resource-efficiency (Tekniska Verken), aviation (Saab) and mobile communications (Ericsson)[198]. It furthermore hosts a university and the Mjärdevi Science Park, both internationally known for their expertise in technology and innovation (Linköping Municipality, 2015b). As one of Sweden's 290 municipalities, the city of Linköping has a local government Linköping and is governed by a City Council, of which Helena Balthammar from the Social Democrats is currently the Chairman (Linköping Municipality, 2015c; Swedish Institue, 2016d). The Linköping Project has however been approved under the Chairmanship of Paul Lindvall from the Moderate Party. The local government in Sweden is *"responsible for a broad range of facilities and services including housing, roads, water supply and waste-water processing, schools, public welfare, elderly care and childcare"*(Swedish Institue, 2016d). When including municipality-owned companies, the city of Linköping has almost 10.000 employees. Sweden and with that Linköping is overall known for its high quality of life and its values based on equality, education, a work-life balance and the environment (OECD, n.d.). Sweden is ranked as the 7th country worldwide for doing business and 14th when it comes to transparency, which also related to the environment of Linköping (The World Bank Group, 2016a).

Figure 16: Location of Linköping (Climate-Zone, 2016)

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Landscape Background

The landscape level in this research has been identified on the national and geographical level of Sweden. With its 447.420 km^2 and around 9.6 million inhabitants, Sweden is a relatively sparsely populated country, known for its lakes and far-reaching forests (53% of its land) up in the Northern part of Europe(Swedish Institue, 2016c). Nowadays, around 85% of Sweden's population lives in urban areas, of which most of them are located in the Central and Southern parts of the country. Within a century, Sweden has developed from a country with a long agricultural and traditional history into a service-based and wealthy nation (ICLD & SKL International, 2011). Sweden ranks 14th worldwide on the Human Development Index and has a GDP per capita of around 58.938 current US dollar a year (UNDP, 2015; World Bank, 2014). When comparing Sweden's ecological footprint per capita to the bio-capacity within its borders to account for this footprint, the country shows no current deficit (figure 17). However, it has been estimated that an average ecological footprint of 1.7 global hectares per person is requires world wide to live within the means of the planet's resources (Global Footprint Network, 2016). Sweden has an ecological footprint of 7.3 global hectares per person, but as a geographical area it has a bio-capacity of 10.6 global hectares per person.

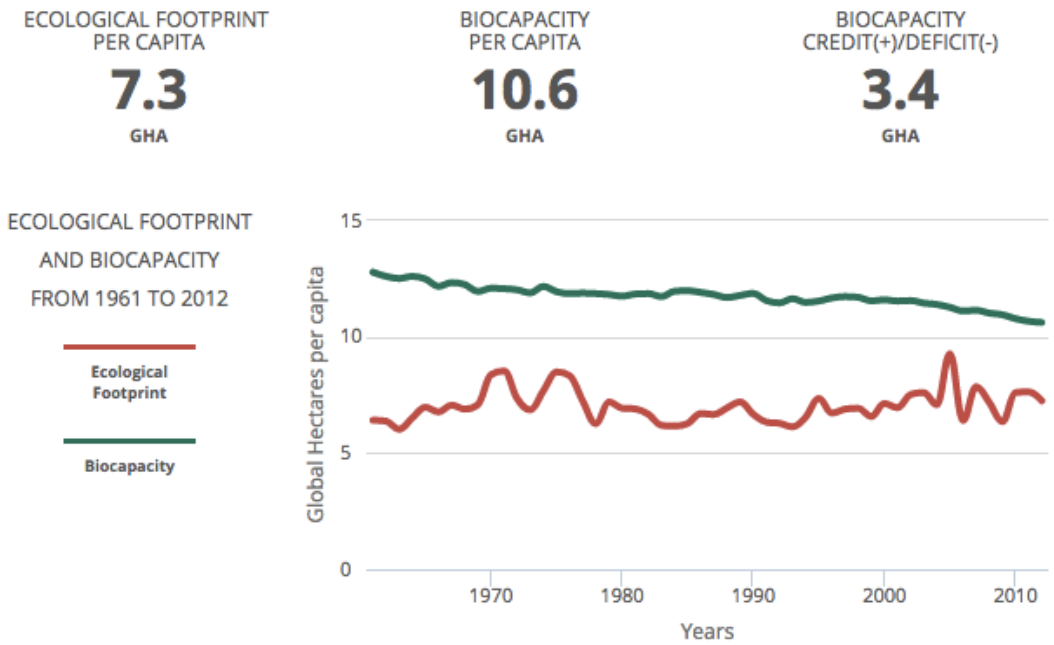

Figure 17: Sweden's Ecological Footprint and Bio-capacity 1961 - 2012 (Global Footprint Network, 2016)

Caste Study 2: Sky Greens & Plantagon - Singapore

Regime Background

To further analyse this niche environment, the city of Singapore is chosen as the regime level (figure 18). The fact that Singapore is a city-state makes the city a rare case, as there is no traditional division between national and municipal government bodies. In Singapore, the national government is highly centralised and completely designed around the development of Singapore as a city. Since its independence in 1965, Singapore became a parliamentarian republic based on the British Westminster System, in which there is an elected President, who elects the Prime Minister, who elects the Ministers in the Cabinet. The People's Action Party (PAP) has been leading the government since its independence, with its current President Tony Tan Keng Yam (Hawkford Singapore, 2016; Parliment of Singapore, 2011). According to (Hawkford Singapore, 2016) the

Singaporean government is characterised as *"authoritarian, pragmatic, rational and legalistic"*. The big role of the government (with 60.000 employees) has according to many benefited the structural development of a nowadays wealthy and thriving Singapore[199]. Overall, Singapore is known for its promotion of CSR, sustainable development and innovation(Agri-Food and Veterinary Authority, 2015a; Cheam, 2012; Ministry of the Environment and Water Resources & Ministry of National Development, 2009, 2014). Singapore is furthermore characterised by a diverse population, recognising four official languages; English, Malay, Mandarin and Tamil (Singapore Tourism Board, 2016). Singapore is ranked as the number one place in the world where it is the easiest to do business and the city with the world's best investment profile (Singapore Economic Development Board, 2016; The World Bank Group, 2016a). Singapore is furthermore ranked as the most transparent city worldwide (Singapore Economic Development Board, 2016).

Figure 18: Map of Singapore (The University of Texas at Austin, 2016)

Landscape Background

The landscape level in this research has been identified on the national and geographical level of Singapore. As already stated, Singapore is the world's only island city-state and the smallest country in the tropical zone of South East Asia. It is located between Malaysia and Indonesia on 63 islands of in total only 718 km^2 (Ludher, 2016). Since its independence from Malaysia in 1965 and its long colonial history as part of Britain, Singapore has over the last fifty years developed from a rural society to one of the most wealthy and urban regions in the world. Currently, Singapore ranks 11th in the world when it comes to the Human Development Index and is, with a GDP per capita of 56.284 current US dollars a year, one of the wealthiest countries in the world (UNDP, 2015; World Bank, 2014). During these fifty year, Singapore's population has furthermore grown from less than 2 towards

[199] Interview 9, 10 & 11

more than 5.5 million people and is expected to grow with another 1 million by 2030 (Ministry of the Environment and Water Resources & Ministry of National Development, 2009; Singapore Department of Statistics, 2016). In its pursuit to create better lives and economic development for its citizens, Singapore has been coping with several challenges when it comes to urbanisation, arable land, land allocation and resource security. Declines in the availability of farmland in combination with a strong and strategic port has led to the fact that Singapore is currently importing over 90% of its food supply, making the country extremely depend on trade (Ministry of National Development, 2011; Ministry of the Environment and Water Resources & Ministry of National Development, 2009; Teng & Escaler, 2010). When furthermore looking at Singapore's ecological footprint per capita compared to its bio-capacity, figure 19 shows a strong deficit. This is largely due to the fact that Singapore is almost completely urbanised and has no substantial natural resource to account for its relatively high footprint (1.7 global hectares per person is desired an average worldwide) (Global Footprint Network, 2016).

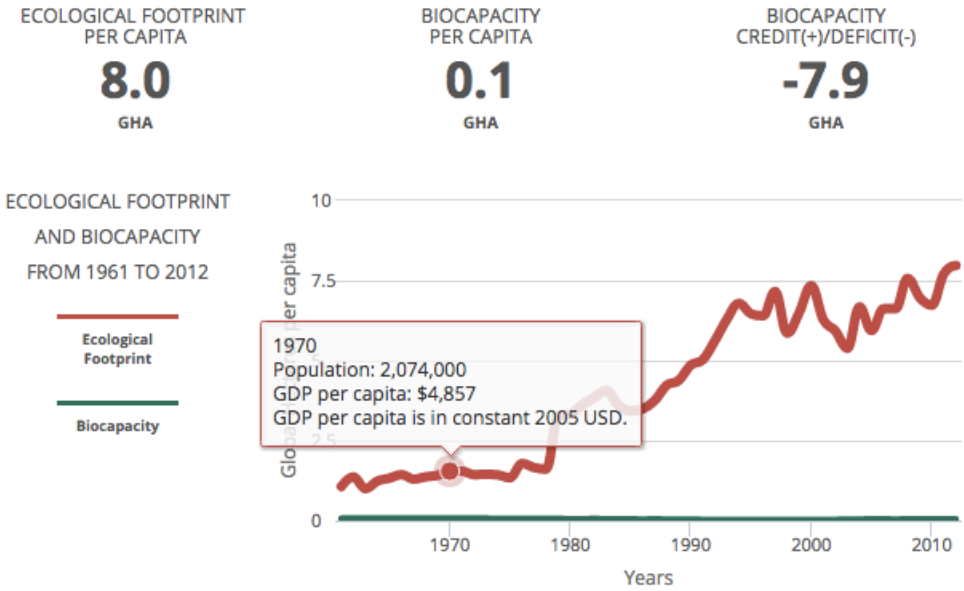

Figure 19:
Singapore's Ecological Footprint and Bio-capacity 1961 - 2012
((Global Footprint Network, 2016)

So, both case studies are examples of a niche environment around vertical-, controlled- and resource-integrated-UA. When looking at their regime and landscape level, the context of Linköping and Singapore could perhaps be seen as complete opposites. Both case studies are in nature highly developed and wealthy, but are hypothesised to cope with different landscape developments, niche pressures and governance capacity (UNDP, 2015; World Bank, 2014). The hypothesis that they are dealing with different pressures is interesting in testing the previously constructed analytical framework in chapter 3. Additionally, the feasibility of these case studies have been guaranteed through an internship with Plantagon in accessing relevant information and contacting involved stakeholders, further explained in the following section.

Appendix III – Semi-structured Interview Questions

LANDSCAPE – LANDSCAPE DEVELOPMENTS			
Independent Variables	**Indicators**	**Questions**	**Order**
-	-	• What are according to you the main reasons for bringing food within the city of Linköping/Singapore?	**1**
Exogenous Shocks	**Experienced Exogenous Shocks** (Yes/No, which ones?)	• Is the city of Linköping/Singapore experiencing any exogenous shocks that might have an influence on the emergence of UA? In case of yes, which ones and how?	**2**
NICHE - NICHE PRESSURES			
Independent Variables	**Indicators**	**Questions**	**Order**
The Expectation Mechanism	**Articulation of Expectations & Visions** (Vague or Clear)	• What is your personal vision on UA? • What was your expectation of the UA project in Linköping? / What is your expectation of UA for the city of Singapore? • Is it easy for you to communicate this vision and expectation to other actors involved?	**3** **4** **5**
	Awareness on Socio-Technical Advantages (Low, Medium, High)	• From your personal perspective, do you feel that all the social and technical advantages of UA are clear (in the case of Linköping/Singapore)?	**9**
The Knowledge Mechanism	**Learning-by-Doing** (Knowledge Generation through Experimentation) (Low, Medium, High)	• What role does experimentation with UA play for you within your network?	**10**
	Learning-by-Interacting (Knowledge Exchange) (Low, Medium, High)	• What role does the exchange of knowledge on UA play for you within your network?	**11**
The Power Mechanism	**Support of Powerful Actors** (Low, Medium, High)	• Which actors or partnerships are according to you the most important when it comes to UA in the city of Linköping/Singapore? • Are there any particular actors (including yourself) that according to you will be able to push UA forward in Linköping/Singapore? Who and why?	**15** **16**
	Financial Resource-Cooperation (Low, Medium, High)	• Do you believe that the involved actors share their resources in order to push UA forward in Linköping/Singapore? Why or why not?	**17**
REGIME - GOVERNANCE CAPACITY			
Independent Variables	**Indicators**	**Questions**	**Order**

The Degree of Awareness	**Access to Knowledge** (Difficult, Rather Difficult, Rather Easy, Easy)	• Is it (rather) easy or (rather) difficult for you to access knowledge around UA? How come?	**6**
	Learning Processes (No/Yes, how?)	• Do you believe that the scientific knowledge around UA is being shared with other actors in the city of Linköping/Singapore? How? • Do you feel this increase/hampers the awareness on the problem and possible solutions around UA?	**7** **8**
The Degree of Willingness	**Inclusion of Stakeholders** (Limited, Medium, Broad)	• Do you believe all relevant actors are recently involved in the project/discussions on UA in Linköping/Singapore? • Are there any additional actors you would like to see participating in the project/discussions on UA in Linköping/Singapore? • So, if I understand right, you would say the stakeholder inclusion in low/medium/high?	**12** **13** **14**
	Political Leadership (No/Yes, who?)	• Do you believe there is political leadership in the city of Linköping/Singapore when it comes to UA? Who and why?	**21**
The Degree of Power	**Financial and Legislative Resources** (Inadequate, Adequate)	• Do you believe the financial resources to push UA forward in the city of Linköping/Singapore are adequate?? • Is there any legislation in Linköping (or Sweden)/Singapore that you believe stimulates/hampers UA? Which and how? • Are there any legislative changes you see needed to push UA forward in Linköping/Singapore	**18** **19** **20**
	Formulation of Long-Term Strategies (No/Yes, which ones?)	• Do you feel that UA is part of any long-term strategies in the city of Linköping/Singapore?	**22**

Table 13: Example of Interview Questions

Appendix IV – Description of Interviewees

In order to show the position of each interviewee as a stakeholder in each case study, this research has made use of the actor triangle formulated by (Evers & Laville, 2004) as shown in figure 20. As the role of actors (as individuals or representing organisations) within transitions it not very well defined, the triangle is helpful in gaining a clearer perspective on the type of actors involved. As Avelino and Wittmayer (2015, p. 7) explain; *"the state is generally characterized as non-profit, formal and public; the market as also formal, but private and for-profit; and the community as private, informal and non-profit"*. The third sector represents, often newly emerging, organisations and types of individuals who do not fit in this strict division, but are cross-boundary. However, within the triangle there is room to place actors who do not comply with these traditional divisions. To give an example; Plantagon is both a for-profit enterprise as a non-profit association, while the Government of Singapore is a state actor that is largely profit-driven (Plantagon International, n.d.-g)[200]. It is important to emphasise that in reality each actor is able to represent multiple roles within different contexts, both professionally as well as personally. In this context, actors will be placed within the triangle based on the company or organisations that they professionally represent within the debate on UA, which is merely a methodological choice.

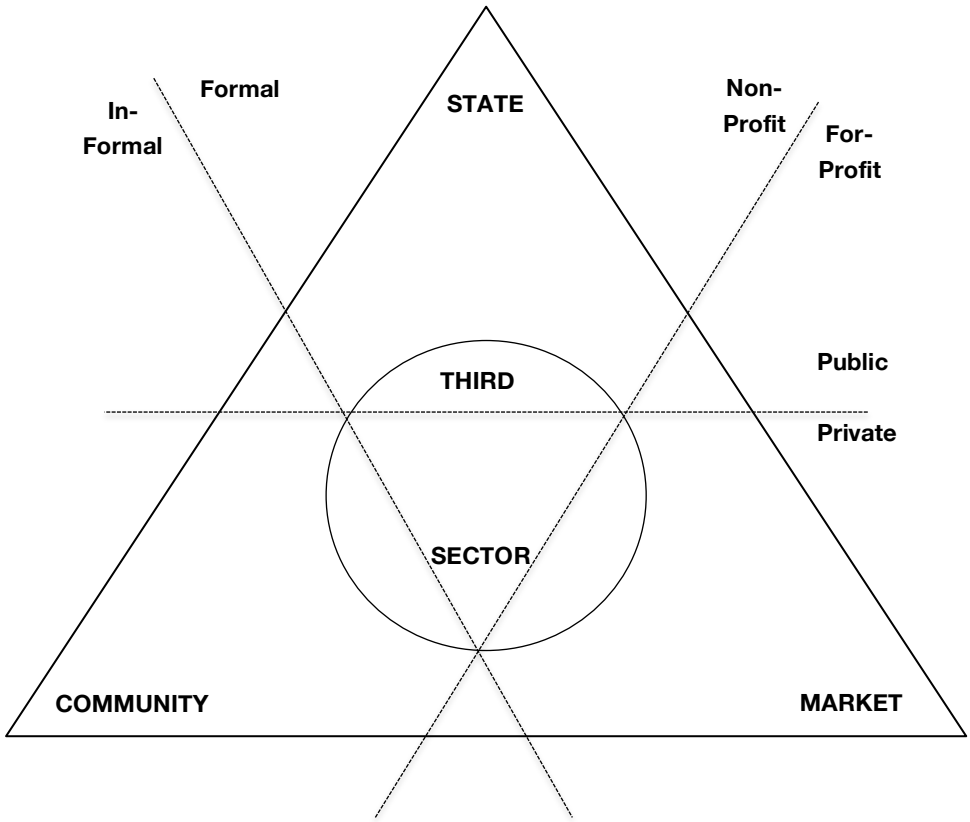

Figure 20: Actor Triangle, Modified from: (Evers & Laville, 2004, p. 17; Avelino & Wittmayer, 2015, p. 9)

[200] Interview 9

The triangle purely functions as a visual representation of where an interviewee is located within the spectra of state, market and community, further specified in informal, formal, non-profit and for-profit. By filling the triangle in for each case study, the reader has a visual overview of what type of actors have been involved in the research, which is important as these might have an indirect impact on the results. The following sections therefore provide an overview the role of each actor and their representation in the triangle (figure 21 and 22). The numbers of each actor refer to their reference in chapter 4.

Caste Study 1: The Linköping Project, Plantagon – Linköping

(1) Hans Hassle is one of the founders and the former CEO of Plantagon since 2008, which means he has been part of the UA project in Linköping form the beginning. Currently, he has taken on the position of Secretary-General for Plantagon International Association, the non-profit side of the companization[201]. Hans Hassle has been highly involved in corporate social responsibility (CSR) throughout his career in the business sector and has written a book in 2012, called *'Business as Usual is over'* (Hassle, 2012; Plantagon International, n.d.-d). He has been the main person behind Plantagon and its Companization model and has won the *"European CEO of the Year*" award in 2012 (Plantagon International, n.d.-d, n.d.-g; World Entrepreneurship Forum, n.d.).

(2) Paul Lindvall is currently the Deputy Chairman of the City Board or in other words Deputy Mayor of the city of Linköping. Between 2006 and 2014 he has been the Mayor of Linköping as part of the Moderate Party in Sweden and during that time he has been involved with the approval of the Linköping UA Project initiated by Plantagon[202]. Paul Lindvall has a background in history, political science and business administration at Linköping University, before going into politics from 2002 onwards. Throughout his career at the Municipality of Linköping he has been highly involved with environmental issues, mainly related to resource-efficiency, biogas-production and waste disposal issues. These issues have at a later stage been linked to the Linköping UA project, as part of the city's progressive attitude towards innovation and new ideas.

(3) Stefan Jakobsson has been Manager Business Development at Tekniska Verken since 2004. Tekniska Verken is a municipality owned company in Linköping that is focus at energy-, water-, and waste-disposal systems. Tekniska Verken aims at resource-efficiency by connecting production processes in order to close loops and with that eliminate a waste of resources. In 2009 he came into contact with Plantagon on the initiative by the former CEO of Tekniska Verken, Stig Holm, who had the idea to combine the biogas plant of Tekniska Verken with a potential greenhouse-system, as an interesting innovation. The reason for this initiative was the fact that the biogas-plant produced an excess of CO_2 and heat, two main components for plant-growth. The collaboration between Tekniska Verken and Plantagon supported a controlled, vertical greenhouse design based on resource-integration[203].

(4) Mats Hellström has been interviewed as the Senior Advisor on Trade and Agriculture at Plantagon. His expertise is based on his career as a politician of the Social Democrats in Sweden, as he has been the *"former Minister of Foreign Trade, European and Nordic Affairs and Agriculture in various Swedish Cabinets between 1983–1991 and 1994–1996".* Furthermore*, "he served as Sweden's Ambassador to Germany in 1996–2001 and Governor of the Province of Stockholm in 2002–2006"* (Plantagon International, n.d.-d). Based in his career and expertise as a politician, Mats Hellström

[201] Interview 1
[202] Interview 2
[203] Interview 3

currently works on a consultancy basis from his own company Matskonsult. His advisory role at Plantagon mainly relates to questions on how the public and private sector can communicate and cooperate in the most constructive way. He aims at being a bridge between governments, universities and the private sector, when it comes to innovation and sustainability within the food and agricultural sector[204].

(5) Thomas Malmer is a Senior Advisor on Academia and R&D for Plantagon and has founded his own consultancy company Percipia AB. He has mainly assisted Plantagon in the beginning of the Linköping project on questions how to establish relationships with universities and research centres on the topic of UA[205]. Thomas Malmer his expertise can be found in "*strategy and policy development in many sectors such as the university sector, life sciences, transport, environment, energy and clean-tech"* (Plantagon International, n.d.-d).

(6) Jan de Wilt is an Honorary Board Member of the Plantagon International Association, the non-profit side of the companization. He is a programme manager at a network called Innovation Agro & Nature, which is an initiative of the Ministry of Economic Affairs in the Netherlands (Innovatie Agro & Natuur, 2015). Within this network, Jan de Wilt is specialised in innovative projects and developments within the agricultural sector. Due to his expertise and experiences within urban agriculture he has both hold a symbolic as well as an advisory role towards Plantagon. He has been participating in the Urban Agriculture Summit in 2013 organised by Plantagon in Linköping, in which he has shared his experiences with greenhouse technologies and experiment in vertical farming within a resource-integrated setting[206]

(7/8) Alessio Boco is a chief architect at Sweco, which is a Swedish company specialised in consultancy, engineering and architecture, with a great focus on the environment (Sweco AB, 2016). He furthermore has a background in engineering in Italy and has over 10 years of international experience in the sectors of architecture, construction and project management (Plantagon International, n.d.-d). Alessio Boco has been involved with Plantagon and the design of the Linköping project from the early stages on as an architect. When the project grew bigger he expanded his team of architects and took on a more management role within the project. His colleague and fellow architect at Sweco Bastiaan Vinkestijn became part of his team and played an important role within the construction and design of the vertical greenhouse in Linköping[207]. Alessio Boco and Bastiaan Vinkestijn have been interviewed together in order to gain insights into the Linköping project from an architectural and engineering perspective. As architects their aims is to take on an interdisciplinary approach in order to understand all the sectors and actors involved in the design of a building[208].

[204] Interview 4
[205] Interview 5
[206] Interview 6
[207] Interview 7
[208] Idem

(9) Johan Mattsson has been involved in the Linköping project based on his personal interest and his professional position at SSAB, a Swedish company and global leader in the steel industry (SSAB, n.d.). He has a background in metallurgical engineering and has over the last 25 years at SSAB worked more towards a position in technical sales and marketing. Currently, Johan Mattsson is the Key Segment Manager Agriculture at SSAB, which mainly focused on steel for machinery in the traditional agricultural sector. When coming across Plantagon in 2014, he became interested in this newly emergent field of UA (vertical farming) in 2014 as potential new segment for the steel industry as well. Premium types of steel consume less CO_2 and could form an important component in the building structure of vertical farms. In that sense, the Linköping project is mainly interesting as a sustainability trademark for the business of SSAB. Currently, an agreement has been signed between Plantagon and SSAB as official partners when it comes to construction material for the building[209].

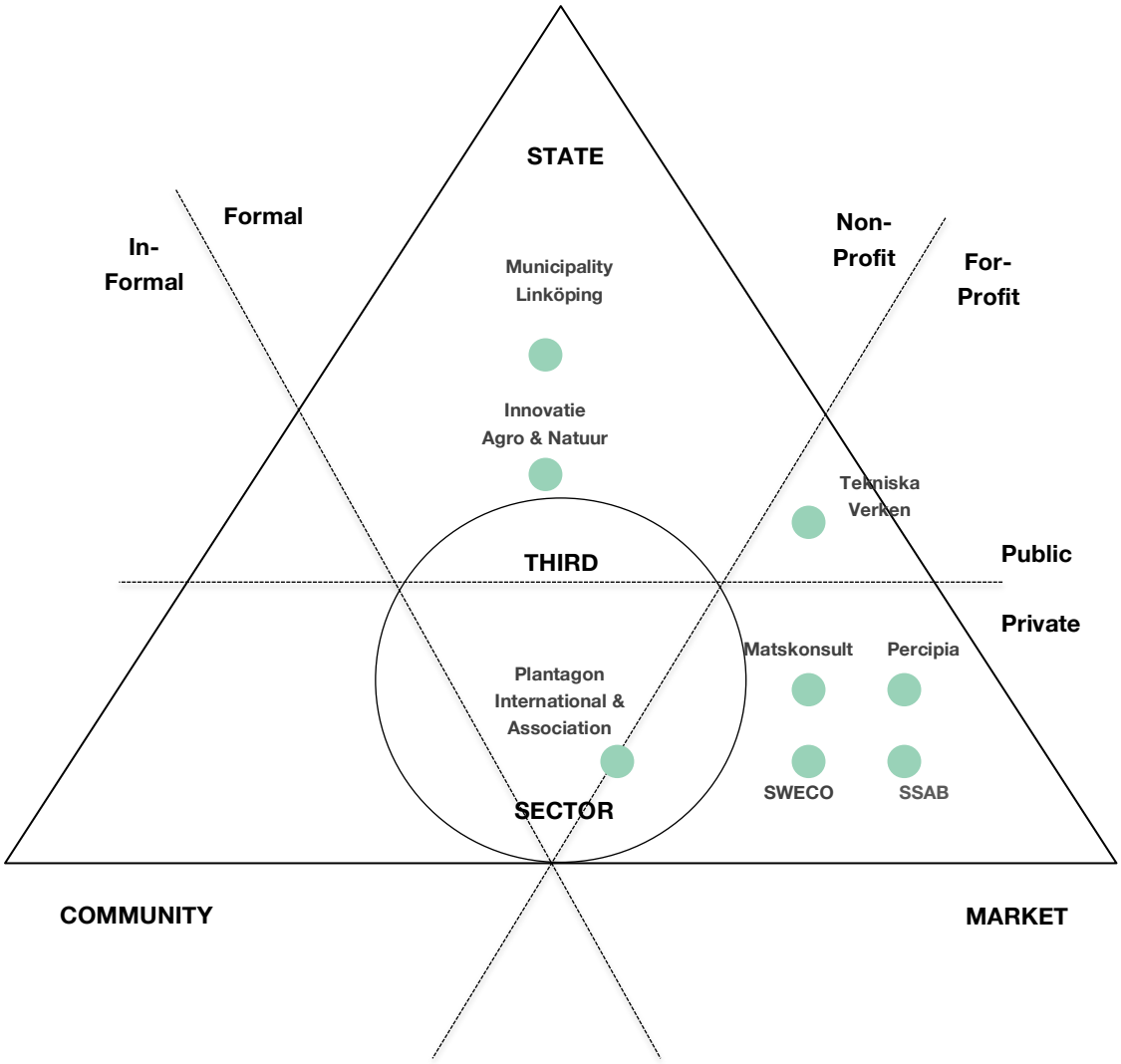

Figure 21: Actor Triangle Linköping

[209] Interview 8

Case Study 2: Sky Greens & Plantagon - Singapore

(10) Shrikant Ramakrishnan is the Global Business Development Director at Plantagon, based in Mumbai, and has been part of the team since 2009. He has an extensive background in business administration, international marketing and international law, while holding an expertise in market research. Before joining Plantagon he has been working in the hospitality-, real estate-and airline industry, not only in India, but also in Europe, the Middle East and other parts of Asia (Plantagon International, n.d.-d). As a global business developer Shrikant Ramakrishnan is focused on exploring and understanding potential markets for UA and on communicating the vision and mission of Plantagon, which are based on UA solutions that comply with a large-scale and the long-term. Understanding consumption patterns and the context-specifics of an urban area are according to him essential in the further development of Plantagon. In order to drive innovation within UA forward, he aims to be the bridge between business, politics and research. Currently, one of the main areas of focus for the further development of Plantagon its UA solutions is Singapore, for which Shrikant Ramakrishnan is the main contact-person[210].

(11) Elyssa Ludher is Senior Assistant Director at the Centre for Liveable Cities (CLC), which is part of the Ministry of National Development (MND) and the Ministry of the Environment and Water Resources (MEWR) in Singapore. The CLC has been initiated in 2008 in order *"to distil, create and share knowledge on liveable and sustainable cities"* (Government of Singapore, 2016a)[211]. Within her current position and with a background in urban planning, Elyssa Ludher is specialised in research, analysis and project management within the urban environment. She is currently specialised in the role of food and agriculture within the context of urban development. The aim of CLC is to understand the development of Singapore as a city-state over the last 50 years in order to derive lesson for its sustainable development in the future, for which a *"high quality of life", "competitive economy" and "sustainable environment"* are seen as key (Government of Singapore, 2016b). CLC is highly focused on innovation and learning, in which it aims to gather best practices from other regions in the world that are dealing with similar urban challenges. In order to build this capacity, CLC organises training programmes, established partnerships and conducts research. Generally, CLC focuses on a variety of aspects in the urban environment, e.g. transport, housing, energy, water, waste en the environment. Within the latter, UA is playing an upcoming role and with her expertise in food and agriculture Elyssa Ludher has gained a lot of expertise in this field form a governance perspective.

(12) Alfred Ng is a project manager at City Developments Limited (CDL), which is one of the biggest real-estate companies based in Singapore (City Developments Limited, 2016). With his background in civil and structural engineering, Alfred Ng has been mainly working on housing and building projects within Singapore. Due to the important role of CSR within CDL, he has been able to take on projects related to greenery and sustainable building[212]. UA mainly comes in as a co-curricular activity related to the sustainability goals of the company within the city of Singapore. Despite the fact that UA is still in its infancy within Singapore, it is relevant to investigate the role of a real estate actor within this emerging field. Especially regarding the UA design of Plantagon in combination with housing or office space, CDL could be an interesting potential future partner for vertical-, controlled- and resource-integrated-UA in Singapore.

(13) Roshe Wong is in charge of Business Development at Sky Greens, *"the world's first low carbon, hydraulic driven vertical farm"* in Singapore (Sky Greens, 2014a). Sky Greens is a privately owned vertical farm that grows leafy greens in the city of Singapore and is with that one of the other pioneers when it comes to UA. The company has been founded by Jack Ng, which has invested his personal

[210] Interview 9
[211] Interview 10
[212] Interview 11

money and time after a successful career into the possibilities of vertical farming from 2009 onwards. In 2010, Sky Greens signed an agreement with the Agri-Food and Veterinary Authority of Singapore (AVA) and in 2012 a commercial vertical farm was opened (Sky Greens, 2014a)[213]. Sky Green has a commitment to creating a vertical, closed and resource-integrated growing system, but is currently growing within a semi-closed environment and in soil. As a business developer Roshe Wong is not so much involved with the daily operations within the farm, but is in charge of selling Sky Greens solutions overseas and establishing partnerships worldwide.

(14/15/16) Prof. Tjin Swee Chuan, Prof. Chen Wei Ning and Prof. Lee Sing Kong have all three been involved with the topic of UA within the setting of Singapore and represent the involvement of Nanyang Technical University (NTU). As a university NTU has mainly been involved in research on the technological aspects of urban farming systems. Prof. Lee Sing Kong is the current Vice President of Education Strategies and the Vice President of Alumni and Advancement at NTU. He has a background in Horticultural Science and Plant Biotechnology and has mainly been involved with UA throughout his career from these two perspectives. His research led to the development of the aeroponics technology, which is aimed at spraying plant roots with nutrient solutions and creating an ideal root zone for plants by root zone parameters, such as the temperature and droplet size. The aeroponics system is highly water-efficient and very suitable for UA. Prof. Lee Sing Kong has through this been involved with the establishment of the world's first aeroponic vegetable farm n Singapore and has receive the *Urban Agriculture Award* in 2000 (Nanyang Technological University, 2016)[214]. Prof. Tjin Swee Chuan holds several positions at the university, which are Project Director in the President's Office, Co-Director of The Photonics Institute (TPI) and Associate Chair in the School of Electrical and Electronic Engineering. Together with his colleague Prof. Chen Wei Nin he has been involved in research around UA systems, in which his areas of expertise are mainly *"fibre optic sensors, biomedical engineering and biophotonic"* (Nanyang Technological University, 2014b). Prof. Chen Wei Nin has a tenured position as a full professor at the School of Chemical and Biomedical Engineering of NTU. He is furthermore the Director of the Food Science & Technology Programme and with that one of the main experts when it comes to UA within Singapore (Nanyang Technological University, 2014a)[215].

[213] Interview 12
[214] Interview 13 & 14
[215] Interview 13

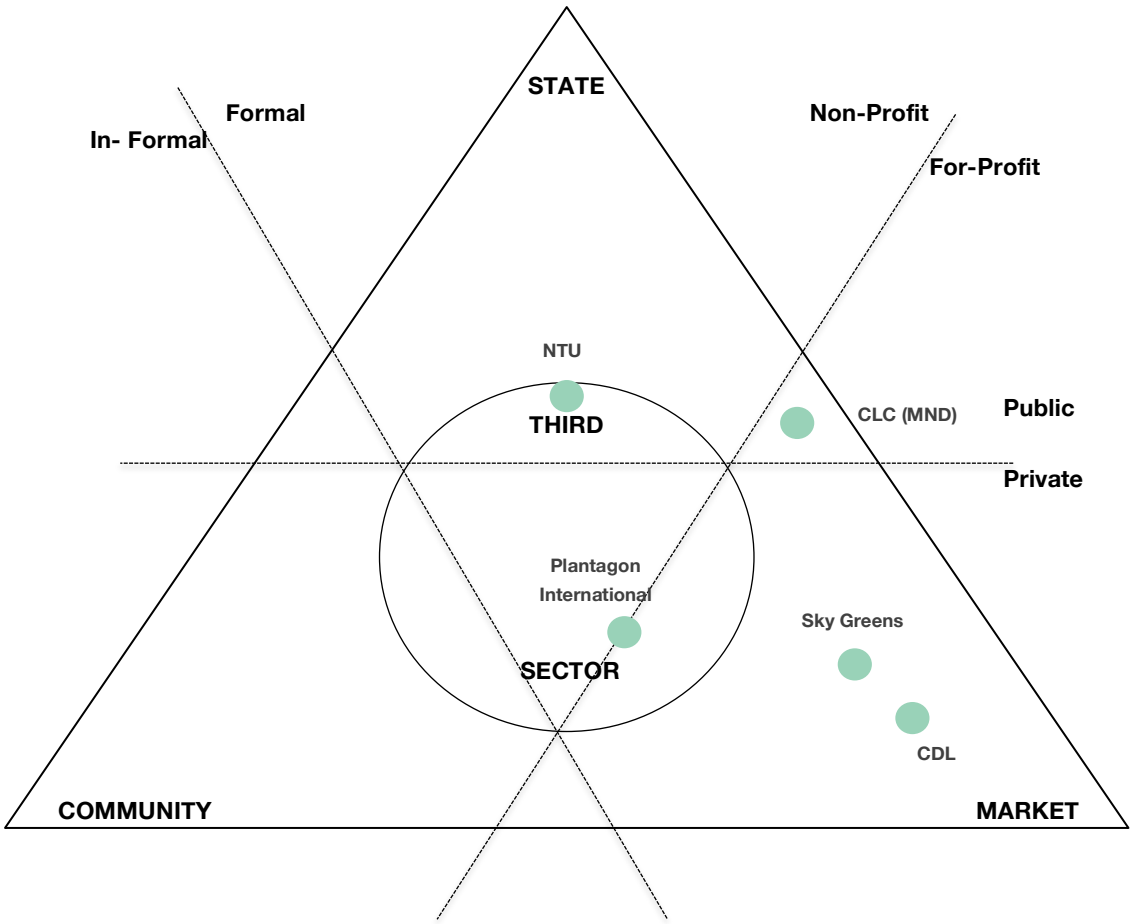

Figure 22: Actor Triangle Singapore