

Norwegian university of life science  
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## **Densification with wisdom? “Fortetter vi med vett?”**

Urban agriculture/vertical farms as a densification strategy.  
Urbant/vertikalt jordbruk som en strategi i fortetting.

Helya Moutouri Skjolden





# Preface

Working with this thesis has been a fulfilling way of ending my studies with. It has been quite interesting and educational. I have learned a lot and I am very thankful for that.

The topic of this study has been challenging due to lack of well established literature. However, this has been rewarding as well. I will therefore give my special thanks to my supervisors Professor Inger-Lise Saglie and Post-doctor Beata Sirowy for giving me the chance to bring this topic, supporting me and giving me constructive input and critique. And special thanks to Henrik Skjolden for all his great support, encouragement and patience.

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And at the end thanks to my family and all my friends for supporting me during this time.

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# Abstract

Projects attempting to implement densification according to national guidelines have resulted in varying success in terms of economical, social and environmental sustainability. Global food production is under pressure by the growing world population. This has repercussions for Norway as well, seeing a rise in food prices as demand increases, as well as putting strain on the local environment and biodiversity.

This thesis discusses how urban and vertical farming can help bridge the efficient use of land and good quality urban environments while providing potential benefits in the three areas of sustainability. Specifically: How can we facilitate and implement Vertical farms in Norwegian context? Why do we need to include vertical/urban farming?

Firstly, a generalized approach, relying largely on literature review, is used to introduce densification and its connection to sustainability, as well as the possible introduction of vertical farming as a strategic tool in densification. Interviews supplement material on vertical farms worldwide, its potentials and planning issues and project implementation. Analysis of this material provides the foundation for studying a specific area and situation, in Breivoll (Oslo, Norway), and is investigated according to criteria of sustainability in relation to vertical farming.

In large part criteria for community-wide sustainability, inspired by Butters refers to in Haas (2012), and different methods and technologies of vertical farming are used as variables. Economic

variables have received less attention and should be investigated in greater depth.

Findings indicate that the widespread implementation of vertical farming to a large degree may help reduce land use. Using volume to produce food rather than area will save space, but the cost efficiency in relation to traditional agriculture is uncertain, at least locally, and in the short term. This has long-term world-wide implications if practical knowledge and expertise are acquired and the proper combination of processes and support systems are incorporated to achieve maximum environmental, social and economic efficiency. In the short-term, it is expected that transformed buildings and warehouses will serve as testing grounds for urban agriculture and vertical farming.

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# Introduction

*I see poverty, I see hunger! I see us consuming resources. I see us damaging the nature and ignore the consequences. I see irresponsible stakeholders prioritizing war over construction. I see them consuming fossil fuel over other energy sources because there is more profit in it. And they ask at the same time? What is happening to the nature, and where does these disasters come from?*

*Jacque Fresco the founder of the Venus Project (Fresco 2002), reminded me of how much life is worth living and how good we can live.*

*Above all the knowledge I have gained during my studies these years, I have grown an ambition. An ambition of being aware of my decisions as an urban planner and understand that everything in a society or even nature is connected. This gives a bigger picture of the whole. It makes finding clues to a better system easier while enabling effective development.*

*Technology and its advances got me to the definition of vertical farming. We often read about how many people die because of starvation, people also die because of eating contaminated food, every year there are several acres of agriculture that are so exhausted because of everlasting human food production that they simply won't function anymore. They have lost all nutrition and the land must be left alone. There are lot's of energy and resources consumed each year only for food production, creating more non-recycle-able waste. Humans way of living through out the history have created challenges like rapid climate change, an incredible growth in population, and a lot of harm to the*

*ecosystem, one thing we share with every other living thing on this bigger system.*

*Back to vertical farming, I learned that one way of avoiding more destruction and delivering safe non-contaminated, locally produced food is vertical farming.*

*It is simply farming vertical. The idea behind is to reduce transport, contamination of agriculture land, water and energy consumption, while creating very little waste. We can by this way save a lot of land while we produce our own food in a safe and controlled environment.*

*Urban agriculture is producing food within the city limits. Using building roofs, backyards, terraces and every possible place to produce food locally. This has indeed lots of social advantages. But that is not enough. It doesn't solve the problem of seasonal changes with its limitation of how long we can produce food each year. Producing ecological cannot by itself guarantee the issue of food safety either. Fukushima disaster in Japan (resulting in contaminated land due to radioactive) must be a reminder that disasters like this can happen and we should be prepared.*

*The important aspects here are to be able to reduce energy and resource consumption while we create as much greenery as we can and invest in the positive effects of our natural resources. Cities are also a controlled environment. We have access to technology, a preparedness that makes our everyday life easier. The way our technologies sometimes fail, has to do with how we implement our own science, sometimes we make things wrong. This does not mean that we can't reverse our failure. Having in the mind that everything is connected, and how we need to cooperate with the natural ecosystem in order to survive, helps us to better take responsibility for our actions. Most of the people now live in cities. We eat all that food and it is time to make our food where we live instead of consuming resources from the*

*outside and occupying the rest of the nature we have left that keeps us alive.*

These were my thoughts behind my research question. Vertical farming in form of urban agriculture has high potential benefits, with gains in varied areas like social, economic, positive health effects, research and environmental effects.

Norway is a country that has long agricultural traditions. With small farms and 3 percent agriculture land with higher rate of import than export.

Norway is not directly exposed to rapid climate change. But it already has a challenging climate and landscape that makes agriculture difficult.

Norwegian government wishes more food production and self-sufficiency. At the same time municipalities use densification as a strategy to develop more sustainable urban spaces and less area use.

While densification has its own disadvantages, like the potential for poor neighborhood to occur or loss of light and view, we can plant more trees and create greenery. We can build vertical farms in each urban district and help produce safe and local food.

Through the study of densification, I learned that urban agriculture or food production is not specifically discussed and there are new policies needed in order to easily be able to implement vertical farms in Norwegian cities. I have studied several examples of vertical farms that function very well worldwide and many examples of urban agriculture initiatives on the national level. Plantagon is a Swedish company that has a concept of delivering fresh, local vegetables daily directly to consumers with no middle hands and no yesterday's food. Plantagon is a more detailed example in this thesis which can confirm that Norway can also benefit from this technology.



## Research question

My main research question is:

***How can we facilitate and implement Vertical farms in Norwegian context?***

Groruddalssatsingen is the biggest financial investment for an area boost in Norway. The initiatives affect four districts in eastern Oslo (Alna, Bjerke, Grorud and Stovner), which together house over a fifth of the population of Oslo. This initiative is a cooperation between the municipality of Oslo and the Norwegian government. Backed by a vision of sustainability and a dramatic transformation effort on the part of the local and national government I am provided with greater opportunity in exploring and covering the potential for vertical farming in Groruddalen.

*I wish therefore to study the potential for building vertical farms in Groruddalen with a feasibility study.*

Subquestions are:

- 1. What is missing in todays planning system and densification strategy?**
- 2. Why do we need to include urban agriculture/vertical farming?**
- 3. Where can we find already existing urban agriculture and how have they been implemented?**
- 4. Where do we start in the Norwegian context? (feasibility study)**

The subquestions are natural additions to my main question to help give the reader a good overview of the situation, including issues and possibilities.

## Structure and refinement

The first chapter of the thesis addresses densification/planning theory:

I will attempt here to define the relevant context and theory in which vertical farming can be integrated. This has its roots in practicality and the scope of the thesis does not allow for a complete debate around the theoretical implications of vertical farming. Nonetheless, I will attempt to connect urban agriculture/vertical farming to relevant theories and provide a backdrop to why vertical farming is a good idea.

In the second chapter I discuss vertical farming:

Due to the open ended definition of vertical farming and non-existing standards I will focus my effort in this thesis on drawing on resources from different projects, at different scopes, localizations and methods, to provide an overview of potentials.

Additionally I will present one concrete example of the planning and attempted implementation of such a structure that has relevance to Norwegian conditions.

Lastly I will present a feasibility study in Oslo, leaning on the information provided in the earlier chapters. Costs of such a project is highly dependent on local conditions, directly influencing which technologies and methods are needed. Also there are no vertical farms today, which employ most of the presented technologies (Appendix) to its fullest potential, making it even more uncertain of the true costs of such a project.

## Limitations

Firstly I wish to emphasize that this is a normative and qualitative study. Providing quantitative analysis or surveys could help to form a complete assessment, but is outside the scope of this study. But more importantly it is because of the limited amount of actual data and studies concerning vertical farms and quantitative data for densification as a strategy. I therefore lean mostly on qualitative dimensions throughout the thesis. Further I will be studying my research question largely in light of social and environmental aspects.

I have done two interviews to supplement my material and to provide a brief overview of an experts opinion of the scope and viability of vertical farming. Further in-depth interviews concerning various aspects such as technology, public awareness and political climate would be at the top of my list had there been more time. Among the most interesting interviewees in this context would be Sky Greens in Singapore and Kono Designs in Japan.

Likewise, it would have been very interesting to perform a full scale case-study of the Breivoll/Alna area, perhaps even extending the area to encompass most of the Alna river areas. This would likely enable me to provide the best location and implementation of a vertical farm or a small series of structures to support more people. As it stands I will show the reader why it is a good idea to prepare for urban and vertical farming, and this remains the focus of my thesis. In this context a proper estimate of costs would also be welcome.

Concerning my first part about densification it would have been interesting to expand upon planning theory and how vertical and urban farming can extend it. In addition, further investigations

around practical planning issues, such as zoning and building regulations, could help strengthen my case.

## Method

This study starts with a literature review and discussions about densification, a strategy Norwegian government has chosen for a more sustainable urban development. Norway is not the only country focusing on this strategy, there is a considerable amount of information about compact urban development, different ways of densification and what kind of pros and cons such a strategy brings, both from national and international references. The literature review and theoretical discussions in this part are then based on Norwegian parliamentary reports, previous analysis and researches from both Norwegian and international sources.

I will use the literature review as a resource towards showing how it is possible to achieve a greater degree of sustainability, both on the physical and social plane. I will highlight the aspects that contribute towards a successful and efficient use of this strategy.

**The main crucial question here is whether densification is the right path to choose, and if yes, how can it be improved to bring more quality towards a sustainable development?**

I then use densification as a general aim in my suggestion, which is developing vertical/urban farms. My research tool here is primarily literature reviews in combination with discussion and analysis. I am choosing these methods in this part because I get to hear about the processes, challenges and technologies being used in projecting and implementing vertical farms and to show the reader in which planning context this idea is most appropriate

and effective. I will concentrate my effort on a few books and authors, and will also be using the latest available information and publications, concerning the climate, provided in large part by the UN.

The interviews are used as supplemental information covering the planning and implementation of vertical farming, as well as contributing directly as experts' opinions on the matter.

Urban places are facing challenges like rapid population growth and thereby more housing, food production, and transport requirements. Food is one of the most essential needs of a community, and one of the biggest sources of energy and resource consumption. In addition to all the factors mentioned above, traditional food production also requires more land use.

Analysis and the interpretation of statistics can help me to find out about the amount of food requirement, energy and resource consumption, from today's Norway food production to waste and recycling. By comparing these results with analysis and data I find from vertical farms, I can confirm whether vertical/urban farms are one key towards a better urban environment. I will also study social aspects in relation to vertical farms by making analysis and a literature review based on previous studies and my own interviews with relevant people. There is a similar project in process in Sweden called Plantagon which can provide information about the whole process.

The last part in this study is a feasibility study on Groruddalen, an area in east Oslo. I wish to examine smaller parts of the area's potential for vertical farms based on the findings from part one and two and the latest municipal and regulations plans that exist for this area by a direct cooperation with the plan and building department in Oslo. In this part I will be using the plans

published by the municipality concerning the development of Groruddalen, in particular focusing on the Principle Plan and Groruddalssatsingen.

## Theoretical basis

*“There are patterns of behavior that promote survival, there are social conditions that changes the values and outlook. No one can write a constitution of required behavior without consulting the environment. We better take care of one another and we better educate people to the highest possible levels of our ability in order to have a society” (Fresco 2002).*

We are now in the 6th wave of innovation based on Hargroves & Smith (2005). Hargroves & Smith identify six waves of innovation that have shaped cities, ultimately creating the poly-centric urban regions of today. Figure 1 is meant to illustrate the potential benefit one can derive from new technological fields and concepts. According to Hargroves & Smith (2012) each successive wave evolves faster and comes more quickly than its predecessor. In our present wave the key terms are: sustainability, radical resource productivity, whole systems design, green chemistry, industrial ecology and renewable energy. All of these keywords can, to a lesser or greater extent, be applied to vertical farming. Concerning vertical farming as a densification strategy the two keywords sustainability and whole systems design are the most relevant.

It is important to understand that to actually harness the full power of our innovations one also need to implement them systematically. This is the point of planning as well: to best utilize the resources at disposal. With new technologies one also gain

World Commission on Environment and Development ( 1987) **(Brundtland Commission)** defines sustainable development as: “Sustainable development is a development that meets present needs without compromising the ability of future generations to meet their own needs. It includes two key elements: “

- Meeting the needs, particularly basic needs of the world’s poor, who should given first priority.
- The idea of limitations that today’s technology and social organization on the environment’s load opportunities to meet current and further needs.” (Guttu, Thorén et al. 1999)

Figure 1: Brundtland commision Source: (Guttu, et. al 1999)

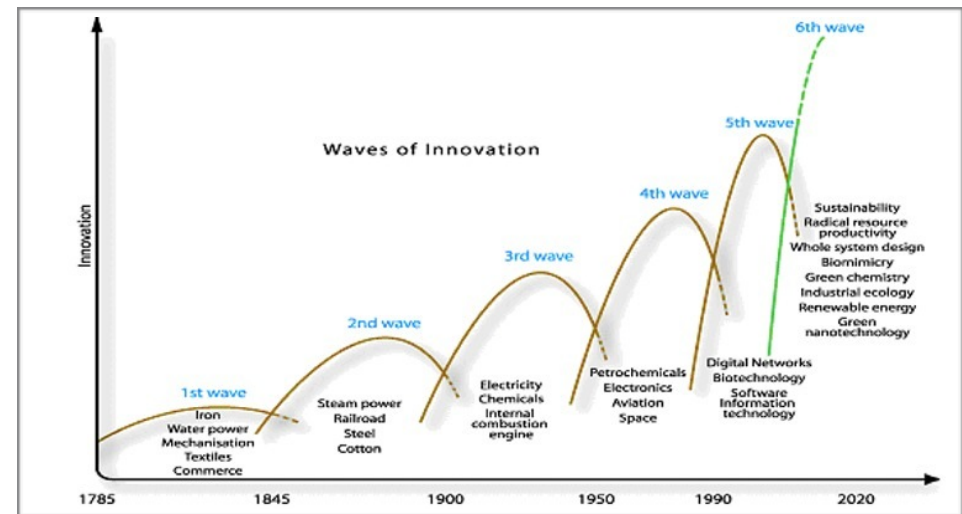


Figure 2: Waves of innovation Source: (Carmona 2010: 24)

new concepts and open up new understandings of how systems and its individual parts work. This is also the aim of this thesis: to

inform of actual possibilities concerning vertical farming and to help establish a way of implementing it.

As Krueger and Gibbs point out: “The discourse of sustainability is being more widely deployed as an urban and regional development strategy than ever before” (Krueger & Gibbs 2007: 11).

Today’s interest for a sustainable development has its roots from the late 1980s and has been largely discussed since then. It is embodied in Brundtland Commission Report (WCED, 1987) and the UNCED Agenda 21 proposals (1993). These theoretical and policy developments differ from earlier efforts. In contrast to the earlier environmentalism of Garden City and Regional Planning Movement, today’s principal preoccupation is with the environmental and socio-economic consequences of energy production and consumption. This is an issue which has never seriously been considered or understood by garden city theorists or even modernists. Another difference is the recognition of a global rationale. Sustainable development has to be considered everywhere and in every level of practice and policymaking. These emanate from the rapid globalization, climatic changes and environmental problems. It is often the lack of understanding of these dimensions that makes it difficult to come to terms with modern or contemporary arguments about densification and sustainable form (Jenks & Burgess 2000 p.10).

Today the term sustainable development addresses three key aspects, environmental sustainability, social sustainability and economical sustainability. The first two aspects are my main focus areas in this thesis.

According to Koglin (2009) the term environmental sustainability in urban context implies: “for example of air pollution, ...and air

quality... or, on a more regional level studies about the industrial metabolism, which means the material flows and transformations caused by different industries” (Koglin 2009). Adding to Koglin (2009) I suggest that it also implies biodiversity.

It is important to register that all the countries have specific environmental conditions and different degrees of impact regarding environmental issues in cities. These differences in development are registered in terms of: “...the levels and types of renewable and non-renewable resource use; the volumes and composition of energy production and demand; the levels of production of CFCs and greenhouse gases; the levels and types of air and water pollution; the volumes and composition of solid and toxic wastes; the levels and types of soil degradation and erosion; the degree of conversion and removal of vegetation: the impacts on biodiversity and differential access to the global commons and their resources” (Jenks & Burgess 2000).

At the same time there are some ideological differences between different groups in the environmental sustainability discourse, this also includes the practical approaches. According to Timmermans (2012) “from the perspective of urban ecologist, cities can act as man-made habitats for wildlife, providing people the opportunity to enjoy wild plants and animals in their own environment,...” while an architect’s viewpoint of sustainability focuses on sustainable buildings, or the ecologist’s perspective seeks available wildlife habitat, thus creating a gap in how the environmental sustainability is viewed and delivered in our practical approaches (Haas 2012: 199).

“In terms of policy, however, sustainable development remains ultimately about environmental improvements and challenges, not issues of social justice per se” (Krueger & Savage 2007).

The term social sustainability has had considerably less attention in the sustainability discourse. However when talking about the

social dimension of sustainability, it can include issues such as: healthcare, social support, human rights, social responsibility, cultural competence, community resilience, and human adaptation (Woodcraft, et al. 2011).

Woodcraft puts it this way: “Social sustainability is an issue of public value as well as the wellbeing, quality of life and satisfaction of future residents. It demands a new approach to planning, design and development that are called social design, which needs to be integrated into policy and professional practice across all the disciplines involved in the creation of new communities — much like the way standards of environmental sustainability have become widely adopted in recent years” (Woodcraft, et al. 2011).

However according to Krueger (2007) “What seems to be lacking in the current sustainable development discourse is an understanding of the real politics and struggle of economic development in and across the city-region, both in terms of the economic forces acting upon them and the people engaged in struggles to shape such forces in different ways” (Krueger & Savage 2007).

In Norwegian context one can find that the parliamentary report no. 31 (1992-93) recommends densification as a strategy for the development of cities and towns. It is directly linked with the connection between area use and environmental burden and is followed up and expanded upon in the parliamentary report no. 29 (1996-97)(Guttu, et. al 1999). The period in between there was a significant amount of densification happening in the municipalities in all parts of Norway. Though, this was, at the time, often performed without a comprehensive and integrated approach. These, in many cases, wasted opportunities for good

solutions leaving behind the values which were supposed to guide the process (Guttu, et. al 1999).

The above mentioned parliamentary reports helped form Norwegian national guidelines concerning planning, and especially densification. The situation has changed since then, yet the use of densification has not been up to standards and as envisioned, in many cases. This is pointed out by Guttu *et. al* (2009). Gathering information for their report they investigated 27 different new and urban building projects in four cities in Norway and found that only 3 projects could be termed moderately successful in terms of densification. Three main problems were found that in large part were shared by all the projects: The connection to the surrounding city is poor, the density and lack of space for people and the shape and form of the outdoor areas are often poor and inconsistently implemented.

An important note to this discussion is the evolution of densification itself and disagreements around the effectiveness of this strategy. This can be connected to Waves of Innovation graph above. In my opinion our current wave of innovation is still unfolding. As time progresses new ideas are added and we witness an evolution of the concepts and ideas, in cases where new ideas relate to an existing idea. The earliest discussions about densification did not include several aspects that are included today, for example the area of blue structure (water), which now is a natural part in densification.

A significant amount of the expansion of the smaller cities and towns in Norway took place on farmland surrounding the town (Guttu, et. al 1999). This was very much the basis of the densification discussion and implementation at the time. This has changed into an approach focused more on the quality of densification and the basis is shifting towards sustainability.

The initial recommendation proposed in the parliamentary report no. 31 has its basis in the planning discussion at the time revolving around densification. One may be able to see also that even close to 2009 there are many qualities lacking in the densification that is taking place. This may also be in part because of the evolution of the term itself in Norwegian planning. Though, this difference in theory and practice holds less sway when looking at just Oslo. In a study by Næss *et. al* (2009)(Guttu , *et. al* 2009) they investigated the city development in the Oslo-region, in light of goals of sustainable mobility and transport distribution. The conclusion is that the development in the region have achieved greater sustainable mobility through the focus on clear strategy of densification over a long period, especially for Oslo.

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## Resilience

*“In our dynamic universe all things change, from the farthest reaches of outer space to the movement of continents. Change occurs in both living and nonliving systems. The history of civilization is the story of change from simple to more complex. Human ingenuity and invention are examples of this fact. No system can remain static for long. Unfortunately, changes are not always for the best.” (Fresco 2002: 23)*

Resilience is a measure of systems ability to recover from disturbances and to adapt to changes. In relation to the more “passive” sustainable approach, the term resilience refers to a more proactive and anticipatory attitude.

As referred to in Gjose (2013) A resilient society seeks its long-term capacity and is able to handle changes, along with developing (Walker and Folke 2007). A resilient society is aware of futures uncertainty where the society will experience constant

changes (Berkes, Colding and Folke 2003)(Gjose 2013) (translated by author).

Resilience can be used in different contexts. Resilience in psychology is meant to measure an individual’s capacity of experiencing traumatic events and continue to function effectively. Ecologists view of resilience includes the idea of a limit to how much pressure an ecological system can take before transforming into a different state.

Based on Vale (2012) Urban resilient is then “the ability of cities to respond to systemic threats, emerging as a more action-oriented alternative to perpetually elusive notions of *sustainability, sustainable development, or sustainable urbanism* (Haas 2012: 22).”

According to Newman *et al.* in their article in Haas’ book (2012): “Resilience for the city of the future is becoming an agenda that cannot be neglected as global concerns accelerate over climate change, peak oil, water, waste, biodiversity, and urban quality of life” (Haas 2012 p.21). Infrastructural changes are needed. It is a challenge but it is also a great opportunity.

However, based on Vale (2012) “when one attempts to link the concept of *resilience* to socio-spatial systems such as cities, one gets into the realm of planning and urbanism in two somewhat distinct ways.” (Haas 2012: 22)

Vale (2012) argues that planners and designers in one way seek how to recover more quickly *if* a sudden disaster occur, this points to the reactive mode of resilience. On the other hand, when it is applied to cities and neighborhoods they search for designs and policies “...that will make communities more likely to be energy efficient, environmentally sensitive, broadly affordable,

physically and socially attractive, and equipped to withstand climate change, security threats, and other likely disasters...” (Haas 2012: 22). This implies the proactive mode of resilience.

Vale (2012) discusses further that: “Urban resilience forces us to ask questions about the steady state, or status quo, that we want our society (our human ecosystem) to maintain or regain. Unfortunately, this pre-perturbation state that many idealize as the goal of “recovery” is often not a very just or equitable system.”(Haas 2012: 22)

He discusses that one must investigate the self-interest in order to “...speed and direct recovery of urban systems...” (Haas 2012 p.22), and in this matter “...the term *urban resilience* over *sustainable urbanism* is that *resilience* is somewhat more explicit in suggesting efforts to improve existing systems, whereas sustainability implies that it may be sufficient merely to sustain them.”

Vale points out that there are the same drawbacks in both terms, resilience and sustainability, in which “...it is all too possible to “bounce back” into an untenable situation that is prone to further breakdown and inequity. Resilience is not always a good thing.”(Haas 2012: 22)

A common and overall accepted stance about the values a society should manifest may form the foundation for planning resilience. There needs to be a clear goal and direction in order to actually progress. While bouncing back to a predetermined state is better than flopping on the floor in crisis, there is a possibility here to improve upon the situation.

Fresco (2002) states that: “Although we accept the inevitability of change, humans also meet change with considerable resistance... Even when individuals adjust, institutions such as

government, education, medicine, and industry cannot. Their size, their infrastructure, their processes, and their missions resist and oppose rapid change.” (Fresco 2002: 23-24)

In spite of that, more and more people have started recognizing that every and each attempt in our development has an impact on the whole. Although we are in our 6th wave of innovation and have gained a lot of skills and technologies as modern people, we have at the same time damaged a lot of our resources, it is therefore essential to avoid doing the same mistakes all over again. Perhaps there is a need to reevaluate theories and practices.

As Fresco points out: “With the advent of the World Wide Web, cybernating, and artificial intelligence, the rate of change is being greatly accelerated. Possibly in the next ten years we will see more change than in all recorded history” (Fresco 2002: 25).

There is nevertheless an opportunity to revise our policies and tune them with a more resilient society and a more sustainable development. One of the most important efforts to resist further damages is to show less resistance to positive changes.



CHAPTER 1  
Densification





# 1. What is densification?

## 1 Densification

According to the parliamentary report no. 31 (1992-93) densification includes all construction projects within the current urban boundary leading to higher or more efficient space utilization. Densification can assume a variety of forms ranging from converting lofts into housing to major redevelopment projects (Kleve Syvertsen 2010)(translated by author).

Densification is a part of the overall strategy of controlling and containing urban sprawl on a national level, but is implemented and carried out piecemeal on the local level. It involves broad, general and national goals concerning preservation and resource-management. As such, this strategy has ripple-effects all the way down to the individual project and lays the preconditions for each.

Densification is using land in more efficient ways, which can result in being able to support more residents within an already developed area. In a nutshell one might say that more people + less land = densification, but this paradigm is becoming more nuanced. A precondition for densification is good living/urban qualities. The point is not just to house as many people as possible in less area, but to do so in smarter ways. I will elaborate on this in the next section.

By using the preceding explanation as a starting point one may see that methods of densification can be varied and take on many forms. A simple conversion of an unused room into a living space may qualify as densification. At the same time, large-scale projects resulting in a higher population density may also be

called densification. Logically any project method aiming, in some form or other, at a higher population ratio is therefore applicable for the term: densification.

Densification with quality can have many positive effects in several areas, a more sustainable development is one of the most important effects. A better area/land use is a densification that takes care of good qualities. This means both a more effective use of already built areas and quality requirements for the result. Quality means to include green structure as a part of urban area, clean air, accessibility, long term sustainable buildings and flexible design. Poor densification, where quality standards are not getting enough attention, can easily be perceived negatively and contribute to poorer neighborhoods / living environment. A good densification can provide urban quality to characterless downtown buildings.

General principles and a common platform of planning are defined by the national government. These are expanded and detailed by the municipalities to ensure everyone is pulling in the same direction.

Different interest groups may promote densification for varying reasons. This is a challenge in terms of planning and implementing densification strategies because it will result in different goals and methods where one wishes to bring these interests together. The main focus on my part in discussing densification is achieving a sustainable city development. This is one of the more important areas of planning based on the fact that an increasing number of people all over the world now live in cities. Consequently, strategies for densification may have profound effects on the human footprint on this planet.

## 1.1 Densification as strategy for sustainability

According to Jenks and Burgess (2000), “One important consequence of the search for sustainable urban development has been a resurgence of interest in compact city theories and policies. The reasons offered for making cities more compact have changed in the 150 years or so since the question was first broached.” (Jenks and Burgess 2000: 9) Jenks and Burgess discuss further that in the current period (note that this book was written in 2000), the compact city discourse is rooted in environmental sustainability, preserving the resources and minimizing waste. Today’s interest in densification may also include the social and economical aspect of sustainability, and focus on issues of density.

As Carmona (2010) states: “Recent debates about creating more sustainable and compact towns and cities have led to a renewed focus on issues of density, especially residential densities.” (Carmona 2010: 223)

As an example for densification can create greater opportunities for meeting places and social activities in residential areas, and help strengthen the local identity. Including mixed use of spaces can help to increase the local economy as well. But these do not come automatically. In order to ensure social and economical sustainability, in addition to the environmental aspect, via densification it is important to consciously balance and include social and economical criteria. It is also important to have conscious debates around issues of density.

Jenks and Burgess also point out that: “Contemporary compact city approaches have become one form of achieving ‘sustainable

urban development’ but that is not to say that they are coterminous with it. There are also a number of other economic, social, cultural and political justifications for compact city initiatives and different and often contradictory policies for sustainable urban development (Jenks & Burgess 2000: 9)”.

It is not only the initiatives that might differ for compact cities. There are some disagreements whether densification is sustainable or not. As an example Hall (1995) points out that even though increasing density is widely discussed to be sustainable, but “... in a challenge to those advocating higher-density living, it has been argued that a renewed emphasis on higher-density development could mean more congestion and pollution and probably the demolition of at least part of the historic fabric.” (Carmona 2010: 223)

However Carmona puts it this way: “While higher densities are sometimes equated with poor quality environments, high-quality urban design is — in principle — achievable at all densities.” (Carmona 2010: 225) Carmona (2010) discusses further that it is essential to support particularly privacy standards at higher-density, in order to provide livable environments.

In the same matter Lieweleyen-Davis (2000)(Carmona 2010) suggests: “the aim should be to generate a critical mass of people able to support urban services such as local shops, schools and public transport.” (Carmona 2010: 225)

For the purposes of this thesis I will define densification as a conscious effort to attain sustainable planning. I approach densification as a planning tool to improve social and economical efficiency and reduce waste, both locally and globally while delivering livable environments. It is in this context that it is imperative to keep an eye on the bigger picture. As the

Brundtland commission defines it: “Sustainable development is a development that meets present needs without compromising the ability of future generations to meet their own needs (Guttu, et al. 1999: 4).” The dimension of time is crucial because rebuilding and renovating expends resources. By increasing the lifespans of buildings by maximizing long-term usability one reduces the need to expend resources for rebuilding, reduces waste and hence increases efficiency.

It is also becoming apparent that land use (i.e. heavy industry pollution) is often a “local” burden, but with widespread global implications. Naturally, to increase total net efficiency, one must take into consideration global needs and concerns. Most of the worlds cities demonstrate the “black box” problem. Resources and energy go into the box, and waste is externalized and goes out. These have economical impacts, social impacts, as health effects and living conditions, and environmental impacts.

In other words one should employ local methods to deal with national or global issues. It is also in the context of, at least, national resources that the Norwegian government employs the strategy of densification in city planning. Each acre given over to urban purposes is an acre less in terms of i.e. food production or natural resources. It is therefore in the interest of the government and the society to contain the urban sprawl. It is a direct threat to our life-supporting natural environment, and hence ourselves. This cannot be stressed enough.

Preserving biodiversity and varied ecosystems is therefore a vital part of both sustainability and densification. Complex integrated systems determine the natural cycles and it is important to approach these with humility and care. There is less to gain from densification without this backdrop.

## 1.2 Densification in action

In Norway densification is a mandatory strategy for the city and town development. Different municipalities have made their own guidelines in accordance with the overall densification strategy, and all the developers must adhere to these rules. This gives a lot of responsibility to each municipality.

The criteria for densification in the earlier discussions in Norway included green structure and quality in design, urban and public spaces, preserving the landscape and valuable older buildings.

According to Guttu *et. al* (1999): “Through planning, authorities must ensure green structure and quality in the design of buildings, urban and outdoor environments, as well as take into account the landscape and valuable older buildings at the same time as densification.” (Guttu, et al. 1999)(translated by author)

Over the last few years Norwegian municipalities have concentrated their efforts on hub development ‘knutepunktutvikling’ as a development strategy. This is an effort in increasing the efficiency in relation to traffic, infrastructure and densification. The idea here is to densify areas around and near hubs and nodes where varied zoning provides commercial and industrial jobs as well as high-capacity transport to other nodes. Local public transports, such as local buses or trams, provide transportation from around the hub to and from the hub. In this regard, it is densification in a sustainable context because of the focus on traffic reduction and transport efficiency. By zoning an area with mixed use one may be able to provide many or most of the jobs for residents nearby, as well as provide most services and goods as well, thus minimizing car use and additional transport.

In terms of hub development, especially in Oslo, there is use of all these types in or around the hubs themselves. Traditional villa areas are densified, while old industrial and port areas are transformed into offices, shops and apartments and unbuilt spaces are utilized. This is, of course, because of the nature of hub development which must be near existing transport infrastructure and therefore near existing built areas.

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### 1.2.1 Basic densification methods

Generally there are three different types of densification methods:

- . Villa and garden densification
- . Conversion and reuse of industrial and port areas
- . New construction within the building zone

These are not strict types, but merely a means of making sense of the basic methods of densification. Often there is a combination of these methods in use. Many Norwegian municipalities emphasize on a goal to renew cities and towns, to reduce transport, a more effective energy use and to reduce pollution and greenhouse gases in the city environment while increasing the life quality and the quality of urban spaces.

What method to use are often decided by what properties are available and what is needed. Often old buildings are reused and renovated to keep the character and style of the area intact. This may help in preserving old facades and buildings as well as increasing effective land use, thus protecting the local history and identity. One reuses what is worthy of preserving and can be combined with the new interior or buildings.

There are three basic types of building patterns for a city block:

- Tower structure
- Perimeter structure
- Terrace structure

## 2 Why densification?

Everything needed to sustain us derives from the natural world. It is therefore imperative that the environment is maintained and preserved along with its life-giving qualities. In contrast to the “natural world” there is the traditional urban environment, I say traditional because I wish to challenge the common perception that these two types of environments are mutually exclusive. Here there is little room for agriculture to any significant degree. The natural environment is covered with “unnatural” constructs such as roads, railways, power grids, pipe lines and other infrastructure as well as buildings for living and working. It is no longer supportive or conducive for natural ecosystems, rich plant life or agriculture.

Both types of environment are needed to maintain the current way of living and it is here densification comes in as a tool for preserving the balance between the two.

Calthorpe (2012) puts it this way:

“More urban development means more compact buildings—less energy needed to heat and cool, lower utility bills, less irrigation water, and, once again, less carbon in the atmosphere. This then leads to lower demands on electric utilities and fewer new power plants, which again results in less carbon and less costs (Haas 2012: 15).”

Due to rapid population growth world-wide, as well as in Norway, cities are growing in size, both in terms of population and in area. It is the desire to do this in an overall effective way that constitutes the need to do planning. In this way densification is a very important tool in changing the urban landscape to the better and strengthening the local quality of life and urban spaces.

Cities and towns in Norway have grown substantially over the last decades, both in terms of inhabitants and jobs. The biggest and average-sized cities are strongly increasing in size, but also the smaller cities and towns are growing significantly. This is also the trend in the years to come, according to indicators (Stortingsmelding nr. 23 (2001-2002)).

## 2.1 Controlling the urban sprawl

According to Calthorpe (2012) Although the traditional city was by necessity energy and resource efficient, it commonly showed a destructive disregard for nature and habitat that would be inappropriate today. Bays were filled, wetlands drained, streams and rivers diverted, and key habitat destroyed. A green form of urbanism should protect those critical environmental assets while reducing overall resource demands (Haas 2012: 16).

In recognizing the interconnectedness of the world, the impact of our technology and lives and thus the global aspect of our civilization, one steps out of the traditional view of an infinite world into the fact of a world of finite resources.

As Calthorpe (2012) explains the traditional city was already energy and resource efficient given the understanding one had historically of our environment. Now, with new understanding, one should recognize that in order to keep the ideals of energy

and resource efficiency, one must review the way cities are organized (Haas 2012: 16-17).

NOU 2003: 14 “*Bedre kommunal og regional planlegging etter plan- og bygningsloven II*” suggests:

- Effective and environmentally friendly land use
- New buildings that should be positive for the area
- Conservation of the valuable qualities of architecture, built environment, cultural history, landscape features and green spaces.
- New development should happen near public transport (NOU 2003: 14)

By reviewing the above principles determined by the Norwegian government one can see that the first and last point is directly linked to our definition of densification. This indicates that politicians, at the very least Norwegian, are not oblivious to the need of a sustainable urban development. There is also agreement that transport behavior and transport systems play a significant role in shaping areas. (Strand, et al. 2009)

To stop the urban sprawl there is only one alternative, that is to change and increase the efficiency of already built or unused space in urban areas. Barring any technological change to our way of living, there is really no alternative to concentrated densification. The tools at our disposal provides us with the means of slowing or, if lucky and skilled, halting the urban sprawl, but it cannot significantly alter or improve our situation.

## 2.2 The socio-economic dimension

According to parliamentary report no. 31 *Den regional planleggingen og kommunalpolitikken*: “A sustainable urban

development suggests that new buildings and developments happen through density and more effective land use in the building zones. This gives a lot of responsibilities to small and big municipalities and developers to make sure that every and all the physical qualities are there and being taken care of.” (Stortingmelding nr. 31 (1992-93))(translated by author)

This may lead to varied results, but may also lead to benefits. Among them are increased local democratic opportunities and

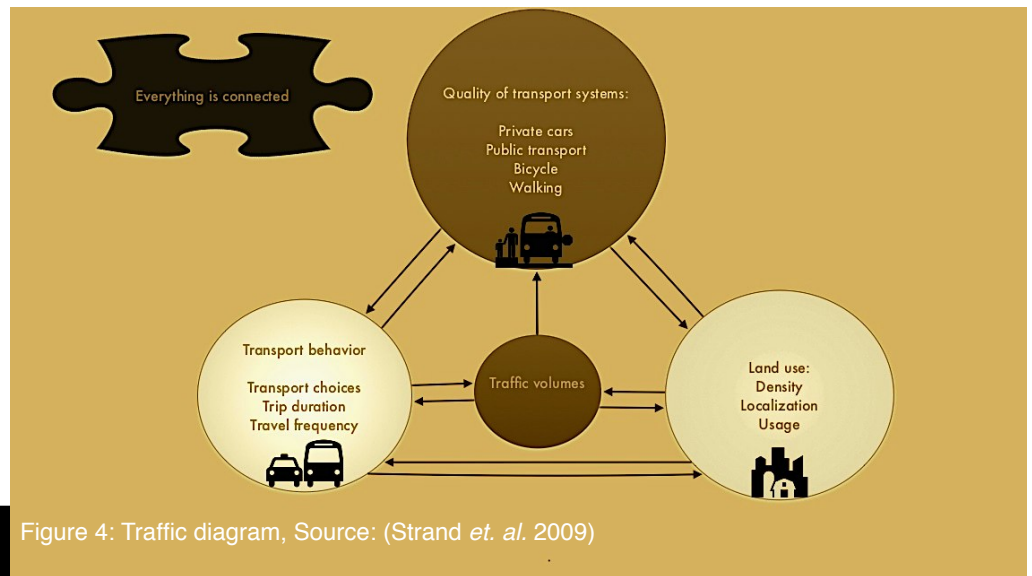


Figure 4: Traffic diagram, Source: (Strand et. al. 2009)

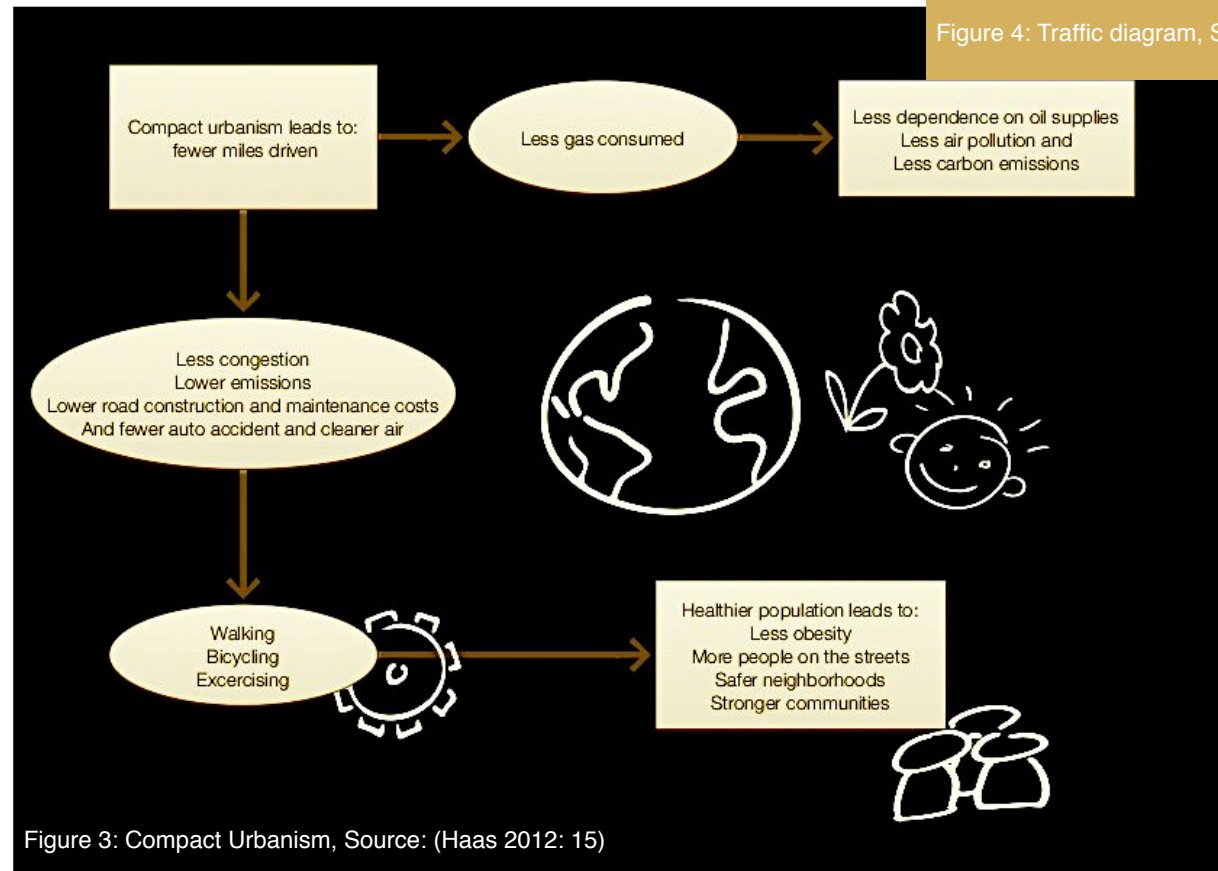


Figure 3: Compact Urbanism, Source: (Haas 2012: 15)

solutions that are often better suited and adapted to local conditions. Local knowledge helps to increase the effectiveness of projects and integrating them into the local community. Both in the field of political decisions and technical planning and design. Of course, this does not mean that there is no measure of top-level control.

In short democratic principles are ensured both at the macro and micro level. This does not necessarily ensure a development in a sustainable and positive manner though.

Studies show that dense urban places are popular because of their density and proximity, activity and life, variation and surprises. Many prefer denser urban places to those places that are spread and require huge traffic systems. It is not even strange that a huge amount of the worlds population seek these dense urban

places. Dense urban places give less operating costs, more varied housing provision, less transport and less land use. These lead to less private spaces and more shared public places which is more efficient and less expensive for everyone (Haas 2012).

By ensuring low-cost living, with public transport and good public places one also ensure maximum benefit for everyone, not just the well-off. This is another way of ensuring social equity in terms of opportunity and is therefore helpful in promoting and ensuring democratic principles. This shows that densification is not necessarily coterminous with the stereotypic notion of urban life as polluted, personally isolating and cramped. There is a possibility of developing and densifying with a degree of quality that improves urban life and attracts people.

The reason for focusing on densification strategies is because of the goal to steer the development of cities in a sustainable direction. By utilizing the space inside developed areas more effectively we contribute to a reduced burden for both the local and global environment. A dense city will reduce transport and thus give less pollution in the urban environment, as well as lower emissions of greenhouse gases. The countryside around towns can be kept free of buildings and still serve as recreational areas. Areas that safeguard food production or biodiversity can be preserved. Resources loaded into the infrastructure and service can better utilized and save society new investments (Guttu, et al. 1999).

## **2.3 Seven reasons why we should use densification as a strategy for our urban development based on Guttu *et. al* (1999)**

Before I start explaining these reasons (benefits) and further hazards by Guttu *et. al* (1999), it is important to note that these aspects are in relation to earlier discussions in densification mainly to control the urban sprawl, preserving and protecting agriculture land and natural landscape, and controlling transport. There are comments and discussions around some of the points to provide more information, for how these may affect and be improved in today's context. In other words, the concept has grown more mature since 1999, considering for instance further studies and researches on different aspects of this strategy in the Norwegian context.

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### 1. Densification gives less transport

According to Guttu (1999) analysis and comparisons between various dense and more concentrated cities show that these cities contributes less to total transport volume (Næss 1996). Reduced distances also reduce frequency of short-distance driving and thus reduces greenhouse gases like CO<sub>2</sub> and NO<sub>x</sub>, which in return gives less pollution and fewer accidents. In turn less resources are spent also spend less resources for road construction. This way the environment is also spared directly as less land needs to be built, and may also provide additional agricultural production when needed. In addition higher density rates help promote efficient public transport systems, which of course reduces pollution further (Guttu, et al. 1999: 5).



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2. Densification can minimize energy use for heating buildings

Based on Guttu *et. al* (1999) building and re-developing in urban areas will most likely result in compact and energy-efficient structures and forms, for example townhouses and apartments blocks. Energy requirements for heating houses is 40-50% higher per m<sup>2</sup> than for flats (Guttu, et al. 1999: 5). More floor area per wall or roof area gives off less energy and retains heat better as well as helping to heat neighboring rooms and flats.

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3. Densification protects agricultural areas, preserves biodiversity and a coherent wilderness and outdoors

“Each new detached house being built outside urban areas will mean a loss of a natural area of about 1000 m<sup>2</sup> (Guttu, et al. 1999: 5).”

According to Guttu (1999) towns and cities are often located in fertile agricultural areas, which involves biological productive and cultural areas that may have value for food production, recreation and cultural history.

Complex natural cycles involving water, soil, wind, plants and animals are dependent on diversity and sufficient space. It is these cycles that ensure a rich and productive natural environment and life-system. More often than not, the consequences of development are not seen and understood until after the fact and valuable resources are wasted.

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4. Densification means spending less resources for the operation of towns/cities

Guttu *et. al* (1999) municipal services and facilities for municipal services, such as healthcare, education and municipal utilities can be utilized more effectively (Guttu, et al. 1999: 5)(translated by author). Distribution of goods, services and personnel are more effective. Additionally, fewer facilities will be able to operate at higher capacity and efficiency, with concentrated populations and fewer sparsely populated areas.

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5. Densification can provide positive urban qualities

Guttu *et. al* (1999) states that a denser urban environment can provide a more clearly defined public space and thus help enable activity and city life. Cities will be more clearly distinguished from the surrounding countryside. There will be opportunity to start repairing and redeveloping inside the towns/cities, with construction on vacant land and fallow land. A denser city can provide basis for a livelier downtown with greater range of cultural activities and trade and greater security (Guttu, et al. 1999: 5)(translated by author).

However, this does not come automatically.

As Gehl (2010) points out: “It is widely believed that the lively city needs high building density and large concentrations of dwellings and workplaces. But what the lively city needs is a combination of good inviting city space and a certain critical mass of people who want to use it.” (Gehl 2010: 68)

It is therefore important to focus on this combination in order to be able to gain livelier downtown with densification.

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## 6. Densification may provide alternative housing accommodations

In residential areas with unilateral and unified composition, densification may contribute to a greater variation and diversity. Additionally, according to Guttu *et al.* (1999), it may provide alternative housing provisions, such as apartments, for people who do not wish to maintain a big garden by themselves. People may then have the option of relocating within the community as better suit their needs (Guttu, et al. 1999).

Even though there are still less density in many Norwegian towns today, and many people still live in villas with gardens, but the demand for apartments are bigger in average big and biggest Norwegian cities. This is due to higher real estate prices, and the inhabitants wish for more life and activity that cities can offer comparing to smaller towns with bigger villas. The point is to address that it is no longer relevant to invite people to live in cities and apartments, when this is already demanding.

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## 7. Densification can provide better services.

“Densification will help ensure that the services can be maintained and that new services can established in the community. This applies both to public services and schools and post offices to private, such as stores and bank branches.” (Guttu, et al. 1999: 6).

It is important to mention that this report was prepared in 1999. Several aspects are not taken into consideration here, and urban agriculture was not taken into account. The discussion about urban agriculture, is not only missing here, but also in Norwegian

planning system, there are no defined standards when it comes to urban agriculture, neither are there zones that would place agriculture in our urban spaces today. This will be discussed more closely in the next chapter: Vertical Farming.

## 3 Challenges of densification

### 3.1 Four hazards during densification (Guttu, et al. 1999)

An important part of the strategy for a sustainable development of cities and towns is a better area/land use in cities and towns. This has also been an important question for the Norwegian government and municipalities. As I have mentioned earlier, many municipalities in Norway have emphasized densification in their plans, but there has been less focus on what kind of challenges this strategy brings during the implementation. In other words, densification can reduce some environmental problems, but it may also cause new ones. It is therefore very important to identify these problems and solve them before they manifest.

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#### 1. Densification may cause the green lungs being built down.

According to Guttu *et. al* (1999) this can mean that children lose play areas, adults lose areas of travel and everyday walking, that urban vegetation and wildlife are poorer and less varied, so the city is losing out on valuable experience. Loss of green space is a very common reason the bigger densification projects

encounters local resistance (Guttu, et al. 1999: 6)(translated by author).

That is why including urban agriculture/vertical farms, green roofs and planting as many trees as possible along with the urban development are some of the best solutions to create greenery and attractive areas in cities and towns. These factors increase the quality of our urban environment and create biodiversity, not the least social activity.

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## 2. Densification may result in adverse traffic impacts.

Construction of new housing means more traffic in the area and thus more noise, pollution and traffic hazards in a road system that is not designed for the increased traffic. More cars require more space for parking (Guttu, et al. 1999: 6)(translated by author).

But this problem can be solved by making good public transport networks, which requires less huge infrastructure and less transport systems. An urban infrastructure doesn't necessarily need to be used by vehicles, by building smart walking- and bicycle ways, one can simply make distances shorter and experience the city by foot. This indeed gives less pollution, energy use and attractive urban spaces for people. Longer distances can be connected with efficient fast public transport, it is time efficient, environmentally friendly and above all it gives rather a greater experience to a traveller. At the same time by reducing space given over roads and parking, one can increase vitality through activity concentration in our cities (Carmona 2010).

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## 3. Densification can reduce living conditions.

It may involve less sun, loss of views and more noise. Densification may be at the expense of public and private outdoor space. The private garden, a significant value of living in a house, can be scaled down or severely degraded. In the central coasts can cause densification speculation denser solutions than desirable to increase benefits of development (Guttu, et al. 1999: 6)(translated by author).

At the same time smart and environmentally friendly designs, which take care of every positive quality in the living environment, can reduce the risks of losing sunlight, loss of view and pollution in form of noise. This can be possible by supporting innovation in design, designing to a human scale and visually attractive buildings. It's a matter of bringing the focus to densification with greater qualities than previous strategies being used.

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## 4. Densification may disrupt or destroy village's character, cultural and historical elements and landscape features.

As Guttu *et. al* (1999) points out, the physical result of densification process can be messy and aesthetically unsatisfactory. Buildings and system that requires space and land is being attacked of aggressive new buildings. Silhouettes and viewpoints can be built down. Green elements in the urban landscape disappears. The lack of fit between the new and old can ruin the character and architecture (Guttu, et al. 1999: 6) (translated by author).

This is why we need to be extra careful with our densification plans, and take care of green elements and let them grow together with all the other elements in a green urban environment. Green elements doesn't necessarily need to be put aside in an urban context, they can simply be a part of it.

The result of densification doesn't need to be aesthetically unsatisfactory either. It is possible to avoid aesthetically poor outdoor spaces and buildings through smarter design and use of available technology for effective implementation.

It is important to register that if we want to achieve political objectives formulated for good homes and good communities, governments should both at the state and municipal level implement measures to ensure good outdoor space in the dense city as well.

However, densification also involves problems. If we do not focus on the quality of densification, we may be in danger of building the inalienable natural values and areas for plat and stay in the villages, reducing living conditions and destroying or tampering beautiful and interesting building environments.

### **3.2 Ideas, norms, perspective**

A potential problem concerning densification relates to its definition and meaning, namely what it is and what it is not. Different groups and people may have different concepts and meanings about it. This increases miscommunication and therefore conflict and mistrust.

I like to provide a quote from Carmona: "These studies (by Martin and March 1972/1967) showed density must be considered in terms of the configuration of urban form — that is,

as a product or outcome rather than as a determinant of design." (Carmona 2010: 100)

One can imagine that problems can arise between two parties if the preceding view of density is held by one party and the other party is focusing on persons per acre. The second issue has to do with why and how it is implemented. All parties concerned need to have a clear picture of the intentions behind densification and therefore why it needs to have certain qualities to ensure a proper and effective implementation.

Additionally it is important that the proper tools are used to provide "neutral" information that can be accepted by everyone. This information must be able to point at where there is a possibility for densification and where there is a need for densification. City morphology analysis can be a powerful tool in this regard. One are not only interested in geometric calculations, but also social factors.

Only when these two issues have been settled is it possible to bring every party together in a productive debate to establish the details and practicalities.

### **3.3 Practical implications**

Urban society contributes to a number of environmental problems because of high energy consumption, pollution and reallocation of space. The way we use our areas can sharpen or help solve these problems. In recent years we have become more aware of these relationships and the central government has staked out a land use policy in which environment to a greater degree will set the premises. It is embodied in Report No. 31(1992-1993), Report No. 29.(1996-1997) "Regional planning

and land use policy” and policy guidelines for coordinated land

**Info box**

It is also worth mentioning that Oslo in January 2014 was called internationally the greenest city from good life report. Durrani (2014) states:

“Why Oslo? It has a long history of environmental concern, long before other cities jumped on the eco bandwagon. The government spurs on the populace by promoting sustainability. The Oslo City council voted to replace heating oil in city buildings with renewable energy sources by 2012, which is ballsy considering how much energy the metropolis uses. The government provides incentives for new buildings to promote energy efficiency. All buses running on fossil fuels will be converted to biofuels in 2011. The city is lowest of all European metropolises when it comes to CO2 emissions. Eighty-five percent of school children walk, bike or use public transportation to school (the rail system is run on hydroelectric power). Ninety-four percent of household waste is recycled. A majority of the population lives within a short distance of public green space, which they utilize in record numbers. All of this in a city that is one of the wealthiest in the world.” (Durrani 2014)

Figure: Oslo - greenest city, source (Durrani 2014)

use and transport planning.

It is worthwhile to note that based on Jenks and Burgess: “The relationship between cost, density and location indicates that costs do not necessarily decrease as density increases, and that cost effectiveness depends on spare infrastructure capacity.” (Jenks & Burgess 2000: 5)

It is therefore important to develop our urban environment with good infrastructure systems, public transport and good bicycle ways in order to get a better, and denser urban environment. This in turn alleviates or reduces overall pollution from traffic and saves space. One can also consider availability for shopping and

cultural facilities, variety and diversity in order to have urban spaces that function.

Densification and transformation of land in cities are demanding, due to complex property rights, conflicts between interest groups, high land values and the heavy investment makes public and private sectors face major challenges. The municipalities have the main responsibility for overall planning to provide a framework for implementing urban development. It is important that local authorities have a conscious densification strategy that supports the environmental, social and economical goals for the city/urban development.

### 3.2.1 Personal reflection

To ensure a coherent and sustainable densification process I suggest these quality criteria:

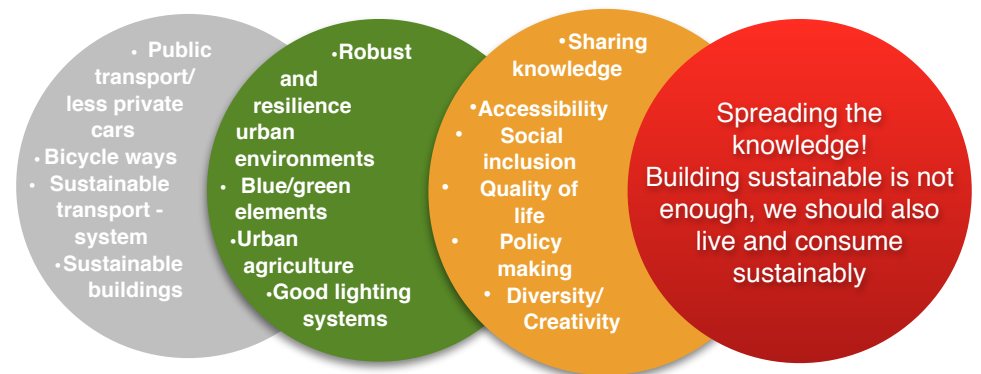


Figure 6: Quality criteria for densification by author

## 4 Vertical farming as a tool in densification

### 4.1 Context

In order to explore the potential benefits and use of vertical farming as a densification strategy we need to define its context and domain. Densification as part of urban development strategies most likely brings up connotations of the city/urban context. Vertical farming on the other hand lends its full strength only when we combine the rural and urban context. Either way one chooses to employ vertical farming, be it as a replacement or supplement, it is directly linked to the rural context where most of our current farming takes place in Norway.

However there are few studies available about vertical farming in the urban planning context. Though, there are many examples of vertical farms internationally (chapter 2), in different size and scope, that implies that vertical farming can work as urban food supply.

Vertical farming can be a form for densification in agriculture for, at the very least, bigger cities. It is often categorized as a form for urban agriculture/food production (different efforts in urban agriculture will be discussed further in chapter 2).

In order to evaluate vertical farming as a strategy in densification I have made an evaluation table. The table is based on and inspired by Butters' (Haas 2012: 111) Sustainability Value Map. The three areas of society, economy and ecology are equal parts of a circle of sustainability. As Butters defines it, in this context

“economics is all the structures, institutions and processes with which we manage society. The money system is just one part of this... Hence economics corresponds to Le Play's *function*, and to Gedde's *work*.” (Hass 2012: 115) Butters have often used the terms ecology, economy and ecosophy while, according to him, the most common setup of the three-part value map is with ecology, economy and society. I have chosen this as it more closely relates to urban planning practice.

It is also worth mentioning that there are other criteria that could be added to this table, but the purpose of this table is to bring an overall picture of the relationship between sustainability, densification and vertical farming.

In table 1 I evaluate densification and vertical farming, as a tool in densification, based on criteria from Butters' Sustainability Value Map. It should be noted that some challenges with densification might be perceived as contradictory to certain criteria for sustainability. However, this mean that limits and boundaries need to be set for densification strategies in relation to these criteria, thus delimiting options and increasing the challenge. At the same time vertical farming's contributions to these criteria are evaluated and explained further. The base of information for this evaluation is from the analysis and studies in chapter 2 (studies of technology is available in the appendix).

This table shows how vertical farming can contribute in different areas of sustainability. One can see that vertical farming can function better as a strategy in densification when it deals and cooperates with different aspects of society such as local food production and distribution, local hub development, education and business.

Table 1: Vertical farming as a tool for sustainable densification

	<b>Sustainability Value Map criteria: Butters (2012)</b>	<b>Evaluating densification based on criteria for sustainability</b>	<b>Vertical farming's contributions to criteria for sustainability</b>	<b>Vertical farming's contributions in detail</b>
<b>Society</b>	aesthetics	Challenge	Yes	Architecture: new or transformed structures with high degrees of visible plant life and/or good architecture and design
	sociability	Opportunity	Yes	Social activities, supports local cafés/restaurants
	variety	Requirement	Uncertain (Possible)	Mixed-use activities, for example: education, research, business, food production, recycling
	security	Challenge/Opportunity	Partially	Food safety/Food security
	identity	Opportunity	Possible	Local monument, attraction, identifier and important community landmark and life-support unit
	accessibility	Requirement	Limited/Partially	Local food access
	socio-diversity	Requirement/Opportunity	Yes	Varied job opportunities, varied tasks, universal product, local food store
	<b>Economy</b>	flexibility	Opportunity	Yes
communication		Opportunity	Yes	Part of local food distribution system, connection to other industries for recycling of CO2, bio-mass, waste management, heat/coolant
services		Requirement	Yes	Food production, local food distribution, education
activity		Opportunity	Yes	Food production to end-user distribution, mixed-use building may allow renting of space (primarily technological/biological, educational and research)
functionality		Requirement	Yes	Food distribution, recycling
costs		Challenge/Opportunity	Possible	Medium-long term economic gain from high productional efficiency, recycling and renewable energy use, possibly high initial investment costs for new structures
<b>Ecology</b>		health	Challenge/Opportunity	Yes
	transport	Requirement	Possible	Depends on distribution system, local food store and local supplier
	material cycles	Opportunity	Yes	Recycling of biomass into fertilizer or fuel, food cycle
	water cycles	Opportunity	Yes	Recycling of municipal grey water, recycling of internal grey water
	energy	Requirement/Opportunity	Yes	Recycling of biomass for fuel, possible use of wind and solar power
	biodiversity	Requirement/Challenge	Yes	Saves land mass for natural biodiversity
	land use	Requirement	Yes	Highly efficient land use when compared to traditional farming methods

It is important to note that the bigger opportunities in vertical farming, as a densification strategy, emerge only when incorporating most of the criteria. More criteria can be added as well if necessary. This means that it is on the level of municipalities (kommuner), regions, counties (fylker) and national level that the topic of vertical farming is most appropriate. It is here most often all three domains of sustainability can be used.

Today the Plan- and Building act of 2008 requires the national government to establish guidelines and general principles that guides the development and planning process in the levels below, most notably on the municipal level. This is where the details and practicalities are worked out according to the national principles. Consequently these two levels would likely be the first to require policy changes to incorporate vertical farming as a densification strategy.

Vertical farming does not ensure all principles of sustainability, but can help in strengthening many of them. For example it is uncertain if vertical farming directly contributes to societal variety. Or when it comes to security, it contains only the aspect of food security and food safety.

However it is difficult to expect that a building in itself could ensure all these criteria.

By firstly including vertical farming as a focus point and a part of long-term densification strategies on the national level we will ensure that it is properly evaluated and possibly implemented. This will require municipalities to consider and discuss the topic, resulting in debates and a raised awareness, at the very least at the administrative level, but hopefully also in the public arena.

I discuss the practical challenges around policy and zoning later in the thesis, in chapter 2.1.2 Policy.

## 4.2 Personal reflections

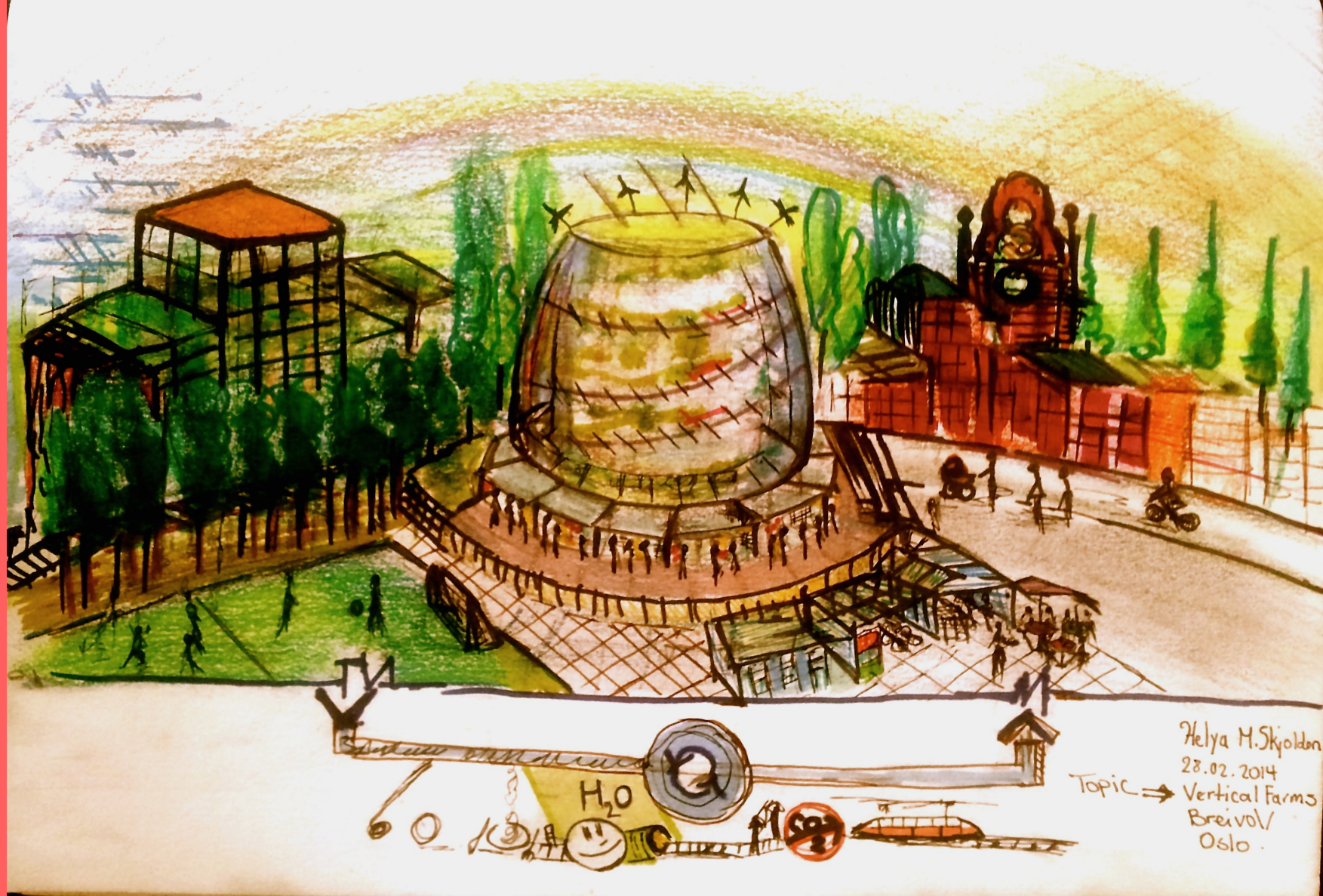
An argument for many, and perhaps the first point we need to take into consideration, is the direct conflict between food production and living. Most arable land in the world is already over-utilized, and we risk destroying what we have because of this exhaustion. I include the whole world in the Norwegian context due to the high rate of food that is imported to Norway, thus challenging Norwegian food security. Perhaps we should start looking for a solution that removes this conflict.

We are already utilizing most of our arable land planet wide. This raises concerns in terms of food production capacity. There are many research projects concerning genetic modifications, pesticides/herbicides and nutrients. Though we may expect these efforts to yield results, there is only so much one can physically gain by sizing or pumping up specific crops. The crops are still dependent on a certain amount of growth area. How much can these projects prolong our current food production scheme?



CHAPTER 2

Why urban  
agriculture/  
vertical  
farming?



## 2. Why urban agriculture/vertical farming?

As it was mentioned in the previous chapter, urban agriculture is missing in today's Norwegian planning system. I will discuss this problem in this chapter. There are several reasons why we should grow food locally within a controlled environment that were briefly presented in table 1. These reasons will be a part of the discussion in this chapter. I will start with discussing environmental challenges, which may be regarded as the foundation for many social and economical challenges in terms of sustainability.

It is worth mentioning that although the environmental aspect is more closely investigated, I do not exclude the social and economical aspect from the urban agriculture/vertical farming domain, but the environment is often the trigger and main contributor to other societal issues. In addition the environmental challenges are closely linked to today's agriculture. Environmental issues heavily influence agriculture, which in turn heavily influence the environment. Challenges in today's food production/consumption such as food preferences and transport patterns also discussed in this chapter.

### 1 Today's world-wide environmental challenges

It is very important to address the different conditions that historically have been responsible for social changes. They are directly connected to changes in our natural environmental and

natural disasters. So every attempt at adapting to these changes must be seen in a holistic level that evaluates the conditions in context.

Calthorpe (2012) points out: "Over decades, I learned each scale depends on the others and that only a whole systems approach, with each scale nesting into the other, can deliver the kind of transformation we now need to confront climate change." (Haas 2012: 14)

At the same time we must recognize the fact that we are all influencing the way change is happening. I am not going to debate global warming and to what degree we are responsible for it, but we should also understand that technology has now provided us with a huge ecological footprint compared to people living previously in history. At the same time there are many more of us here than there has ever been. It is important to understand that this, in a much greater way than ever before, makes us a much greater part of the changes that occur. Change is happening anyway, it is for us to learn to adapt to it and influence it to the positive, if possible.

World's population is growing, it has increased twofold since 1970s and indications suggest that this trend will continue. "The trajectory of the world's future population rests heavily on assumptions about fertility rates. If rates in high-fertility countries continue to grow as projected, there will be an additional 2 billion people by 2050, with a much larger proportion living in urban settings." (FAO 2013: 22)

Consider also the effect this will have on the rates of energy consumption and pollution. Urbanism is more demanding and taxing on the environment in that transportation of goods and

trash goes in and out of the city. Consumption and subsequent waste leads to greater environmental impacts.

Calthorpe (2012) has this to say about green house gas emissions:

“The remaining 53 percent depends on the nature of our buildings and personal transportation system — the realm of urbanism. As a result, urbanism, along with a simple combination of transit and more efficient buildings and cars, can deliver much of our needed green house gas reductions.” (Haas 2012: 15)

Traditional farming has been pushed over its limits and has, with technology, evolved into a wasteful and destructive effort. Arable land is being lost due to exhaustion and misuse.

As Despommier (2011) states: "Environmental scientists predict that if things do not change soil will soon collapse under the heavy burden of the application of too much short-sighted technology and not enough long-term ecological planning." (Despommier 2011: 137)

According to FAO (2013) the statistical yearbook 2013 from the Food and Agriculture Organization of the United Nations, more than a third of the world's population is dependent on agriculture, with the largest amount of them living in Asia.

One can find in FAO (2013) that not all of the increase of people living in cities stem from rural-to-urban migration, but also from rural areas turning into urban areas. In other words, the cities are not only getting bigger, but we are also getting more of them. It is also indicated that most of the world's population is going to be living mostly in cities. By 2050 more than two-thirds are going to live in urban areas. Considering the fact that most food production is situated in rural areas, we may understand that this

will require a greatly expanded transport system, related costs and maintenance and consequently more pollution. At the same time less land and resources will be available for use in, for example, agriculture (FAO 2013).

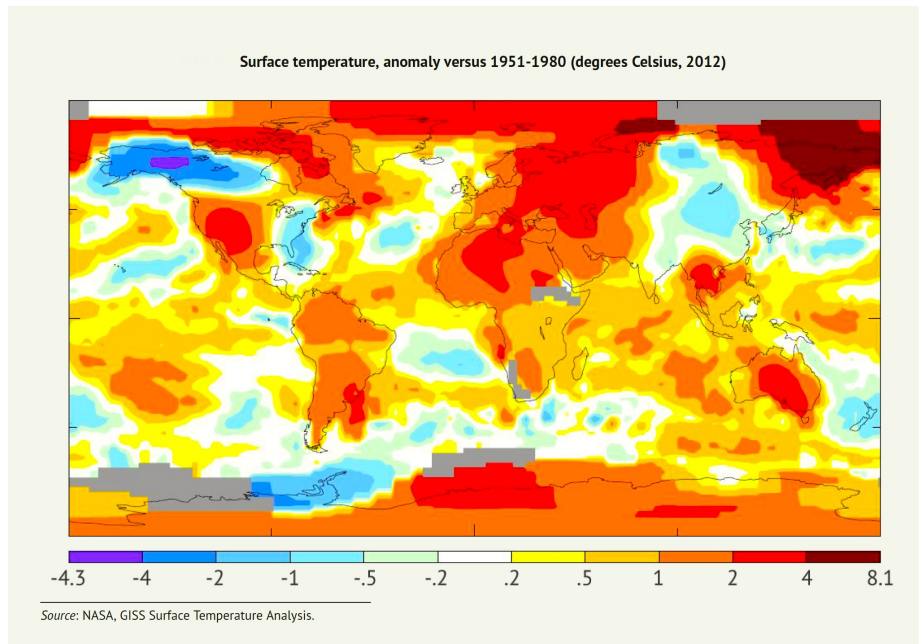
Additionally, many countries import great amounts of food from other countries and continents (Norway for example) due to differences in production costs either through taxes or labor costs. This consideration of relative monetary gains from physically moving food longer distances indicates that pollution may rise even higher than anticipated.

And at last, but not least, let us not forget the added burden and pollution from the two billion extra people who will make their home on this planet. We have no system for a pollutant free society and each person adds to the pollution by contributing to consumerism. Little is recycled and little is meant to last very long, giving us great amounts of trash which we do not know where to put, earlier referred to as the “Black Box” problem.

Global warming and its long term effect accounts for an increase in regional natural disasters across the globe. This has devastating effects on our environment in terms of habitat and food. Map 1 from FAO (2013) shows average annual temperature deviation across the world today compared to 1951-1980.

According to NOU no. 16 (2009): IPCC (2007B) summarizes the effects of global warming. Even temperature fluctuations in the range of 1,5 to 2,5 °C could, according to the IPCC, result in dramatic effects (NOU 2009:16: 30):





Map 1: World's surface temperature

- Between 20 and 30 percent of the world's plant and animal species could become extinct as a direct result of global warming.
- Reinforcement of rainfall patterns, meaning dry areas get drier and wet areas wetter.
- Glaciers, which today contribute to a steady supply of water for a significant part of the world's population, will disappear.
- Worsening health conditions through an increasing number of heat waves, floods, storms and forest fires.
- More extreme weather gives more material damage.
- More frequent flooding of low lying areas near coastal regions, often with large concentration of population.
- Lost area due to ocean levels rising.

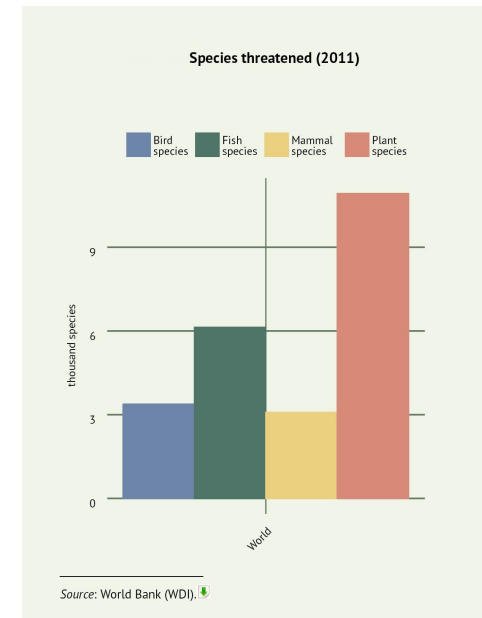


Chart 1: species threatened (FAO 2013)

According to NOU no. 16 (2009) all these effects will increase if the mean temperature rise above 2,5 °C. With more than a 3 °C rise in temperature there will be a reduction in the world's food production (NOU 2009:16).

The report from FAO (2013) also states that food insecurity is one of the most common outcomes for countries in protracted crisis, for example armed conflicts or long droughts. This in turn may lead to undernourishment and starvation. Prevalence of undernourishment ranging from about 30 to 65 percent is associated with large numbers of population at risk in countries such as Eritrea, Liberia and Sierra Leone (FAO 2013)

By way of decreasing biodiversity we add to the risks we are putting ourselves in. Fewer species leads to higher vulnerability

to disease both for animals and plants. Diseases often exploit weaknesses in certain species which may not trigger the disease in other species. By having monocultures of plants and animals we are that much more vulnerable to outbreaks of different kinds (see chart 1).

Our understanding of disease, bacteria and viruses makes it plain that they also change, sometimes very rapidly. Remedies that we thought fool-proof are proving to weaken with each passing year. Our modern day miracle cure, the antibiotic, is itself giving rise to numerous new and resistant bacteria.

## 2 Today's agriculture

Traditional agriculture, one of the oldest human inventions, and an important factor in human history considering socio-economic changes, is one of the biggest factors of resource consumption, waste creation and pollution concerning the amount of land, water, agrochemicals, such as pesticides and fertilizers, we use in producing our own food.

Agriculture, the key development in the rise of sedentary human civilization, started ca 10,000 to 12,000 years ago. Already in the early age, due to lack of knowledge about how the natural environment works, we started charging the soil and started using up the nutrients in the soil and never replaced them. This resulted in great damages to the agricultural lands. These damages gave birth to droughts and degradation of land and water resources. As the sedentary human civilization rose with the benefit of food production, the human population also started growing incredibly fast.

Despommier (2012) puts it this way: "Once farming became routine and reasonably predictable, we proceeded to convert much of the earth's natural landscape into food production. History has recorded in a wealth of cultural expressions the progression of events regarding the evolution of settlements and cities; the emergence, flourishing, and eventual collapse of entire civilizations; and especially the relentless, irresistible growth of the human population." (Despommier 2011: 49)

By entering the modern era and all the technological improvements that followed by, we increased efficiency in cultivation by using new technologies and agrochemicals such as pesticides and fertilizers, without recognizing that we were causing broad ecological damage and negative human health effects. This also applies to modern practices in animal husbandry and genetically modified organisms. Industrial meat production has also brought a lot of concern due to animal welfare, the health effects of antibiotics, growth hormones, and other chemicals commonly used in industrial meat production. Water management due to traditional agriculture has also become a global issue.

Despommier (2011) points out further: "Yet never did it occur to any human population, regardless of the time period or the fertility of the land, that what they were doing to the environment by farming was actually destroying the very tapestry of what allowed us to evolve into human beings; namely, an intact ecosystem." (Despommier 2011: 68)

Based on FAO (2013) the global distribution of risks associated with main agriculture production systems, shows biggest risks derived from agriculture such as: land and water scarcity, deforestation and not the least loss of biodiversity and loss/low

soil fertility. Food insecurity as mentioned earlier is one consequence of this (FAO 2013).

It is indicated in the FAO (2013) report that today more than 1.5 billion ha—about 12 percent of world’s land area—is used for crop production (FAO 2013). According to Despommier (2011) considering the land we use for animal husbandry as well, at present we use more than 80 percent of the available dry land (Despommier 2011). It is also stated in the FAO (2013) report that there is very little area for easy development of agriculture land and it is due to the amount of land that are available but covered by forests. The point is protecting these areas considering environmental issues we are facing today (FAO 2013).

## 2.1 Climate and food—warnings of collapse

*“The global abundance of N fertilizer has dramatically increased agricultural productivity. However, when N escapes to the atmosphere as ammonia (NH<sub>3</sub>) gas, NH<sub>3</sub> loss can cause undesirable effects. In addition to a loss of a valuable resource, it can have negative impacts on air quality, ecosystem productivity, and human health (Ammonia Emissions from Agricultural Operations: Livestock).”* (Bittman & Mikkelsen 2009)

Another area where the consequences are dramatized is the world food situation. On several occasions CICERO, Centre for Climate research, has argued that global warming will result in “food insecurity” and major famines, and that global warming could cause a collapse in global food supply (Holtmark 2008) (translated by author).

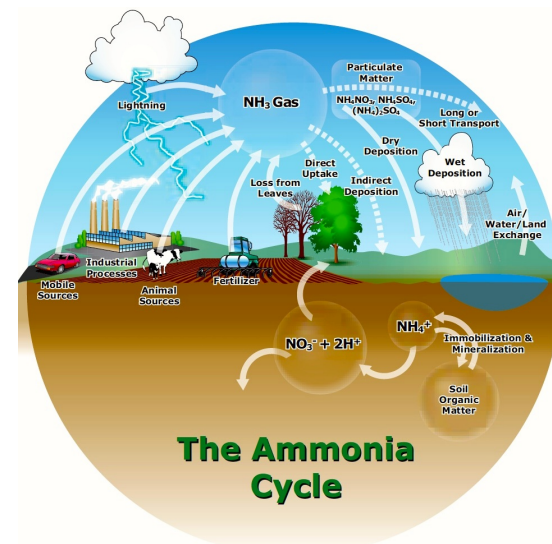


Figure 7: Ammonia emission, transport, and deposition from major sources.  
Source: (Bittman & Mikkelsen 2009)

This is a subject that has been seriously researched the last few years. This research concludes relatively clearly that the global food supply is not threatened by the human made climate changes. But the climatic changes might, sometime in the future, contribute to an increase in food prices, because it will become too warm in several agricultural areas near the equator. Because hunger and malnutrition is primarily caused by lack of money can the climate changes make the problems of famine worse than they otherwise would be (Holtmark 2008)(translated by author). The scope of the effects of climate changes on the agriculture is still somewhat uncertain, though, especially because the increased concentration of CO<sub>2</sub> provides a significant stimulant for the photosynthesis and therefore increase productivity. In some scenarios there may be a shorter or longer period of increase plant activity overall, that *may* lead to an increased

productional capacity over the short term. There is, however, the problem of displacement and lack of adaptability for developing countries. Production may rise in technological sufficient countries, while dramatically falling in others.

One should not forget that CO<sub>2</sub> is what keeps the plants alive. In many areas a warmer climate will also be beneficial to agriculture. A warmer climate will also give more evaporation of the oceans, thus also more rainfall. Overall it is expected that agriculture in large parts of North America, the whole of Europe, Russia, Argentina and China will gain a significant increase in productivity as a consequence of these effect (Holtmark 2008) (translated by author). This also means that areas who are already receiving enough rainfall may expect more rain to drown or wash away parts of the local agriculture. Increased global heat may also see shifts or strengthening of general wind patterns which determine the direction of evaporated water, as clouds, and hence areas receiving rainfall. Should the above mentioned areas receive better growing conditions at the cost of for example India, the Middle East and Africa, we may see increased poverty rates and subsequent malnutrition and starvation. Hence, the serious studies mentioned earlier have helped map possible future outcomes and scenarios, the exact variation in production detriment and local and regional environmental effects and its consequences are complex and need further studies.

Fossil fuels (oil, gas and coal) is the dominating source of emissions, and this is related to the fact that more than 80 percent of the worlds energy needs are covered by fossil fuels. Another important cause of emissions is area transformations, mainly when tropical forests are converted into agricultural fields. If one wishes to reduce climate gas emissions, one have to limit the process where tropical forests are converted into agricultural

fields and at the same time find a main source of energy other than fossil fuels. Both are very difficult to accomplish (Holtmark 2008)(translated by author).

Coal is cheap and easily accessible over large parts of the world, and is the main resource used in energy production. The increase in energy use will in this century first and foremost happen in the developing countries where, today, there are large unmet energy needs. Poor people will put much effort into paying as little as possible for their increasing energy consumption. Therefore it will be difficult to gain acceptance for the world to now switch to more expensive alternatives such as solar- and nuclear power. We may be able to achieve this in the richer part of the world, but it is a great deal more challenging to gain approval for this policy in the poorer parts of the world (Holtmark 2008)(translated by author).

Stopping the process of deforestation in the tropics is also challenging. It is about poor people wanting new agricultural areas. Often these processes happen outside the control of the government in the affected countries. Nobody therefore has an answer today about how one should stop the deforestation in the (translated by author).

This has contributed much to pollution of local and regional rivers and coastal areas as well as pollution of the air. The climate gases methane and nitrous oxide, coming from both manure and artificial fertilizer, contributes to global warming. While pesticides are unhealthy and damaging to human, animal and plant life. Standards for chemicals, equipment and use are set by the government food agency (Rognstad & Steinset 2012)(translated and edited by author).

A report from the Food and Agriculture Organization (FAO) states that the livestock sector is "responsible for 18% of greenhouse gas emissions". The report concludes, unless changes are made, the damage thought to be linked to livestock may more than double by 2050, as demand for meat increases. Another concern is manure, which if not well-managed, can lead to adverse environmental consequences (Steinfeld & FAO 2006).

### 3 Agriculture in Norway

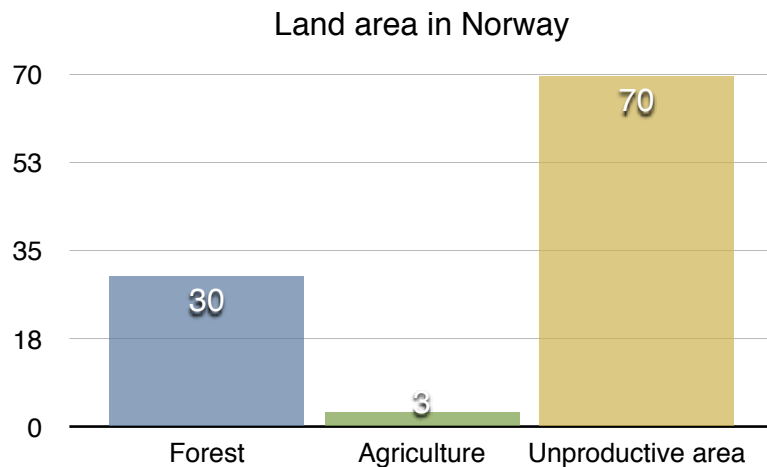
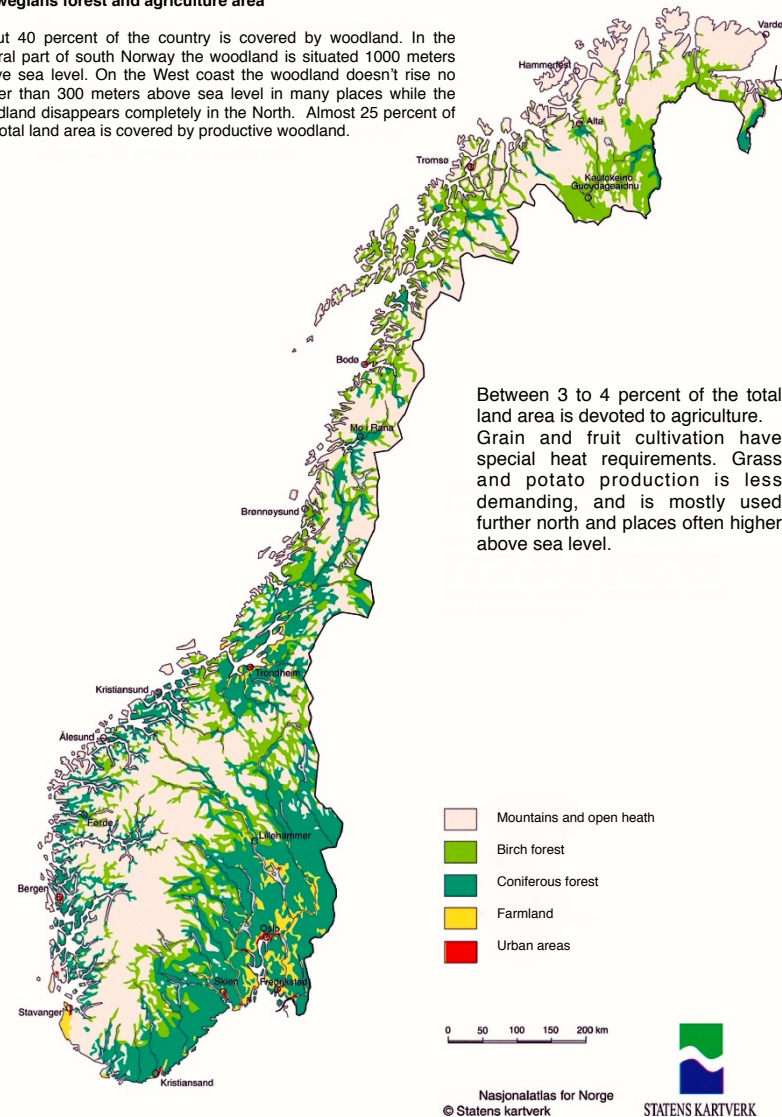


Chart 2: Created by the author Source: (Syverud & Bratberg 2013)

Norway is strongly influenced by its geographical location when it comes to agriculture. There is very little area that is suitable for agriculture. Today there is hardly 3 percent (10,068 km<sup>2</sup>) of the total land area that is devoted to agriculture due to landscape and climatic challenges, and only 1 percent of this for wheat. 70

#### Norwegians forest and agriculture area

About 40 percent of the country is covered by woodland. In the central part of south Norway the woodland is situated 1000 meters above sea level. On the West coast the woodland doesn't rise no higher than 300 meters above sea level in many places while the woodland disappears completely in the North. Almost 25 percent of the total land area is covered by productive woodland.



Map 2: Translated by author Source: Statens skartverk



Allocation of cultivated and arable land to other purposes than agriculture. 2012. Percent

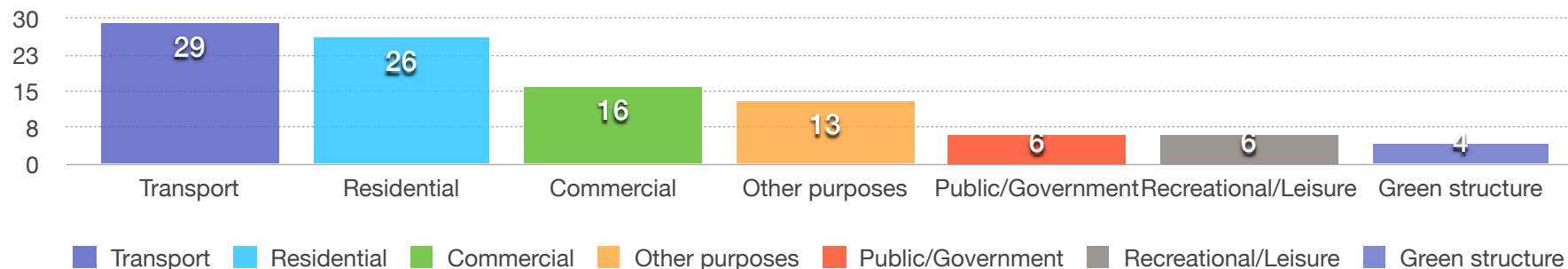


Chart 3: Created by the author

Source: (SSB 2014)

percent of the total land area is unproductive area and 20 percent is woodland or forest. Conditions for agriculture operations and the growing season duration varies a lot between different parts of Norway.

In many valleys, fjords and mountain villages, it is steep and creates difficult terrain but at the same time Gulf Stream makes it possible to farm even in the northernmost areas (Syverud & Bratberg 2013).

According to Norwegian Central Bureau of Statistics, in 2012 6,600 acres of cultivated land and 4,600 acres of arable land was allocated to other purposes than agriculture. It is interesting to point out that it was as much cultivated land allocated as the year before, while allocating of arable land has increased with 700 acres from 2011 to 2012 (SSB 2014).

In 2012 a total of 11200 acres of agricultural lands were allocated to purposes other than agriculture. The biggest part of the allocation were regulated by the Planning and Building Act as 82% went to regulating for transport, infrastructure and buildings. Of the allocated area 29 percent went to transport, 26 percent to

residential and 16 percent to commercial/industrial. At the same time 13400 acres were approved for new cultivation and allocated to agricultural lands from the reserve of arable land

Based on Syverud & Bratberg (2013) after the second world war Norwegian farming became practically completely mechanized. The number of people working in agriculture has been significantly reduced. The use of artificial fertilizer and animal feed have increased strongly resulting in bigger crops per unit and greater production per animal, also as a consequence of plant and animal breeding (Syverud & Bratberg 2013)(translated by author).

A great increase in efficiency took place as the manpower needs decreased and crop gains increased. Thus freeing manpower for other tasks. These positive changes also came with a more negative impact on our environment. What this means however is there is little room to improve efficiency through mechanization, which has already been done, thus losing us one tool for increasing production in the short and long term. It may

take years yet, but we are slowly draining our reserve of arable land. This is cause for afterthought as only 1 percent of Norway is suitable for wheat produce.

Drawing on chart no. 3 one may find that most of the allocation were regulated by the Planning and Building Act of 2008 for transport, residential and commercial purposes. This means more urban spaces and less potential green structures that again leads to more environmental challenges. It is also against densification strategy which is meant to ensure less area use. This also means that Norway is getting less self-sufficient and more reliable on import when it comes to food production, unless we use some of these areas allocated from agriculture for to, a more area efficient, vertical farming.

According to the Norwegian industrial policy Norway today has an import protection. This is a prerequisite to have food production in Norway. It is used as an instrument to equalize costs between Norway's own food production and food production with countries Norway trades with. The reason for that is that Norway has generally much higher costs than other countries. Since Norway is a rich country, its workers have also much higher salaries. This also applies for farmers that have to pay much more for those products and services they need to buy to produce food.

It is stated in The Norwegian Agriculture Cooperative (2014) that this leads to higher prices for food products compared to other countries, but not for the people who live in Norway considering their high salaries (Norsk Landbrukssamvirke 2014)(translated by author). This in turn would lead to a closing down of all Norwegian food production and related industries, thus destroying jobs.

The Norwegian Agricultural Cooperatives say:  
"The world needs more food. Soon we are nine billion people. The Norwegian population is also increasing. Norwegian food production must grow with Norwegian resources. We want to produce more quality food for the Norwegian population in the years to come." (Norsk Landbrukssamvirke 2014)(translated by author)

### **3.1 Overall goals for food production in Norway**

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Policy framework:

Agriculture is a regulated industry, and the agriculture policy has a major impact on what is being produced, the amount of production, and where the production should take place. In Norwegian context agriculture is also intended to fulfill goals that goes beyond just food production. Parliamentary report no. 19 (1999-2000), (Quoted from (Rognstad and Steinset 2012)) states that agriculture in line with the needs of society will produce:

- Safe food with high quality based on consumer-preferences
- Other goods and services based on industry's total resources
- Public benefits as viable communities, a wide range of environmental and cultural goods, and long-term food supply (Rognstad & Steinset 2012)(translated by author)

Based on Rognstad *et. al* (2012) international agreements provide a framework for the national policy. The main international agreements are, the EEA and WTO (World Trade Organization). The World Trade Organization (WTO) sets

constraints on import protection (tariffs), the amount, and what kind of budget support (transfers of state budget) that can be provided. There has been negotiations about further liberalization of trade in progress in WTO, but after 2008 there has been little progress in those negotiations (Rognstad & Steinset 2012) (translated by author).

Many of the political parties in Norway support a higher degree of self-sufficiency. Supposedly there is also then some concern given to the fact of national food security. There are also variations for the amount of food grown each year due in fact to annual seasonal conditions such as temperature, wind and

precipitation. In addition several regions and areas in Norway are threatened by the seasonal flooding of rivers in connection with snow-smelting.

This contributes to both temporary and permanent damage to agricultural areas due to erosion. Likewise coastal areas are under threat of storms which may disrupt and damage nearby acres. While these natural challenges are usually not excessive given the small amount of arable land in Norway we are still vulnerable.

These challenges can to some extent be met by creating a more controlled environment in which to grow food, for example: green houses and/or vertical farms. These would have to be constructed in a durable fashion, but would allow for a more predictable crops as well as being able to harvest several times annually.

### 3.2 Urban agriculture in Norway

According to Lehmann (2012), on his principle of local food and short supply chains, “The various aspects of this principle include: local food production; regional supply; and an emphasis on urban farming and agriculture, including “eat local” and “slow food” initiatives (Haas 2012: 24).”

As consumers are increasingly concerned about content, production processes, health, environmental and social impacts of the food they eat, and at the same time have Norwegian consumers proven to be particularly concerned about health, which is also reflected in the increased demand for organic food products and the shift from meat to fish or to vegetarian (Forum for utvikling og miljø 2006)(translated by author). It is therefore a bigger demand for producing food locally, we should thereby not



Figure 8: Norwegian Party Programs, source: Author

only use urban recreation areas to actively produce food but also to include more zones dedicated to urban farming in different forms, e.g vertical farms. Municipalities could take this into consideration and invest more for food production within the cities.

Urban agriculture can be a part an urban resilience. Resilience in this sense can have two modes, the first mode is how human generally react to sudden disasters and changes, called the reactive mode. The other is the proactive mode where planners and designers are brought in to prevent the effects of disasters before they occur. This is an anticipatory action. Including local food production gives food security.

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### 3.2.1 Urban agriculture: reactive mode of resilience

As it was discussed in chapter 1 the theoretical basis planners and designers are often brought in after a disaster has occurred. This is a reactive resilient mode. This requires searching for clues and investigating the aftermath to prevent similar destructions in the future. Analyzing the event helps the decision-makers to find ways of adapting to the environmental challenges and be flexible to types of change.

Having history in mind and analyzing the pros and cons helps us find better solutions to similar future challenges. Food shortage during the war period and the way people reacted to it shows that people during a crisis seek every possible solution to survive, those with more creativity often have bigger chance of surviving. At the same time it is important to avoid situations like that again, however should perhaps every society learn to be resilient and be more aware of future changes while seeking to

adapt. Self-sufficiency therefore is a good starting point for every nation in order to be able to prepare for changes.

When it comes reactive mode in urban agriculture, one can point to The Victory Gardens in the United States during the WWII. As Despommier (2011) states The Victory Garden propaganda poster encouraged every American citizen to help the war effort by the growing their own vegetables in “victory gardens”. This was because commercial farmers were responsible for supplying sufficient food to the troops overseas (Despommier 2011). The same efforts were made in Europe, for example in Great Britain, Germany and Norway. Most people who owned a small patch of garden dug it up to plant potatoes and other vegetables. Many



Figure 9: Green roofs, urban agriculture Source: Author

also got themselves a pig, not only in the countryside, “villa pigs” were common (Nyborg 2013).

“Today, there is a movement to return to locally produced crops, only this time its epicenter is situated within the urban landscape, not the suburban backyard.” (Despommier 2011)

This reactive mode of resilience includes Norway as well. According to Nyborg (2013) even before the war came to Norway on 9. April 1940, Norway had started to ration some goods: Flour, coffee and sugar. This list became longer, during the first year of the war, and included all imported foods, bread, fats, sugar, coffee, cocoa, syrup and coffee substitutes (Nyborg 2013)(translated by author). The war and the consequent food crisis followed by war forced people to use every possible place to grow their own food, also within the city limits.

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### 3.2.2 Urban agriculture: proactive mode of resilience

Allotment gardens (kolonihager) in Norway is an example of local food initiatives. They were first established by *Norsk Kolonihageforbund* in Oslo when the municipality embarked parcel pieces on the city's old landfill Rodeløkka in 1907. Those who were interested applied to the municipality of Oslo and the assignment followed a social profile (Røsjø 1994). The gardens were primarily intended for families in apartment buildings and city apartments as a recreation area, a place to grow own food and refuge.

The goal of *Norsk kollonihageforbund* is: "The gardens will help improve living conditions for children and improved quality of life for adults in urban and suburban areas. The gardens will appear as green spaces and parks available. They should be seen as an important resource for local communities. The Association "*Norsk Kolonihageforbund*" shall support the work of several allotments and help preserve existing allotments and allotment gardens in the country." (Norsk kollonihageforbund)(translated by author)

As it is indicated in the goals of Kolonihageforbund, these allotment gardens are meant to create more greenery and to increase life quality in the cities. Originally they were meant for *matauk* (food production), but they are now not directly meant to produce local food for the inhabitants (Røsjø 1994). They now serves as recreation and social activity to improve urban living qualities.

#### **Transition: network and movements**

As Lehmann (2012) states in one of his *Guiding Principles of Green Urbanism for Local Action and a More Integrated Approach to Urban development: Principle 11 Local food and short supply chains*: "The sustainable city makes provision for adequate land for food production in the city, a return to the community and to the allotment gardens, where roof gardens can become an urban market garden. It is essential that we bridge the urban-rural disconnect and move cities toward models that deal in natural ecosystems and healthy food systems (Haas 2012: 28)."

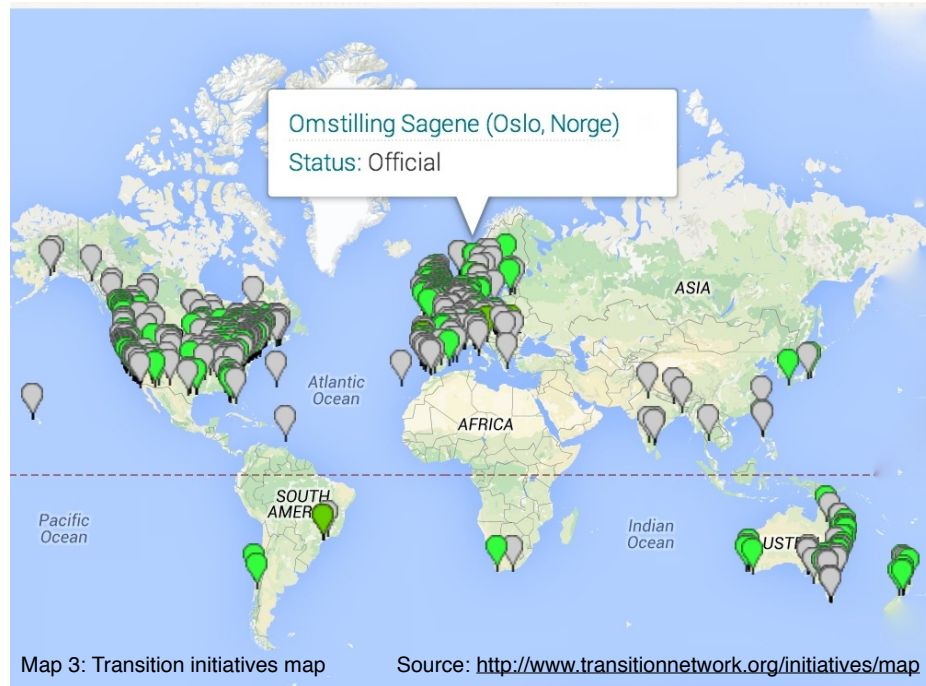
Transition model on the other hand is a community project that seeks to build resilience in response to peak oil, rapid climate change, and economic instability. It's a place where there's a community-led process that helps that town, village, city or neighborhood become stronger and happier.

According to Wessling (2014) "The transition movement often refers to itself as the "head, heart and hands" of the energy and cultural transition. With that comes the importance of maintaining a balance between these three components, so that none outweighs the others." (Wessling 2014)

Wessling (2014) discusses further that.."the "head" refers to scientific and mental conclusions and facts that inspired Hopkins (the founder) and his collaborators to establish the first Transition Town in Totnes. It includes the insight that the present Western



lifestyle is not sustainable, particularly when looking at it with an awareness of Peak Oil (and other resources peaking), climate change and global justice in resource use.“(Wessling 2014)



The transition model has spread quickly around the world. There are now 320 official initiatives in 14 countries and thousand more in development. Norway has several initiatives actively searching to create the transition model. Here are some examples: *Omstilling Sagene* in Oslo, *Bærekraftige liv Natland og Sædalen* in Bergen, *Landås Transition Initiative - "Bærekraftige liv på Landås"* in Bergen, *Horten*, *Omstilling Norway*, *Omstilling Nessodden*.

Transition is a movement that helps the least to make new friends locally, get to know people thus creating stronger communities.

Map 3, shows *Omstilling Sagene* in Oslo as a transition network. As it is described in their website (*Omstilling Sagene 2014*), “*Sagene* is an urban district in the centre of Oslo with approximately 35,000 inhabitants.” This group started in November 2010 and has since implemented a number of projects in the community. Here’s a brief list, relevant for urban agriculture initiatives, of what this group has managed to carry out with a tiny budget and lots of enthusiasm as it is described in their network website:

- Soil building project/local food production
- Gardening at kindergartens
- Fruit press and juice stands on *Park(ing) Day* with local pears and apples from the local parks
- “exchange markets”
- The Garden Trailer—challenging the street parking paradigm in Oslo: volunteer-based collective food packaging
- Permaculture park gardening
- The “Wish Tree”—a project supporting local democracy (*Omstilling Sagene 2014*)

It is explained further that all the initiatives and courses are offered free of charge or for a low cost. Anyone is welcome to attend courses or take part in their project, regardless of where you live.

The Transition movement as a community based initiative may also be delineated by Rydin’s (2013) observations on community initiatives: community initiatives are more about creating social capital within residential and local business communities. This is



for enabling community-based initiatives and providing means for putting them into action. It is also about building communities using the resources of connectivity, trust and reciprocity and strengthening them. (Rydin 2013)

I mentioned earlier in Chapter 1: personal reflection, by a diagram that it is essential to spread the knowledge. And create more accessibility in order to get the optimal densification with quality. Transition is a model that engages people in sharing and exchanging knowledge with a common ground which is creating a stronger community that handles transition. Technology has improved the way we communicate and how fast the information spreads. Considering this perhaps transition can work as a great community model that helps bring people together. At the same time it makes the inhabitants aware of the benefits of cooperating with the natural environment. As for social advantages like spreading the knowledge mentioned above, this creates deeper bonds between people. Comparing to the consumerist society and the role of customer, in the transition model people get to create other levels of communication where there are a lot more than money that is being exchanged between people.

However, when it comes to food production, relying only on producing food locally by using rooftops, parks, backyards or even every green patch available, while positive in itself, would not be enough. The reason for that is the seasonal limitations in Norway and the amount of food one could produce. It is also important to add that these local food initiatives vary in approach. This is good because it deals with different aspects of a resilient society such as building stronger communities, social activities and to produce food locally.

### 3.3 Recycling and re-use

Recycling is very much part of overall resource consumption and efficiency, and it is an integral part of any urban farming and vertical farming project. Firstly, as direct reductions in resource use and waste production for the farm itself. Secondly, as catalyst for greater community-wide recycling, for example conversion of certain municipal waste to fertilizer, biogas or direct burning to heat and energy. This directly enables material and energy re-use and is therefore important in all three aspects of sustainability: economy, environment and social. It is therefore beneficial to investigate current network and distribution of waste and recycling thereof, specifically in a Norwegian context.

The official waste statistics are not so detailed, that includes absolutely all kinds of food waste and how this is handled. SSB surveys are essentially asking for organic waste, which includes biodegradable organic wastes not from parks and gardens, but more of food waste, such as crop residues, diapers, paper towels, etc.

However, according to Brunvoll (2010) there is ambitious goal of increasing the recycling tare for the total waste to 80 percent to the national level. Several municipalities have implemented new comprehensive waste management plans for achieving these goals, and the municipality of Oslo has now invested around a billion NOK on increased recycling and recovery. But recycling targets are not justified by cost-effective emission reductions and effective resource management (Brunvoll 2010)(translated by author).

A recent project by Lyse Energy and the municipalities around Jæren aims at recycling the gas produced by the livestock in this agriculture intensive area: The agriculture at Jæren is a large

producer of milk, cheese and meat, but it also produces more than 1 million tons of livestock waste each year. Now the municipalities in cooperation with Lyse Energy and the farmers wants to utilize household waste and animal waste for bio-gas production equivalent to about 500 GWh. The waste keeps its nutritional value and can be used afterwards as fertilizer for the agriculture (Statusrapport 2010)(translated by author).

This bio-gas consists mostly of methane which has climatic effects at roughly 21 times the same amount of CO<sub>2</sub>. The climatic bonus is staggering, adding that this gas may also be used as fuel for cars which reduces the overall climatic effects even further.

### 3.4 Transport in agriculture and food production

Food transportation is an interesting symbol and example of how small and at the same time intricate the world has become. It illustrates how the goal of sustainable development must be dealt with on several levels. Harvesting/fishing, production, transportation and consumption of food are all important when calculating emissions.

According to Brænd *et. al* (2006) Food supply in an industrialized society like Norway requires large amounts of fossil fuels such as oil, gas and coal. Transport in all parts of the supply chain are energy intensive and represent an environmental impact that is often omitted in environmental accounting. Developments with regard to the transport of food has been changed gradually. For example: fishing has changed from fishing close to the coast with sails and oars as propulsion to the current fishing vessels, which operate far out to the sea and across the globe. Similarly,

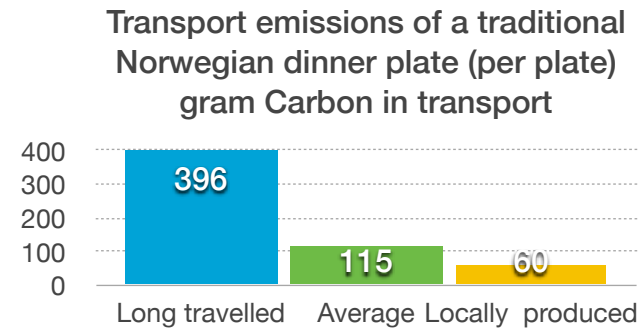


Chart 4 Source: Forum for utvikling og miljø 2006

transport of fish from sea to the table has become increasingly energy-intensive concerning the transport by trucks, trains and airplanes. Today's food production is totally dependent on fossil fuels. World Watch Institute has estimated that between 10-20 percent of a family's energy consumption is related to food production that is important (Brænd, *et. al.* 2006)(translated by author).

Based on a calculation from a report produced from Framtiden i våre hender called "*Kortreist, langreist eller vegetarisk*" (referred to in Brænd *et. al* (2006)), a typical Norwegian Sunday dinner dish, which is long travelled, gives 6,5 times higher transport emissions than locally produced food. While emissions from the actual average dish is about twice as much as the locally produced food. The report warns us focusing solely on locally produced food, as it is the sum of emissions from food production and consumption (Brænd, *et. al.* 2006)(translated and edited by author).

It is further discussed in this report that traceability is increasingly a demand from consumers. In other words, the consumer wants to know where the food comes from, who has produced it, what

kind of chemicals are used during the production and other information like taste, price and packaging. The shorter the distance between producer and consumer, the easier it is to obtain such information (Brænd, et al. 2006)(translated and edited by author).

At the same time in a resilience perspective mentioned earlier, energy shortages is described as a threat to a society. As the fossil fuel is to end one day, it is risky to rely on an energy-intensive infrastructure and transporting goods with long distances (Gjøse 2013)(translated and edited by author).

### 3.5 Import and trade

Import and trade may be areas of interest in relation to food production and vertical farming. This is related to aspects of self-sufficiency and material and energy cycles. Using vertical farms as supplements to national traditional agriculture may help produce goods not otherwise able to grow locally. Ultimately it might be wishful to achieve complete self-sufficiency.

Norway imports more agriculture products than it exports. In 2011 according to a study from SSB, the total imports of agriculture products, both raw and manufactured goods, was 39.9 billion NOK, compared to 25.3 billion NOK in 2006. During this five-year period, the value of imports increased by almost 60 percent, measured in current prices. Conversions amount for 2006 to 2011 values gives an increase in imports by 42 percent. In 2011, the exports of agriculture commodities was 48 million. Exports were stable in those five years, calculated in current prices (Rognstad & Steinset 2012)(translated by author).

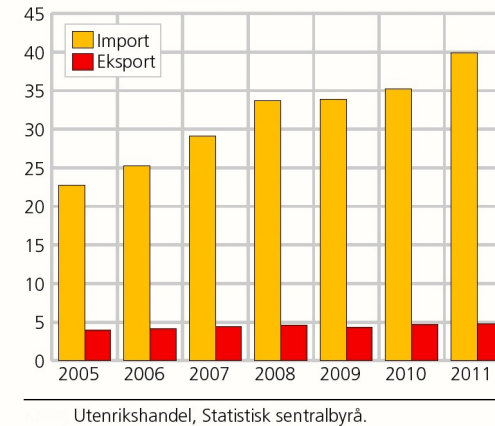


Chart 5: Export and import of agriculture products 2005-2011. Billion NOK

The Norwegian import protection mentioned earlier leads to higher agriculture prices in Norway than the world market prices, thus making the local production bigger than it otherwise would have been. The support from the state budget is often divided into:

- Direct support
- Support dependent on production such as price subsidies on products
- Support independent of production such as subsidy per animal or per acres of agriculture land in use as well as various social arrangements
- Support for investment
- Indirect support through research, teaching and consulting

To achieve the political objectives of agriculture much of the support is differentiated by production, region, herd size and area size (Rognstad & Steinset 2012)(translated by author).

At the same time according to SSB, the international aspect of a sustainable development has fundamental importance and is an important policy area in Norway's strategy of sustainability. A major challenge to promote a more sustainable development is to reduce global poverty. Assistance funds to developing countries can be an important tool to achieve this. Poverty reduction is the most central of the Millennium Development Goals, adopted in 2000. Net official development assistance from Norway was NOK 27.7 billion in 2011, the same as 2010. As a percentage of gross national income (BNI), however, the share fell from 1.1 to 1.0 percent, but the government's stated goal of 1 percent of (BNI)/(GDP) was still reached for the third consecutive year (Brunvoll & Kolshus 2012)(translated by author).

Import of goods creates transport as well. As it is indicated in part 1.4.6, transport is followed by more transport emissions which causes more environmental challenges.

Poverty is also an essential problem, but supporting developing countries by trading goods from them, might help a little economically, however as long as these only lead to covering basic needs for most of these developing countries, it wouldn't prevent them from difficulties they meet when it comes to environmental challenges, such as droughts, water scarcity and so on. What these countries need help with are technology, knowledge and self-sufficiency.

## **4 Urban agriculture/Vertical farming**

Despommier (2011) states "Regardless of location, the city has grown helter-skelter, and its insatiable appetite and out-of-control

metabolism produces nothing more useful than lethal bubbles of heat and contaminated air and water laced with the by-products of its mechanized infrastructure. "Metropolis" has become synonymous with consumption (Despommier 2011: 231)."

As it was discussed earlier one of the most challenging environmental issues we are facing today is the rapid climate change and environmental damages. The growth in population and the demanding consumerist society is also an environmental and social issue. These issues influence and impact each other. Cities viewed from an ecologist perspective are not only in disharmony with the surrounding nature, but they also are a place to produce waste and pollution. The black box issue concern the cities' need for input of energy from the environment, then produces and returns dangerous waste.

As it was pointed out earlier there are different attempts and initiatives to grow food within the cities. There are i.e. attempts to produce ecological food or grow food with hydroponic systems. Some groups produce ecological because they are concerned with food safety, other groups or movements seek sustainable development and resilient communities. At the same time there is a common ground for all the different attempts to produce food locally, the direct access to fresh crops, and short travelled food that simply tastes better.

The visions different communities or groups have, is reflected in the different methods they choose to employ to produce food within the city. As an example the transition movement has a food production initiative, among others, where they use traditional agricultural methods with the aim of producing ecological food. The transition movement support small local food production initiatives and brings them together.

Producing food locally requires less transport. This gives the possibility of less heavy infrastructure.

Urban agriculture can create jobs and act as or open up for recreational areas. And in cases like vertical farms in urban spaces it can be used as local research and educational centers. This makes sure that the inhabitants get safe local food and gives the possibility for social and economical advantages.

As a student in urban planning I see many advantages in producing food locally. Imagine a vertical farm, in a city district that is used also for school tours and as a research center. The area around has small local shops that offer fresh vegetables, herbal medicine, food and drinks. Placing the vertical farm on a pedestrian street can help create a social hub. The surrounding market, with a small park or recreational area, will be filled with happy people.

Cities are in constant change, and they have changed significantly. This means that the idea about how to design urban spaces has also changed. Carmona (2010) puts it this way: “As assumptions of centralized urban form and dominant central business districts become less tenable, the traditional vocabulary of ‘city centre’, ‘suburb’ and ‘city edge’ also becomes less meaningful.” (Carmona 2010: 21-25) The traditional idea of producing food outside the city limits and mostly in rural areas is also becoming less meaningful in many countries all around the world. For Fishman (1987) quoted in Carmona (2010), the new city’s ‘true centre’ is no longer the downtown business district but each individual residential unit, whose member “...create their own city from the multitude of destinations that are within suitable driving distance.” (Carmona 2010: 21-25)

Sustainable design by spatial scale by Carmona (2010) suggests that when it comes to self-sufficiency quarters one must “build a

*sense of community, involve communities in decision-making, encourage local food production allotments, gardens, urban farms, pay locally for any harm and design to encourage cycling.”(Carmona 2010: 59)*

Further when it comes to pollution Carmona (2010) suggests “re-use and recycling of waste water, insulate for reduced noise transmission—vertically and horizontally, on-site foul water treatment.” In urban spaces based on Carmona (Carmona 2010: 59) we should: “reduce hard surfaces and run-off, design in recycling facilities, design well-ventilated space to prevent pollution build-ups, and to give public transport priority.” (Carmona 2010: 59)

## 4.1 Vertical farming

I believe we can take urban farming further and push for food production within a controlled environment also making use of the volume of the space not just the flat area, hence vertical farms.

Design and innovation born from human’s creativity are the reason we have so much access to goods and technology today. With a brief look at the human’s history, one can see how we might have succeeded or failed in history. For example:

According Carmona (2010) during the nineteenth century and early twentieth century, industrialization changed the scale of development. This coincided with other major developments in technology such as railways, the safety elevator and the internal combustion engine, and a host of related social and economic changes. Architects and engineers sought to meet the new demands and challenges of the period (Carmona 2010: 21).

One of the conclusions one might draw is how the technology has evolved faster than our understanding of it. The industrial revolution marked a turning point in that technology started evolving at a much greater pace. In contrast our learning and development techniques have not kept pace with technology. The trial-and-error method was perfectly sufficient until the twentieth century. One can no longer afford to wait for the manifestation of the consequences of the actions before changing directions. Our multitude and technological power some times make our mistakes global and potentially irreversible.

It is therefore my argument that we cannot wait for a complete system failure before containing our consumption patterns. We can for instance re-introduce farming to our cities.

Consequently it is not the architects or engineers that are wholly responsible for our urban landscapes today, they are agents acting on behalf of politicians, entrepreneurs and the inhabitants. Certain paradigms and assumptions about cities are still prevalent today.

Growing food inside the city is inefficient, potentially produces toxic food and is “unnatural”. This may be one, or three, of the paradigms today that is just now beginning to change. This inefficiency relates to traditional agriculture and large fields required to gain mechanical efficiency in terms of planting and harvesting, light and soil. These are all now, technologically speaking, irrelevant, we have the means to bypass these earlier challenges. For now, we may also use greenhouse technology to create closed-loop systems thereby bypassing environmental hazards and pollution, both into and out of the system. The last is just a mindset we have evolved that this is the way things are

done, but we should not forget that agriculture in itself is “unnatural”, it is only roughly 10 000 years old.

As an example of successful urban agriculture one may look to Japan. It might come as a surprise that almost one-third of all agricultural output in the country is, in fact, generated by urban agriculture.

Furthermore, Japanese urban agriculture is more productive than its rural counterparts. According to 2010 data from the Ministry of Agriculture, Forestry and Fisheries (MAFF) (2011), urban fields are the most productive kind of agriculture in terms of economic value of production per area (...). As Moreno-Penaranda (2011) argues: Even in Tokyo, one of the largest and most congested cities in the world, among the intricate networks of railways, roads, buildings and power wires, local agriculture produces enough vegetables to potentially feed almost 700,000 city dwellers (Moreno-Peñaranda 2011).

Just by shifting our view to different solutions and agricultural methods around the world can we get an idea of what is possible and feasible. Only after doing this can we get a complete view of all possibilities and a true picture of potential solutions.



## 4.1 Policy

We cannot put the blame and responsibility of our current transport challenges and city helplessness to our technicians. It is the “will of the people” and politicians that form the policies which guide development. It is also through decision-making that we should look to today in increasing our overall efficiency and reducing our overall destruction. Policies can be enacted much faster than changing the mindset of people in general. The age of information, which we have entered, can also be labeled the age of misinformation. People, more often than not, listen, watch and read information they approve of through channels they like and will therefore often disregard anything “unpleasant”, “inappropriate” or “propaganda-like”.

It is here that politicians need to step in. At the very least policy should not stand in the way of potential improvements. Specifically regulation and zoning are key areas that could help improve innovation.

There is no zoning scheme that supports urban agriculture or vertical farming. Different municipalities and government institutions may categorize these structures differently. For example, is this a commercial, industrial or, in some cases, even a residential building. Can we plan for it to be built in any of the existing zones or do we need to modify existing regulation policies? Changing policies might also take years. By providing a more specific zone for this type of structure one may also help investment in a project. Providing specific guidelines for allowed construction in an area may ensure that real estate prices does not inflate and discourage potential investors and entrepreneurs. It may also help identify key areas or properties especially suited to this task in terms of neighboring resources and consumers.

Doing this early on may speed along the process of planning and building and help reduce conflicts.

By taking into account the slow political processes needed to implement these policy changes, this is something the government should have been prepared yesterday. As providers of food, jobs, research or even residential units on a, hopefully, city-wide scale these buildings will be of great importance to the city as a whole, yet are not necessarily public buildings. This points to that they should have their own specific zone.

As an example of policy difficulties we can again turn to Japan:

The first difficulty in dealing with urban agriculture lies in its definition and, hence, its regulation. In Japan, urban agriculture falls under the MAFF, which is in charge of policies concerning agriculture, and the Ministry of Land, Infrastructure, Transportation and Tourism (MLITT), which deals with urban planning. Since the two ministries use different zoning classification systems to distinguish between areas in which urbanization is a priority and areas in which farming is, there are conflicting definitions of what in fact constitutes urban agriculture. This, in turn, results in policy challenges at the ground level, often aggravated by regional and local regulation (Moreno-Peñaranda 2011).

This has in turn resulted in greater difficulties for Japanese urban farmers and is probably responsible for at least some of the loss of urban farmers in the country. Complicated incentive-schemes requiring farmers to be full-time farmers or have 30 years of experience haven't helped either. High inner-city real estate prices combined with these challenges gives a picture of the resilience of urban farmers and the demand for their products in Japan.

Another policy problem example may be taken from Plantagon's attempt at building a vertical farm prototype in the Swedish city of Linköping. No zoning exists here to provide a foundation for urban or vertical agriculture. This has lent extra strength to local arguments against building because of wildlife preservation and aesthetics. Had the property been located within an urban or vertical agricultural zone, these arguments would either disappear or diminish. A zone would have been setup that would not endanger local wildlife, and arguments about aesthetics would have held less sway because of inherent greater legitimacy of building in a suitable zone.

The point here is to set certain standards which will help people, both professionally and in general, to incorporate the idea of urban agriculture and local food. This is one way of transmitting information, surely there are other different methods to use as well, but they are not part of this thesis.

Lastly there may be a need to provide an alternative to the current planning regime. The Plan and Building Act of 2008 does try to implement criteria other than economic growth, but does not present alternative approaches. According to Rydin (2013) today's planning regime is largely based on the prospect of perpetual growth, a growth-based planning, having its foundation on the economic theories of Keynes. This very much puts focus on economic growth and control is in large part delegated to market-forces (Rydin 2013: 1-3).

Rydin's argument (2013) is that a reliance on growth-dependent planning is by itself insufficient:

- Insufficient to meet the needs of all sectors of society
- Insufficient to ensure quality of life for all inhabitants

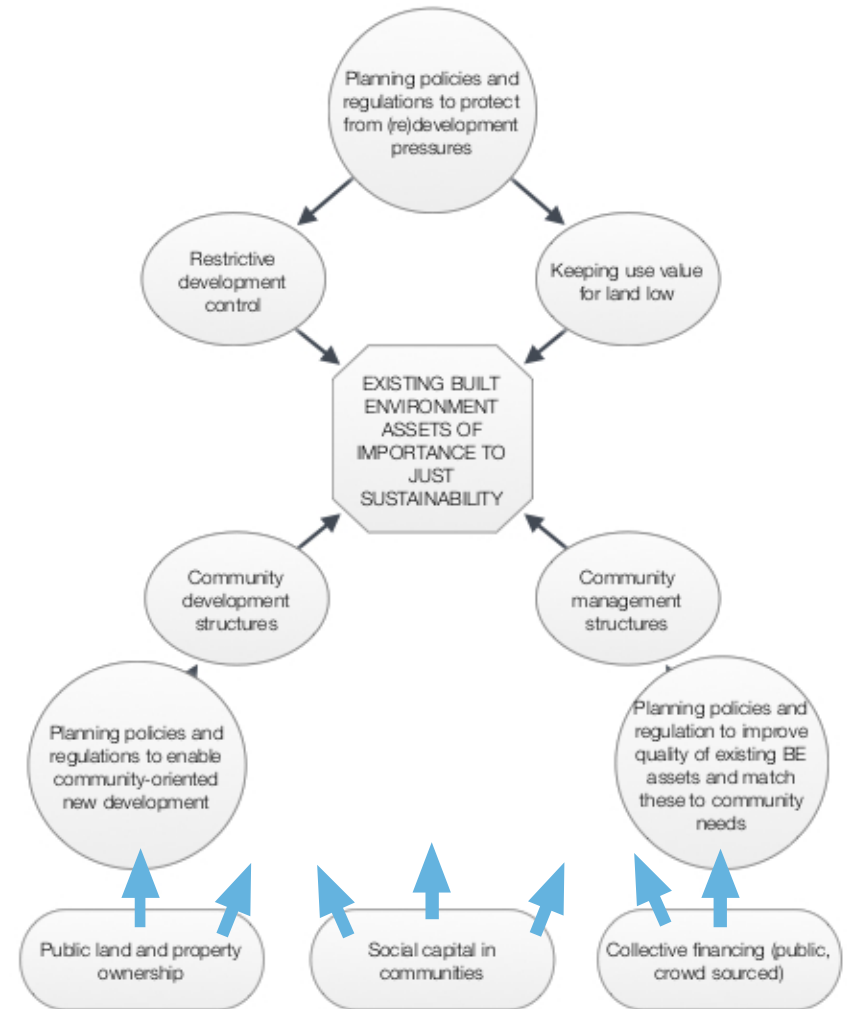


Figure 10: Planning beyond growth-dependence, Source: (Rydin 2013)

- It is not addressing major social inequalities and environmental injustices.
- It is not always supporting the well-being agenda so as to challenge the dominance of the pursuit of economic growth

- It is not enabling natural resources and ecosystem services to be sufficiently stewarded, promoting continued exploitation (Rydin 2013: 188).

Reviewing figure 9, Planning beyond growth-dependence, one can see that the process of planning starts both at the top-down and bottom-up. Overall policies and regulations protect specific areas or districts, using the alternative planning approach. Local assets, such as social capital, collective funding and public ownership are driving force behind local planning. Operating by the top-down policies, key criteria for the sustainable local development can be found and acted upon. This may provide a powerful tool in selected districts where economic, social or environmental criteria may not be met by the growth-dependent planning model.



Figure 11: Pasona HQ Source: (Konodesign 2014)

## 4.2 Today's existing vertical farms

While the idea of the vertical farm has surfaced several times during the twentieth century, it is just these last 15 years that it has started taking a hold. Now there are many planned projects and much more detailed work being done.

According to Despommier (2011) "Several vertical farms were erected between 2010 and 2011. The first examples are all prototypes and are in Japan, Korea, Holland and England. I know of at least two more in the planning and fund-raising stages. Both of these are in the United States." (Despommier 2011: 269)

We should not forget that this idea has only recently been presented. But it is already being implemented in various places around the world. As Despommier states:



Figure 12: Pasona: Rice



Figure 13: Pasona: Salad

"It is owned (Seoul vertical farm) and operated by the Korean government, and the building's supervisor, Dr. Min, informed me during my visit that the project was begun as the direct result of

learning about the concept of the vertical farm at the 2008 Seoul Digital Forum, at which I spoke.” (Despommier 2011: 269)

Singapore has recently opened the worlds first commercial vertical farm according to Dvorsky (2012) “Developed by Sky Greens Farms, the vertical farm consists of 120 aluminum towers that extend over 9 meters (30 feet) in height. In total, the vertical farm is able to produce vegetables at a rate 0.5 tons per day.” (Dvorsky 2012)

It is commercially viable and helps alleviate local demand. Already they are looking to expand this venture with a quadrupling of their output to 2 tons of produce each day.

This is stated in the website of Inside Urban Green (2013): “A local inventor in 2011 came up with a way, in landscape S’pore, to increase the supply of leafy vegetables. He came with a solution to vegetable farming yield five times more produce than it normally can with the same amount of land.” (Inside Urban Green 2013)

Singapore is a country with only 0.5 percent of total land area assigned to agriculture. This is not enough to produce food for the whole population. Therefore, they have to import about 97 percent of their food, creating an issue when it comes to food safety. Singapore wishes, due to the issues of food safety and the urge to be more self sufficient, to produce its own food within the city limits.

According to my interview with Dickson Despommier Japan now has around 300 to 400 vertical farms. It is interesting that Japan is producing much of its own food within city limits. The Fukushima nuclear disaster in 2011 cost many people their lives and contaminated the agricultural lands with radio activity. The

government set in place an evacuation process, and “got behind this indoor growing system movement with special incentives for those who were willing to take the chance to open up an indoor farm.” (Despommier 2014)

Urban Farm at Pasona Tokyo Headquarters is a nine story high, 215,000 square foot corporate office building for a Japanese recruitment company, Pasona Group, located in downtown Tokyo. It is a major renovation project consisting of a double skinned green facade, offices, an auditorium, cafeterias, a rooftop garden and most notably, urban farming facilities integrated within the building. The green space totals over 43,000 square feet with 200 species including fruits, vegetables and rice that are harvested, prepared and served at the cafeterias within the building. It is the largest and most direct farm-to-table of its kind ever realized inside an office building in Japan (Konodesigns 2014).

Using both hydroponic and soil based farming, crops and office workers share a common space. For example, tomato vines are suspended above conference tables, lemon and passion fruit trees are used as partitions for meeting spaces, salad leaves are grown inside seminar rooms and bean sprouts are grown under benches. The main lobby also features a rice paddy and a broccoli field. These crops are equipped with HEFL, fluorescent and LED lamps and an automatic irrigation system. An intelligent climate control monitors humidity, temperature and breeze to balance human comfort during office hours and optimize crop growth during after hours. This maximizes crop yield and annual harvests. Seasonal flowers and orange trees are planted on the balconies between the double skinned facade, partially relying on natural exterior climate to showcase changing of leaves and colors to the exterior facade. All plants are maintained and

harvested by Pasona employees with the help of an agricultural specialist (Konodesigns 2014).

## 4.2 Critique and discussion

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### 4.2.1 Challenges in urban agriculture and vertical farming

The difference of urban agriculture and vertical farms lays in that vertical farming is part of urban agriculture, but is in itself primarily a structure for the industrial production of food. Urban agriculture on the other hand can encompass a wider range of activities of which not all of them necessarily aims at community or city-scale food supply. For instance, transition aims at strengthening the local community and includes urban agriculture for primarily social benefits.

There are several issues concerning urban agriculture. Primarily they deal with food production and end-product.

#### **Productional challenges in urban agriculture:**

- Pollution
- Space
- Capacity

Various and diverse visions of inner-city agriculture and green-structure exist. These may include open/closed-systems (i.e. terraces/greenhouses), public space utilization, buffer-zone green structure (i.e. between roads and pedestrian lanes), terraces, roof-top utilization wall coverage and more. In cases where there is food production of any kind and an open air

system, there is the issue of pollution and health. It is not hard to imagine how dirty run-off from traffic along with air pollution may contaminate inner-city food. This does not exclude green structure in general, but it does exclude open systems from contributing to food production in larger and/or polluted cities.

In addition there is the linked issues of space and capacity. Often the property value of inner-city areas are significantly higher than in rural areas, which is also apparent in Oslo. This means that any green-structure or food production scheme may have to compete against other purposes which generate more money per area. This has also been an issue for Japanese urban farmers, where many have sold off their agricultural properties at high prices. This does not prevent the potential of public spaces and public properties and small periphery areas from having green structure.

#### **Non-productional advantages of urban green structure:**

Also, I do not find any disadvantages to implementing green roofs for every city structure that does not otherwise require a special roof configuration. Roofs and roof terraces is a much underutilized area and is more often than not roughly equal in area to the building footprint, thus providing large quantities of new inner-city area. It can help with climate control, by capturing sunlight, recreation/natural connection, air quality and help prevent flooding by capturing rainwater.

This does not, however, provide enough area to produce most of the food for the inhabitants of the city. Additionally, the degree of food supply coverage will drop as the city (and its buildings) grow in size and especially height. In other words, roof areas should probably be put to better use, but is largely inefficient in terms of general food production and supply.

**Vertical farming challenges:**

An important aspect here are conceptual issues relating to how people perceive vertical farming. Many have not even heard about it, and few know more than having just heard about it. This gives way to assumptions and misconceptions. Often, there are assumptions about scale and technology which are largely detrimental for constructive debate. The lack of awareness and the fact that we haven't implemented vertical farming to any significant degree seems to lend strength to perceptions of hugely complex and large structures with cutting-edge and expensive experimental technology.

While a vertical farm may be of this kind, there is, as discussed in this thesis, no solid standard for how a vertical farm structure should be. The criterium here is first and foremost the vertical implementation, be it a shelf or a hundred-story skyscraper or anything in-between. Additionally, the technology for growing is already available through greenhouse technologies. The trick here is to combine common technologies to create synergies and efficiency boosts. The complexity is decided by the planner, developer and owners. It is these synergies that may help vertical farming to reach its full potential as a tool in sustainable densification.

Concerning vertical farming (and urban agriculture) in a planning context there are challenges and potential areas of improvement. As mentioned earlier this concerns largely standardizations and planning policy which are not adapted to the concept of urban or vertical farming. Policy and building requirements put restraints on building practice in cities, as well it should, but these limitations will also often conflict with vertical farming purposes in a manner which probably was not intended when the specific law or regulation were laid down. An example of this, also mentioned earlier can be found in the case of Plantagon regarding their plan

for Linköping. Standards are also very much non-existent which puts additional stress and weight on potential developers to figure out all the details themselves instead of leaning on pre-defined specifications, which increases risks and potentially reduces investments. Standardization is another focus area of Plantagon.

In addition there are challenges in maximizing output and recycling, which can be further researched and improved. There are no technical show-stoppers, but there are many different types of technologies working in concert. The challenge here lies in arranging systems for maximum efficiency and improving upon existing technologies, for example LED lighting, automation techniques and renewable energies.

Technological challenges, examples:

- Maximum re-use and recycling
- Effectiveness of lighting
- Energy consumption and maintenance
- Industrial synergies and symbiosis
- Automation

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#### 4.2.2 Discussion

As stated earlier the Norwegian discourse of densification were centered on the goal of preserving arable land and high-yield soil. This goal is mostly centered on the possibility and opportunity for food production, not the production and its methods themselves.

Perhaps vertical farming can be that added dimension to the debate. I do not wish to exclude traditional farming, and cannot



see that it is necessary to replace all Norwegian food production. I do, however, see little reason to expand when we have more efficient means. It can be implemented to supplement and to provide products that are otherwise imported or in low supply. I additionally do not wish to exclude other forms of urban agriculture and green structure, for example roof gardens or green roofs.

Earlier I discussed Norwegian food imports, which are a deal higher than its exports and this gap is increasing. Compared to many countries Norway has a decent degree of self-sufficiency, but there are issues of food safety and food security due to imported food. Why not use vertical farming as an opportunity to provide fresh food, food security and jobs?

Some could argue that importing food could be cheaper, but this is a matter of debate. What is the determining factor food safety and self sufficiency or cheap food?

There are now several successful vertical farming businesses in various parts of the world. Many of these, however, are smaller in scope than what for example Plantagon is envisioning, both in terms of size, capacity and technological implementation. In the United States several projects have been done by transforming old buildings, for example Farmed Here in Illinois. It is therefore reasonable to assume that there is a possibility of economic gain from vertical farming.

## 5 Plantagon

Below follows a highlight of Plantagon and their attempt at constructing a vertical farm in Linköping.

### 5.1 Highlighting Plantagon

I have chosen to give extra attention to Plantagon in my thesis. This is because I find that their partnership with SWECO in Linköping closely resembles possible scenarios in Norway and Oslo. This is in terms of government policies and building codes, both nationally and local, namely political, and cultural, environmental, social and economical factors. For natural and historic reasons the similarities between Norwegian planning and its context closely resembles that of Swedish planning and its context, where Norwegian planning theory has been historically influenced by Swedish theory. That is to say they are not, of course, identical, but may help provide the most similar reference to a Norwegian project. Cultural factors, in its widest sense, and physical attributes of the environment, climate and landscape are more similar than in comparison with for example: Singapore, Japan or the United States.

By providing this reference project I also wish to highlight the different aspects of the Linköping-project which may provide similar challenges here in Norway and provide comments about possible solutions. Additionally I wish to give an overview of how such a project can be carried through and implemented.

### 5.2 Short presentation

Here I will provide a summary of who and what Plantagon is, who their relevant partners are, and their goals and methods.

## 5.2.1 Who is Plantagon?

“In our organization model, a hybrid between a company and a non-profit organization, we combine commercial and value based driving forces in one organization, we call this hybrid the companization.” (Plantagon 2014)

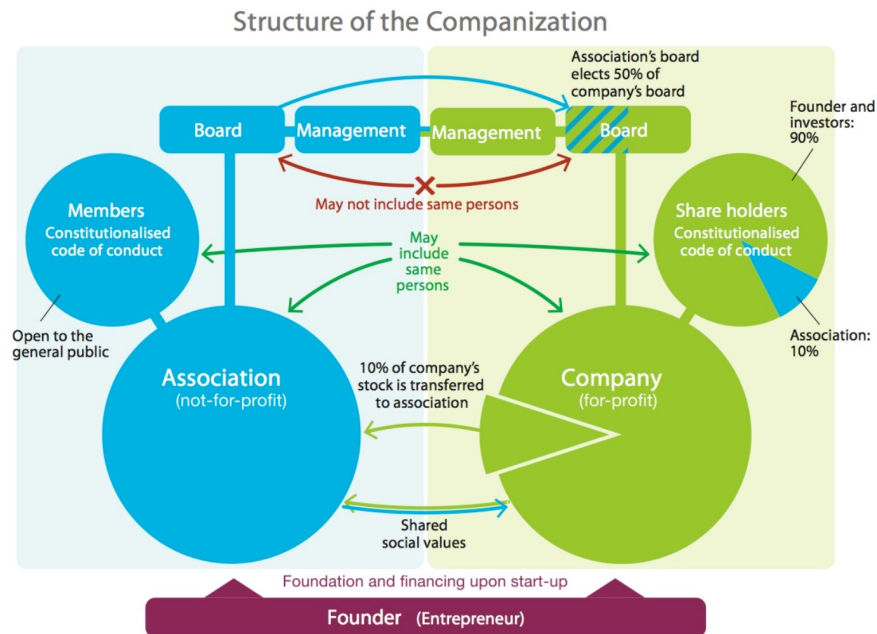


Figure 14: Structure of the companization Source: (Plantagon 2014)

Plantagon was founded, and is owned, by The Onondaga Nation and Swecorp Citizenship Stockholm AB, represented by Oren R. Lyons and Hans Hassle, respectively. Together they provided a statement outlining their aim in creating this new organizational form for Plantagon:

Economics has played a major role in creating this situation, and will continue to determine future directions. Political power is fighting to regain influence, but we already know the economy, or at least the major part of it, is driven by corporations. Today, many of the world’s largest economies are corporations, not nation states. This situation confers enormous responsibility on the owners, their boards and their managers, a responsibility that comes with being the dominant institution on the planet.” (Plantagon.com)

By forming a two-bodied entity, with identical values connecting them and the association given pre-eminence, they hope to harness the productivity of a company with the responsibility of a non-profit organization. Both implement The UN Global Compact and The Earth Charter in their Articles of Association and founding documents to review their compliance at each Annual General Meeting.

They now have offices in Onondaga, New York, New Dehli, Singapore and their legal domicile and office in Stockholm.

From their homepage I have included a small excerpt which I find describes their activities best:

The object of the company’s activity is development, sales and franchising of new technology for production of cultivated food, selling cultivated food directly to consumers, selling cultivated food directly to industry, development of technologies for production of medicine, development of technologies for production of pesticide, development of technologies for production of paper pulp, consulting on strategy, management, education, communication, Public Relations, Public Affairs, research projects, risk projects and with that compatible activity (Plantagon 2014).

Many of the activities of Plantagon is in the realm of planning/development and other means of facilitating the establishment, production and distribution of vertical farm crops. It is through their partner SWECO that much of the technical research and engineering is being made. (see appendix for Plantagon in details)

## 5.3 Linköping

*“Actually we have not started building in Linköping. The reason for that is the permits to build... We started (the project) two years ago. We have bought the land and there is a ceremony that you can see on our webpage where our Chief executive officer Hans Hasle standing with the mayor of the Linköping and taking the first ground-breaking ceremony and I think that was two years ago. It is frustrating that it takes so long.”*

*- Joakim Ernback, Technical Manager, Plantagon*

This is an excerpt from the interview I had with Ernback. In it he explains how objections from the local inhabitants and the Swedish Environment Party is likely to halt or slow the project. Legitimate concerns have been raised in relation to a nearby wetland bird breeding and feeding ground. Due to the known phenomena of birds flying into glass surfaces there are concerns for the safety of these birds. This is also underlined in the plan for Linköping. Here they highlight the fact that around 100 million birds are considered to die because of this phenomena every year, in the US. In addition, the wetlands has been deemed vulnerable and is under protection.

A very important aspect of the Plantagon vertical farm is its glass exterior which covers the building, at the very least on the side

facing the sun. From the detailed plan of the Plantagon prototype in Linköping:

- The south-facing facade of the greenhouse and larger parts of the building towards the east and west will consist of a transparent shell that allows view and sight from the inside out and vice versa.
- Facades of glass, EFTE (ethylen-tetrafulor-ethylen) or other visually similar materials can be chosen

Several examples of guidelines and possible solutions are offered\_

- Bird-safe Building Guidelines (New York City Audobon)
- Vogelfreundliches Bauen mit Glas und Licht (Schweizerische Vogelwarte, Sempach)
- Bird-Friendly Building Design (American Bird Conservancy)

This may also have relevancy towards a similar building on Breivoll, as the area have the Alna river and adjoining wetlands in the valley floor. This means that solutions and measures which may help to reduce or remove bird deaths is necessary to integrate into a final solution. The focus of this thesis deals in sustainability, which of course encompasses natural ecosystems and their inhabitants.

*“The environmental party in Sweden doesn’t like what we are doing, because they mean that Linköping is a farm-land city and we should not bring this fancy thing to this city. They are legally allowed to say no and they are going to use this.”*

*- Joakim Ernback, Technical Manager, Plantagon*

The second objection concerns the aesthetic and cultural. There are people in Linköping who does not want this structure here because it contrasts severely to the picturesque farmland surroundings. This point is less valid for a project in central Oslo.

There are already notable modernistic “features” in downtown Oslo, namely the Opera and the neighboring “Bar Code” block. In addition, Breivoll itself has a thoroughly light-medium industry and service area profile. Meaning, that most new buildings will serve as generally more appealing than existing features. There are few preservational issues concerning existing building mass, with a few exceptions. While there is always a good chance of debate and disagreements concerning larger building projects in the Norwegian capital (Lambda/Munch and Bar Code Project), it is likely to be less controversial and project blocking as the situation in Linköping.

Another very important issue, in regard to the planned construction at Linköping, concerns building regulations.

“... one major obstacle is that you can grow food on the roof tops, but the building code says that the building could only be a certain height, which makes it impossible to utilize the surface on the roof...Certain areas i.e. are banned for the production of food, this is the obstacle we are meeting in Linköping, the code for that area says that one cannot have a restaurant, or you can sell your products but you cannot have a shopping area. So we have been thinking about creating a small farmers market, and contact the local farmers to bring their products to our facility and sell them together with our vegetables. But since the building codes are so strict, this is not allowed.”

- Joakim Ernback, Technical Manager, Plantagon

This is perhaps the primary concern for Plantagon. This project is a prototype and research center for further development and testing of their vertical greenhouse concept. This means that much of its floor space is going to be of mixed-use, and not strictly for farming purposes. They are going to rely on income from the renting out of office space for running this facility. It is

mainly in connection with the research center that the growth of crops are going to take place, but already in this limited scope they are running into issues which limit the potentials of their project.

In addition they seek to create a new labeling system to help identify food stuffs which are produced in a vertical farm.

Current Certifications for organic labeling is not a possibility for Plantagon since the prerequisites for certification are not congruent with sustainable farming within a resilient urban food system of industrial scale. Branding of Plantagon systems will instead focus on added values and the fact that products are produced extremely locally with Best Available Practice in environmental terms (Plantagon 2014).

## 5.4 Standardization, policy

*“When you speak about city planning today, food production is rarely taken into consideration, and we are trying to change that. Yesterday we appeared in the European parliament and we spoke in front of the head of agriculture in the European parliament. So we are trying to bring food production up in the agenda.”*

- Joakim Ernback, Technical Manager, Plantagon

The standardization institute in Sweden has contacted Plantagon to write new standards about how food is going to be produced inside cities. It is very much the aim of Plantagon to create debate and awareness around urban and vertical farming and food production in general. They are doing so by also trying to implement standards which may help regulate and determine what constitutes urban farming and how it should be

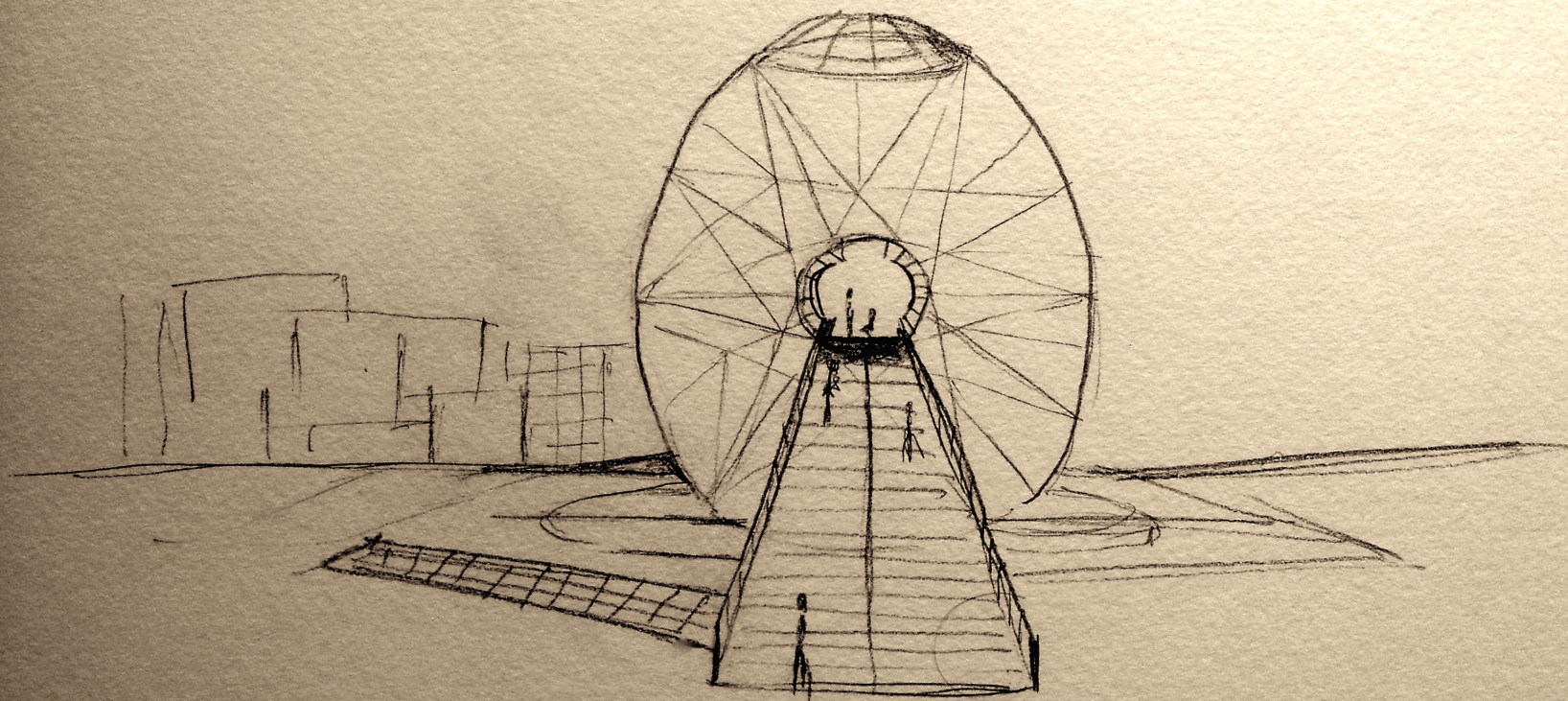
implemented. We find that Plantagon is already trying to implement the necessary policy changes in Sweden and even the EU. It is the strategy of Plantagon to use branding to strengthen their position and ideas. Therefore it is very important that they can strengthen their products and brand with appropriate and informative labels highlighting its eco-friendly production. At the same time it is of vital importance for them to bring about changes in planning and political practice to facilitate their concept and prototype in Linköping. For them to attract investors they need to finish their prototype to prove its viability.

This is one of the better examples of political and practical issues that may arise with the advent of vertical farming in Norway.



CHAPTER 3

**Feasibility**  
**— study:**  
Groruddalen/  
Breivoll area





### 3. Feasibility study: Groruddalen

#### 1 Purpose

This feasibility study is an evaluation and analysis of the potential for vertical farms in Groruddalen; Alna/Breivoll and the analysis is based on earlier investigations and underlying plans and guidelines.

The study's aim is to objectively and rationally uncover the strengths and weaknesses of Groruddalen:Breivoll/Alna area and it fits into the Program area 3b in Groruddals-initiative (I will be discussing this later).

In 2012 and 2013 I had two courses (*Architecture and Urban Design in Urban Development LAA350 and Projects Initiation and Implementation in Urban Development APL350*) where we studied Groruddalen: Alna/Breivoll.

*"Energy effective housing models"* is the title for the project me and four other students handed in *LAA350* taught by Professor Elin Børrud. The main aims of that study were to offer:

- Energy effective housing models
- Recreational areas
- Improvement of public transport
- Availability and accessibility

This study is draws on these earlier projects, but it seeks to analyze the potentials for urban agriculture/vertical farms.

Groruddalen is an interesting area to implement vertical farms considering The Groruddals-initiative and its goal to improve

living quality and conditions. Breivoll in the Alna district is located at the entrance of Groruddalen (south in Groruddalen) and is one of the focus areas in this initiative.

Breivoll is also situated between Alnabru terminal and Bryn. It is a smaller area mostly committed to industrial and heavy logistic purposes. As characteristics for this area are the existing heavy infrastructure and commercial/industry suburban buildings that are placed mostly facing the highway with big parking spaces.

This area is challenging, in terms of development and planning, but this is also why it has a lot of potential.

Breivoll/Alna is challenging because of the industrial character, pollution, lack of integrated public transport and challenging cross-links issues because of the demanding landscape, thus few interested private investors who could help speed up the development. On the other hand, the Alna river and surrounding green provides ample opportunity for recreation for nearby residents if proper connections and access is provided and commercial and industrial properties are transformed or removed.

Considering how big Groruddalen is in total, and how many interesting issues there are to be solved, I see also that there is maneuverability. This is one of my main motives to study one of the smaller parts of this area for its potential for further development and vertical farms.

My second motive is to introduce a new aspect to the initiative. The relative openness and long-term vision for this area provides ample and flexible opportunity to introduce new solutions.

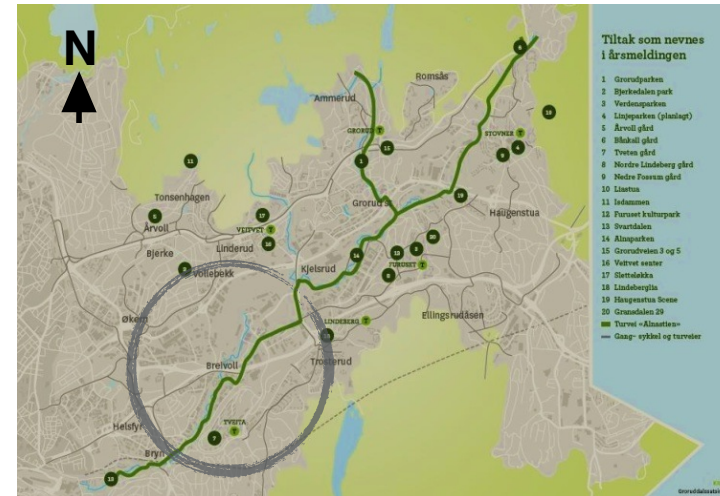
Vertical farming can help bring about the lift and change of the area as envisioned while providing groundwork for a new way to build and support cities.

Another aspect is the lack of debate about food production when it comes to Groruddals-initiative. Presenting another study introducing local food production in this initiative could awaken the interest for other investors, at the least public actors may consider this for further urban development.

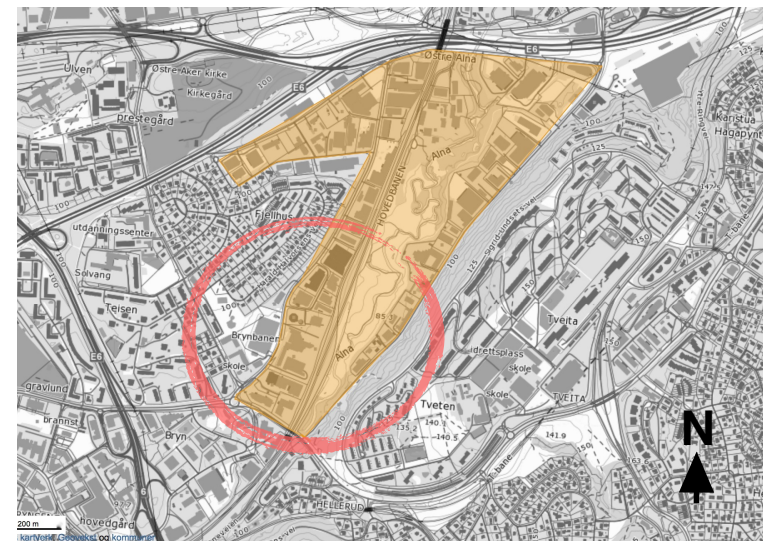
A vertical farm that also offers a research center in this district could make this area more attractive and strengthen the identity of this area.

## 1.1 Location & situation

Breivoll/Alna is an area dominated by commercial functions including retail, warehouse and gas stations. It is located in the southern part of Groruddalen and has the main goods terminal in Oslo. In addition, Tveita is a residential area east of Breivoll and is bounded with forests and steep terrain. A bigger service-retail area is on north-east Breivoll and is divided by E6-highway into an upper and lower part. There are several car-based commercial buildings in the lower part of this area. Alna Center is on the upper side. There are also several furniture stores, kiosks and gas stations in this area (Grimstad, et al. 2012).



Map 4: Groruddals-initiative Source: Municipality of Oslo



Map 5: Breivoll; Southern Breivoll  
Source: Google maps/Municipality of Oslo

## 1.2 Landscape and the blue-green structure

Alna valley nature-park is located on the west side of Breivoll/Alna, where the Alna-river is open to meander through a beach swamp area with Arrow trees and Alder-woods. Trosterud creek emerges on the east before disappearing into a culvert and it comes out in the southern outskirts of this area (Grimstad, et. al 2012).

Ole Devik-road frame the area to the west, and works as a barrier to the east. In the same manner as Alna-river and railway forms a barrier to the east. In the south and Tveten-road and the bridge over the Tveita a natural transition forms. There are lines of site from several locations on southern Breivoll to the hillside

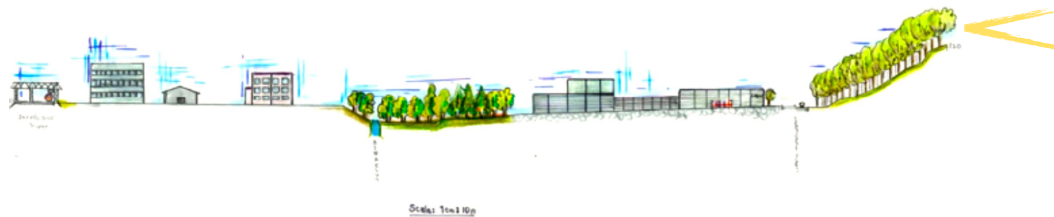


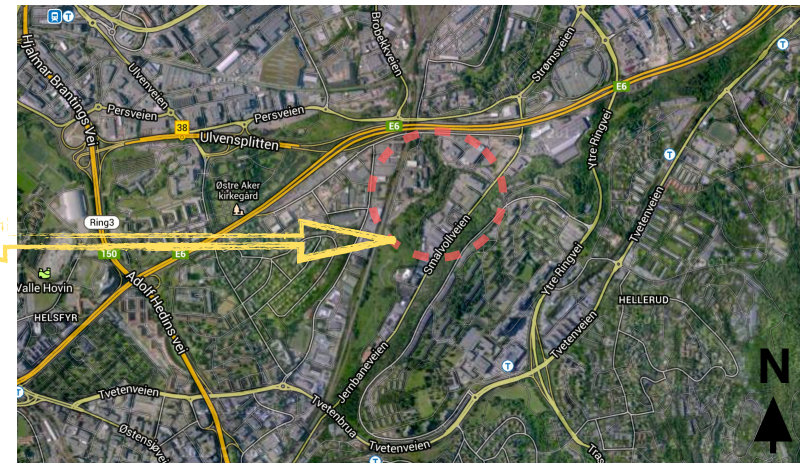
Figure 15 : Breivoll; North-east, source: Author

on Tveita residential area, but the low-incline slope with the trees and Tveita buildings on the top can block the vision.

An underpass, bridge or a combination of these two can provide better access to the great natural resources and recreation area, but this is dependent on good solutions considering noise issues and lack of good cross-links. This in turn can increase the availability of bordering areas to the east.

## 1.4 Infrastructure

This area is dominated by gray-infrastructure like asphalt and cement. Most of the plots are utilized to stock, bulky trading areas and industry that are attached to large paved surfaces. In addition the high voltage wire which crosses this area on the North side makes parts of this area uninhabitable.



Map 6 : Main infrastructure, source: Statens kartverk: Kart i Skolen

## 1.4 Pollution

Breivoll is surrounded by railway and E6-highway and Strømsveien. This gives the area major challenges in terms of pollution.

Much of Breivoll is polluted today, the biggest and the most powerful portion of pollution can be found close to the old landfill



“Stubberudfeltet”. There are also other less polluted areas around Alna watercourse. A prerequisite for the development of this area should be an environmental clean up (Høgestøl, et al. 2013).

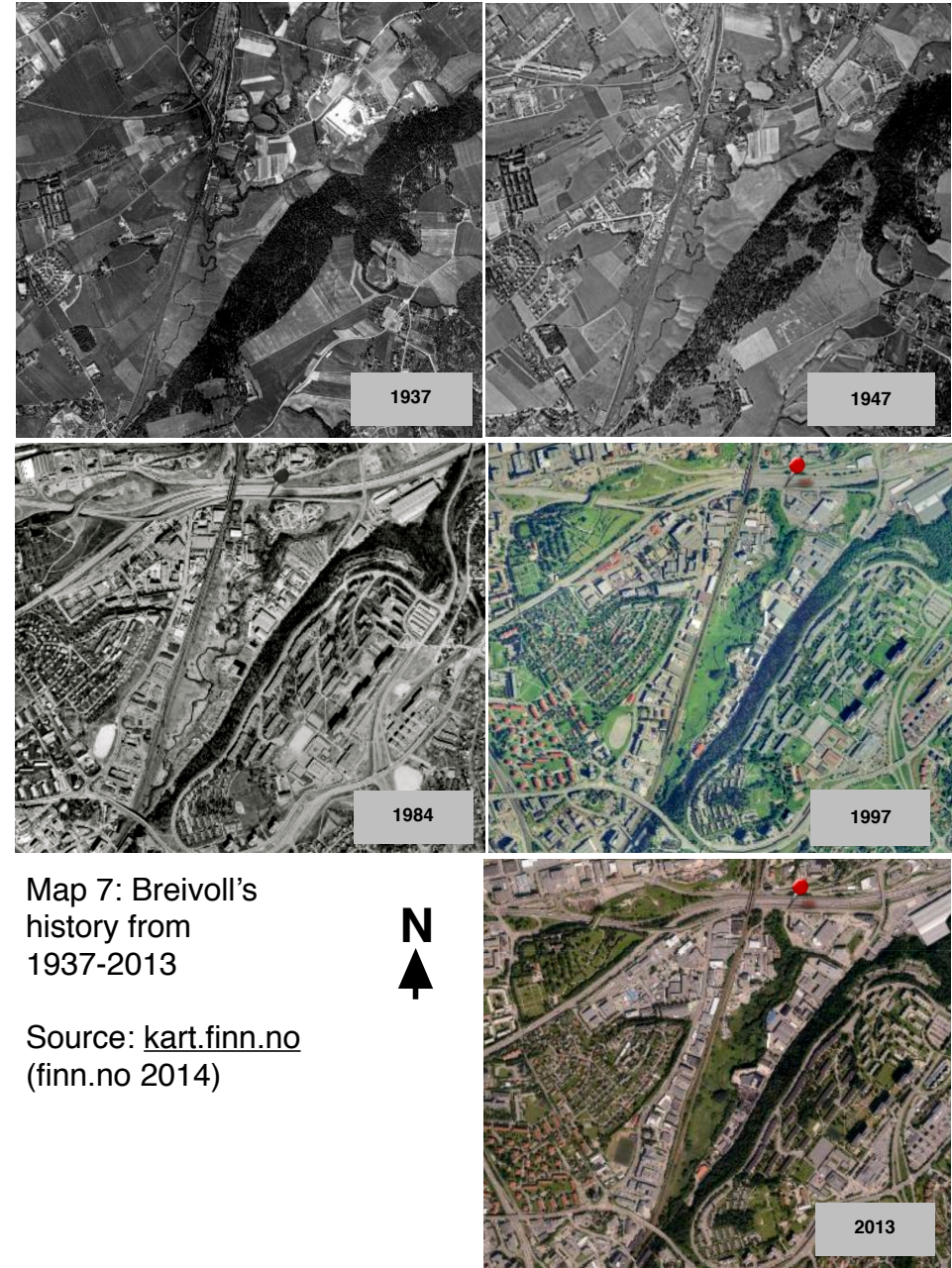
## 1.5 Noise

The area is exposed to noise along the north side because of the E6-highway, where the noise level is between 78-80 dB. The east side is also exposed to noise from Smalvollveien, where the noise level is between 70-75 dB. The south side of this area has a lower noise level. This is due to the longer distance from the main road and the existing large storage buildings serving as noise barriers (Høgestøl, et al. 2013).

## 1.6 History

Groruddalen has gone through several phases of change during history. Until the beginning of the industrialization this area was dominated by agricultural land (Grimstad, et al. 2012). When the railway was established in 1850s the whole landscape changed character. It gave new possibilities such as brick production, chemical industry and lumber, that became new focus areas. This affected this area in the decades until the end of that century (Høgestøl, et al. 2013).

In 1918 Alna goods terminal and later several large housing fields were established. The biggest changes have occurred after WWII when several large municipal housing projects and the development of the subway systems were launched. The valley went from rural areas to commercial and transport area. In



recent years, the shift from manufacturing to trade has constituted the biggest change.

Breivoll is named after the Breivoll farm located relatively centrally in the lower part of Groruddalen facing Økern and Bryn. It stands between Hellerudsletta Skrenten and Alna-river. The name describes Breivoll area's topography considered to have a widespread landscape (Grimstad, et al. 2012).

In the early 1900s existing allotments in Teisen-road were allocated to new villas, one can still find some of these houses in the area.

In 1930s there was a construction-stop, but during the post-war period Oslo grew and the housing need increased. OBOS began building Teisen and the first residents moved in, in 1950. Development of E6-highway led to demolishment of several old houses, where some of the old Teisen disappeared (Grimstad, et. al 2012).

This area is today characterized by railway activities, major road infrastructure, trade and industry. Breivoll has long been influenced by Alnabru terminal and one can find a combination of green-structure and industry in this area.

## 1.7 Demography

Oslo is a fast growing city with 634,463 inhabitants in 2014 (SSB 2014). According to the UN, Oslo is the city that has grown the most in Europe since 2006. According to Nadim (2008) here lives some of the richest and poorest people in Norway, where the difference between the east and the west side of the city is reflected in inequality in income, life expectancy and living conditions (Nadim 2008).

Based on Dyb *et. al* (2011) Groruddalen is an area that has a population with relatively poorer living conditions than the average population in Oslo. This applies to areas such as income, health, employment and education which highlight the work and programs for improving the living conditions in this area. It is important to note that this district scores lower in the socio-economic variables (Dyb, et al. 2011).

This area does score well when it comes to social well-being and good community relations, with matching conditions compared to the rest of Oslo. The residents in this area are mostly plagued by noise and pollution. The crime level is not higher than the rest of Oslo. In Groruddalen in general most of the residents have good social relationships and contact with other residents. Almost eight of ten seem to be satisfied with the social interactions in the neighborhood.

## 1.8 Overall plans

Groruddalen with the extension to Lillestrøm via Lorenskog is typologically and geographically the most central transformation and densification area in the region. This area also has the heaviest transport corridor in the whole country.

Overall objectives for Groruddalen are environmental improvements and better utilization of space. A new road system is also determined and plans show merchandising and service functions with regard to localization and development, though with certain limitations. The same applies to social squares and meeting places where main objective is to facilitate the establishment of new and further development of existing venues (Regjeringen 2014).

Groruddals-initiative (Groruddalssatsingen) is a 10-year partnership between the Norwegian government and the municipality of Oslo to improve the environment and living conditions in Groruddalen.

According to the Norwegian government's official website (Regjeringen 2014) the work is organized in the following four program areas:

**I. Environmentally friendly transport**

**II. Alna, green-structure, sports and cultural**

**III. Housing, city and local development**

*Program area 3a*—Housing, town and local development (Area lift)

*Program area 3b*— Area planning and urban Development

Responsible groups: Municipality of Oslo by the Planning and Building Services.

The Norwegian government and the ministry of Modernization have the responsibility for the program 3a. In 2012 they granted 40 million NOK for this program. Housing Bank "Husbanken" administers the state's funds. Cooper, companies, cooperatives, associations and NGOs can also apply for grants to improve the living conditions.

**IV. Early life, education, livelihood, cultural activities and inclusion**

The Groruddals-initiative includes the following districts: Bjerke, Grorud, Stovner and Alna (Breivoll) in Groruddalen. These four districts have a total of over 130,000 inhabitants. This represents about a fifth of the population of Oslo. Many of the valley's areas

are changing rapidly, both in terms of demographics, traffic and residential areas. The rapid development brings with it positive changes, but also several changes that need to be solved.

According to the information on the Norwegian government's official website: the state, represented by the Municipal and Modernization department, the Ministry of Transport, and Ministry of Children, Equality and Social Inclusion are all cooperating with the municipality of Oslo in the Groruddal-initiative. The initiative started in 2007 and lasts until 2016. Every year the Norwegian Government, along with the municipality of Oslo, grant at least 50 million NOK for this effort. During these 10 years the government will invest over a billion NOK in Groruddalen in total (Regjeringen 2014)(Translated by author).

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1.8 1 Plans for Breivoll/-Alnabru area

Based on a planning program from the municipality of Oslo, the purpose of the planning program specifically for Breivoll/-Alnabru area is:

"To facilitate nodes and urban transformation in line with 2008 Municipal plan — Oslo 2025. This area is very complex. The planning task is to have an integrated land use and transport that requires long-term, coordinated efforts between the Norwegian government, local government and private actors. Systematic clarification and determination of future overall infrastructure (transport and road system) is essential for the development of Breivoll to the potential hub and later to clarify the possibility of an urban transformation." (de Vibe & Nyrnes 2010)(translated by author)





Figure 16: Visions for Breivoll  
 Source: Municipality of Oslo: Groruddalsenheten (2012)

Further in the planning program for Breivoll/Alnabru area prepared by the municipality of Oslo (2010) it is stated: “A traffic safe and efficient road system, along with a good public transport adapted to the future urban development is very important for further development of this area.” (de Vibe & Nyrnes 2010) (translated by author) The proposal involves new roads and highway access ramps to the E6 highway.

There is a special comment from the City Council’s case presentation on the above mentioned measures, which is relevant for the planning program for this area: “The City Council is unsure whether the proposed road connection to E6 highway in Alnabru is the most optimal solution. The municipality of Oslo and the Norwegian Public Roads Administration will therefore investigate this direct link between Alnabru terminal and E6 highway to relieve the including Strømveien and Tettgrenda significantly for traffic and environmental impact (de Vibe, et al. 2012)(translated by author).

**Principal plan for the public space on Breivoll (de Vibe et. al 2012):**

As it is show in the diagram above the vision is for a sustainable, vibrant and efficient area that engages people. Smart and integrated solutions are needed that help bring each part of the area together.

“The vision is of a safe, open and inclusive Breivoll. A place that will be connected with the world, but also with neighboring areas to provide residents with the ability to use the variety that Breivoll offers.” (de Vibe, et. al 2012)(translated by author)

It is further discussed: “While the existing qualities are taken care of and enhanced Breivoll must gain new activities. This may be the development of existing industries or the introduction of new ones. The public spaces will be important venues for these activities and must be attractive.” (de Vibe et. al 2012)(translated by author)

Based on the Principle plan for Breivoll/- Alnabru area: “Environment-friendly and sustainable development is a cornerstone in Breivoll’s development.” (de Vibe, et al. 2012) (translated by author)

It is further explained that: “To achieve the objectives of the vision for the public spaces, it is important that the plan deals with more than just the placement of street spaces and places. It is equally important to fill the rooms with activity; create energy, expectation and attitude for the place. The city is growing not around us, but evolves based on our beliefs and our curiosity.”(de Vibe, et. al 2012)(translated by author)

## 1.9 Summary of issues

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Challenges specifically in Breivoll/-Alnabru area:

- Pollution: noise, air, light and visual
- Landscape: Topology
- Infrastructure: car-oriented infrastructure-design
- Infrastructure barriers by railway and E6-highway
- Buildings: introvert setup and big-box structures
- Characterized as an industrial area
- Limited access to good public spaces
- Cross-links: impossible to get around

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Long term overall plans for this area:

- Transport-/and social hub development

- Improving the infrastructure
- Offering better public transport solutions
- Improving the environment
- Improving the existing green-structure
- Later — offering new housing models

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Opportunities based on the principal plan made by the municipality of Oslo in cooperation with Jan Gehl:

- Waste management businesses
- Varied and dramatic topography which provides great view and overview
- A lot of generously, robust and flexible room for every possible thing
- An exciting and fascinating industrial history with Gresvik bicycle factory, Rodeløkken car workshop Wilh. Lütticher Chemical-plant and “Accordion” that highlights the industrial identity of this area
- Alna watercourse with its rich nature
- Interesting buildings’ related to spatial units

The lists above are some important aspects of this area that are interesting for further examination of the potential for developing vertical farms in this area.

Considering the wish for developing a transport- and social hub in this area placing a multi-functional vertical farm could, in addition to producing local food and connecting the east and west side of this area, contribute to reaching the goal of developing a hub. I will examine and discuss this possibility further in the next section.

## 2 A new vertical farm on Breivoll

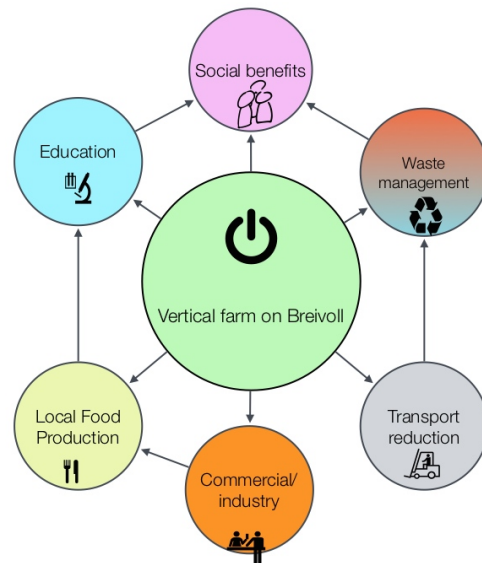


Figure 17: Benefits of vertical farming on Breivoll  
Source: author

The structure I propose to build on Breivoll is a building which can serve several purposes. It is more than a simple production unit and it can fit into the area on several grounds which may include: education, research, recreation, aesthetic/visual, waste

recycling and food production. In order to take the most advantage of the vertical farm it is important to couple it with existing features and plans. This is why I will start this chapter by describing spatial features and connections.

### 2.1 Establishing connections

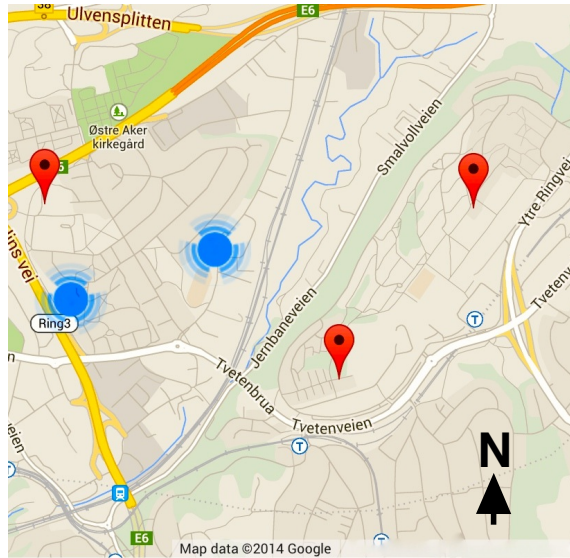
As mentioned earlier the southern part of Breivoll is an industrial area bounded in the east and west by residential area of Tveita (east side) and Fjellhus (west side). There is a big football field next to this area and Ole Deviks-road on the east side.

There are several kindergartens both on the east and west side as well as one on the site itself and 17 schools in the whole district of Alna. In other words there are a lot of activities in different forms in this area.

Looking at the industrial area with its heavy transport being placed between two residential areas, one could estimate the risks for the inhabitants, and it is not promising. This industrial area works as a barrier with many unneeded industry buildings, in an area close to central Oslo. This area needs to be transformed to a safer social hub with a possible urban industry that serves a lot more than producing goods. Considering Alnabru terminal being close by, and Breivoll being closely connected to E6 highway shows the potential for being able to support a connected infrastructure. As well as providing public transport. However, this area would probably need a lot of development on the local infrastructure.

Two issues and possible solutions are offered by the principal plan for Breivoll. Firstly, there must be a bridging of connections on the east and west side of the river and railroad. This can be done by either bridges or tunnels or both.

Secondly, a sufficient number of main streets and pedestrian paths must be identified and provide access and connections to neighboring areas.



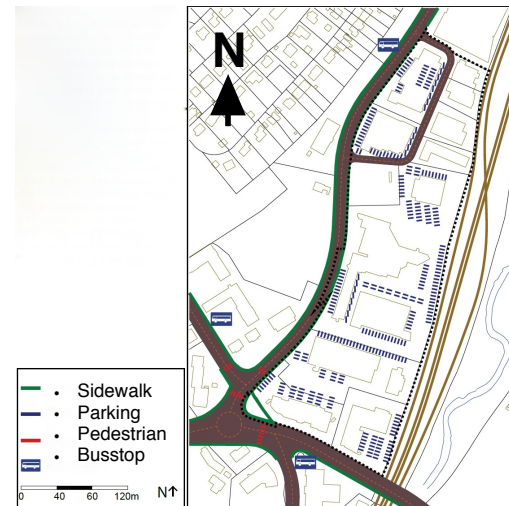
Map 8 : Kindergartens in southern Breivoll  
Source: Google maps and municipality of Olso

Providing sufficient and proper connections in the area itself and to its surroundings is necessary to help establish a social hub. People need access or there will not be people there, simple as that. Dead-ends, single-use areas and bottleneck connections are all part of limiting area use and thoroughfare of the general public. Correcting this will lay the foundation for the establishment of a hub, but it is not in itself sufficient.

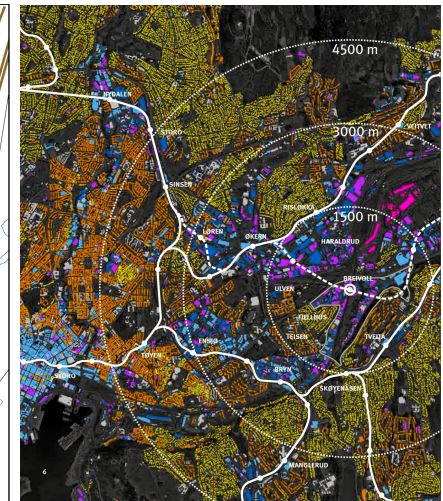
## 2.2 Public transport

Building on the foundation provided by an improved infrastructure there also needs to be a well-functioning public transport system. By the connections to the highway and surrounding areas, both local and express buses are an option. Strategically placed in the Oslo-Lillestørm corridor, Breivoll may easily integrate into existing bus-lines.

The nearby railway also provides ample opportunity to provide enhanced local connections to nearby train stations. This is an



Map 9 : Accessibility  
Source: (Grimstad, et. al 2012)



Map 10: Breivoll's distance to Oslo-centre  
Source: Municipality of Oslo: Groruddalsenheten

important aspect and requires connections for local traffic, but mostly in terms of pedestrian and similar traffic. This requires the aforementioned east-west connection, as well as a connection

from Breivoll to the Alna main area, likely underneath the highway splitting the areas valley in a north and south side.

I find that the local train station at Alna is sufficiently close to the Breivoll area if proper connections are provided, and if there is also a subway connection centrally located. This is another point from the principle program of Breivoll. Three nearby stations provide some opportunity for locals to access the subway, but in hoping to establish a hub, there must necessarily be provided a “high-speed” method of accessing it.

According to a session in a course I am attending in *NGI101x Next Generation Infrastructures* at [www.edx.org](http://www.edx.org)<sup>1</sup> “Infrastructures provide critical services such as the transportation of people and goods, the provision of energy, water and sanitation, and telecommunication and information services. We say critical services, because these infrastructure systems form the very backbone of our society. They create the conditions for livability and economic development”. (EdX 2014)

In this category one can find local train, subway or express bus. The fact there are close-by stations also points to the fact that there are close-by subway lines to which a connection can be established. Express buses, as stated, is a natural connection, but may not provide the same traffic as a subway. It is therefore important to plan for the addition of a subway station to the area.

As a side note, it is interesting to note the relative importance of a subway station to help develop an area. This was one of the triggering factors for attracting private investors and businesses

to Nydalen when it was under development. It was first when the municipality got involved in the building of the new subway line that local business flowed suit and started taking an active and interested role in the local development. This underlines the importance of establishing a subway-link here.

## 2.3 Public spaces

For urban activity and urban life to visibly evolve one also need public spaces in connection with their surroundings. This translates to adapted public spaces open to pedestrians which provide thoroughfare and recreational opportunities in tune with the surrounding landscape and buildings. A public space should encourage gatherings and activities and provide a positive common area for everyone.

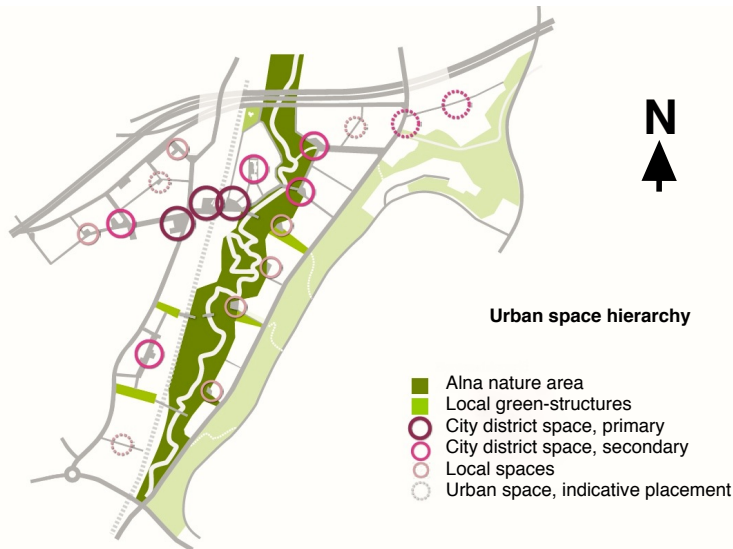
Without proper public spaces there is a good chance that most of daily life activities are moved indoors or to private spaces. So the connections provide the public traffic and the spaces provides opportunity for the traffic to translate into local activity and life.

It is therefore important to identify key connections in the area and in light of this identify key spaces which can help enhance the overall structure and use of the area. The principle program suggests a subway connection on the north side of Breivoll, in the area west of the river, just south of the highway and on the north-east edge of Fjellhus. This area forms a natural crossways and may also serve as a hub as it is provided direct connections from most surrounding areas. Due to the relative ease of access,

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<sup>1</sup> EdX offers interactive online classes and MOOCs from the world’s best universities. Online courses from MITx, HarvardX, BerkeleyX, UTx and many other universities. Topics include biology, business, chemistry, computer science, economics, finance, electronics, engineering, food and nutrition, history, humanities, law, literature, math, medicine, music, philosophy, physics, science, statistics and more. EdX is a non-profit online initiative created by founding partners Harvard and MIT.





Map 11: Urban space hierarchy, principle plan for Breivoll/Alnabru area  
Source: Municipality of Oslo

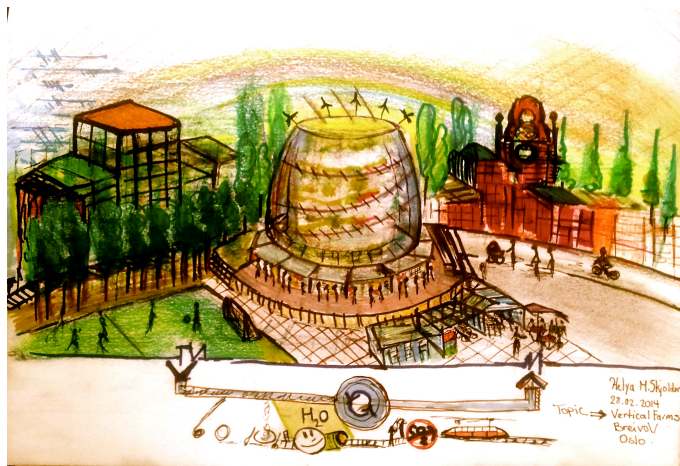


Figure 18: Public spaces: A vertical farm  
Source: Author

with the provided east-west connections, from all surroundings it may be the most efficient location for the subway. In addition to the subway there needs to be one or more main public spaces, as suggested by the principle program.

It is in connection with the proposed east-west links that additional public spaces are suggested at the western side. It is also in connection to these spaces or the main spaces near the subway station that a vertical farm could be built and give the greatest synergetic effects.

## 2.4 Vertical farm: A social hub

The vertical farm may be installed in or adjacent to the blue-green strip and enhance the intentions, a vertical farm would fit here on Breivoll. This building, with a correct placement, can become a local landmark and tie the Breivoll-hub together with other parts of the district and city.

The demography analysis shows that the inhabitants work good as a community, but when it comes to their income level, they score lower than the rest of Oslo. A vertical farm, will also be a good source of local income, by creating many different jobs. The building in itself, being placed next to the park and close to the planned transport/social-hub, can make an attraction area. School tours might be possible to arrange for the students to observe the controlled ecosystem that produces their food. The building can also work as a research center.

It is natural to locate shops and restaurants in close proximity and around the vertical farm. They would be able to get fresh crops every day delivered right on the doorstep. Restaurants and shops would be filled with people waiting for the train or bus,



those who want to get a warm coffee after a walk in the park or



Figure 19: Social hub: Green and vital Breivoll Source: Author

two friends meeting over a cup of coffee. It would serve as a meeting place and all inhabitants would benefit from this.

Knowing that the restaurants serve locally produced fresh food, would gather a lot of people. Mathallen in Vulkan, an area in central Oslo along the Aker river, is an interesting example:

This is stated on their website: “The Food Hall in Oslo is modeled on the European food halls. Here you will find special shops, cafes and eateries. In addition, the Food Hall also offers a variety of food-related activities such as conferences, courses, exhibitions and competitions.” (Mathallen Oslo 2014)

And further it is explained: “Participants in the Food Hall offer



Figure 20: Social hub: Mathallen in Oslo Source: Mathallen Oslo

food and beverage of high quality, with emphasis on the uniqueness. Here is a combination of meat, fish, vegetables, baked goods and coffee-everything from the best manufacturers and distributors in Norway, but also imported products. Here, both consumers and chefs find inspiration, share knowledge and experiences. Food Hall Oslo will be a center for Norwegian food culture - an enjoyment of good food!” (Mathallen Oslo 2014) (translated by author)

This place is always filled with a lot of people. It’s a centre where people meet, and there are indeed a lot of unique food products, which is a key point.

Placing a vertical farm in southern Breivoll, between Tveita and Fjellhus, creates a local social hub and an attraction, like the

food hall, that can help attract people, thus creating vitality all day long. The placement of local shops, restaurants and cafés in or around the public space encompassing the vertical farm ensures activity during the daytime and evening. While to the building itself is a centre for jobs and tours.

Because of the importance of public spaces in local public social life it is my preference that the vertical farm should be located next to one of these. This is to have the structure add societal benefits outside the purely productional domain. I use the proposed main and secondary public spaces suggested by the principle plan as a baseline for locating the structure.

## **2.5 Vertical farm as commercial, cultural and educational tool**

Hanken is an area in the northern part of southern Breivoll, the rehabilitation company and second hand shop Fretex is located in this area. It is important to note that this property is owned by the municipality of Oslo. The principle plan suggests that Fretex should be preserved and the orange lines in the map below (based on the principle plan) outline potential diverse commercial areas.

The principle plan discusses that it is the activity along the outer edges of the streets and squares/plazas that decides what kind of life and activity which will be filled in the public space. This is natural as the boundaries of a given area is also very much a defining factor in the experience and use of the area itself. It is the edges and boundaries of a “container” that gives away the purpose of its space, and it can be also said to be so on a human/building scale. This is also what the principle plan explains: that the buildings forming the outline of streets and

squares/plazas, and the activities they provide, define the public spaces.

A vertical farm being placed near the park and Fretex, defined as diverse commercial area, could bring along the livability the principle plan suggests for this area.

As for this area having industrial characteristics, a vertical farm can help to partly preserve and partly transform this heritage in a new and sustainable form, while functioning as a source for local food production. Considering the many abandoned or underutilized urban plots one can find in Breivoll, a vertical farm can contribute to the revitalization of the nearby urban landscape, and bring social and economic benefits to this area. This adds to the sustainable character of the Fretex concept as well which together may bring a distinct character to this specific location. It the sustainable industry (clothing) of old combined with the sustainable industry of the future.

These factors marks this location as a cultural and possibly commercial site. With the close-by residential/villa area of Fjellhus and a connection over or under Ole Deviks road helps bring people and food together, and this may be the farm’s first long-term commercial market.

A vertical farm could deliver fresh crops every day to the schools, kindergartens and other services and businesses close by, and therefore reduce transport and help to improve the local environment as well. This fits well into the first program (Environmentally friendly transport) of the Groruddals-Initiative.

Combine this location with the proposed connection to Fjellhus with the nearby elementary school of Bryn and we have immediate educational opportunities. This is not to exclude any other Oslo schools, but is an opportunity that is less dependent

on the inclusion of a new subway station in the northern part of Breivoll. This also combines with the opportunity of having the farm deliver fresh food to the school each day. It would be necessary to implement a program for the school to provide the students with free vegetables or fruits, but that is another discussion.

A vertical farm can create different jobs that requires various expertise, it can therefore attract people with or without education. A commercial building like this can also attract different investors for further development of this area. This can also help create local businesses in one of the districts in Oslo that scores quite low when it comes to areas of income, health, employment and education.

In order to be able to use vertical farms as a source for local income, it is important to develop a plan for the start-up and operation of the business. In relation to this it is also interesting to contact local waste management/recycling businesses to research the opportunity for cooperations and joint efforts in creating resource/waste loop-systems to increase total efficiency.

In this regard it is also interesting that the property holder near Hanken is the municipality of Oslo. As a stakeholder and property owner the municipality can to a greater degree help integrate municipal services such as waste management and water treatment into the project. With the expertise of local waste management businesses and municipal services there exists the possibility of using local municipal waste as energy supplement and fertilizer commodity. There is also an opportunity for the municipality to have a share of the profits, small or large, in this venture.

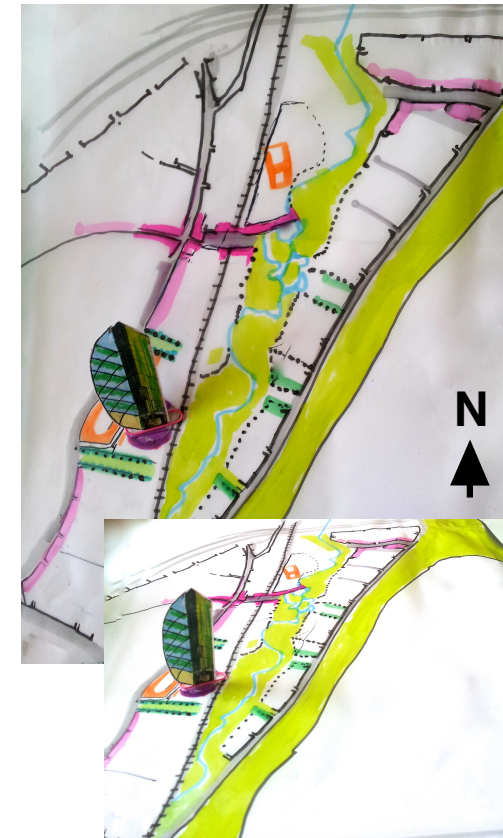


Figure 21: Vertical farm on Breivoll next to Fretex and Alna nature-park  
Source: Author

There is therefore ample opportunity in integrating resources/waste from different areas to create efficient and sustainable loop systems.

This is at first a commercial interest, and possibly research/ educational, secondly it may help awareness, local identity and the local environment, thus also spanning the social domain.

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### 2.5.1 Spectacular architecture – effects on urban development

According to the visions stated in the principle plan for Breivoll, one vision is: Breivoll a pilot-area for future oriented urban development. Considering also that this area is part of the climate and architecture focus of Oslo with innovation, one can suggest that vertical farming would meet these criteria, and may fit into the plan.

The influence of architecture is a dimension which is difficult to measure, but it has great significance when it comes to health, well-being and sustainability. It is the shaper of an experience and is in this regard determining in relation to an areas identity. A vertical farm in this area will stand out and be visible from a certain distance and will therefore be a critical contributor to the cultural and social identity.

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### 2.5.2 Risks of greenhouse in the city

There are certain risks involved and which has to be taken into account in planning a vertical farm that also aims at social and cultural values. But, firstly, what if the venture goes bankrupt? What is done with the building then? It is a building of certain proportions and the construction of a building of this size and shortly having to tear it down is in no way sustainable or commercially viable. It is therefore of great importance that long-term planning of the venture takes place.

There is also the possibility that the building and its glass-surface may experience issues with humidity, algae, fungi and general deterioration of facades due to the nature of its purpose and the amount of plants. Depending on the severity it may be an issue for many people should it appear ugly.

## 2.6 Symbiosis

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### 2.6.1 Waste and energy

As mentioned earlier, it is important to look for opportunities to form waste-to-resource connections with other nearby industries in order to increase overall efficiency and waste reduction. This is also an argument in making the product of the vertical farm economically viable. Based on Rydin (2010) we have an example of successful integration. We can look to Kalundborg in Denmark where they have slowly established an eco-park since the 70's. This was initially only bilateral economic agreements between companies for saving money, but has evolved into an "eco-park" since then. The main flows of material and energy are listed below:

- the provision by Statoil of excess gas to Gyproc, reducing flaring
- the substitution of gas from Statoil for some of the coal used by Asnæs power station
- the extension of district heating using surplus steam from the power station to Novo Nordisk and Statoil
- the use of salt water from the sea instead of local fresh water as coolant thereby also generating hot sea water for use in the fish farm



- the use of sludge from Novo Nordisk and the fish farm as fertilizer for local farms
- the use of the by-product *gypsum* from the power station to Gyproc as basic raw material
- the use of sulphur from Statoil/Asnæs power station by a local sulphuric acid producer
- the use of surplus yeast from Novo Nordisk for local pig feed

We find that over time eight separate connections have formed to increase efficiency and economic viability for the local industries of Kalundborg. The total annual exchange amounts to about 3 million tons with consequent benefits in terms of reduced pollution to land, air and water and resource conservation (Rydin 2010: 8).

Their point is to find any stream of material or energy that is not put to use and find possible connections for harnessing these resources.

For the vertical farm the most notable possible connections are in relation to recycling of bio-waste and excess biomass into fertilizer, converting biomass into bio-fuels, excess heat and CO2 transfer to the greenhouse and recycling of farm grey water and separation of excess nutrients. It would additionally be possible to set aside a portion of the building to grey water reclamation by plants where excess plant material could be used for generating bio-fuel. This could even be expanded to include “black” water where the separated sludge could be turned into fertilizer or fuel.

Right across the highway from Breivoll on Haraldrud lies *Norsk Gjenvinning's* main recycling center. According to Norsk Gjenvinning (2014) the facility is Northern Europe's largest of its kind where both construction technique and architecture have been designed with the environment in mind. The result is a

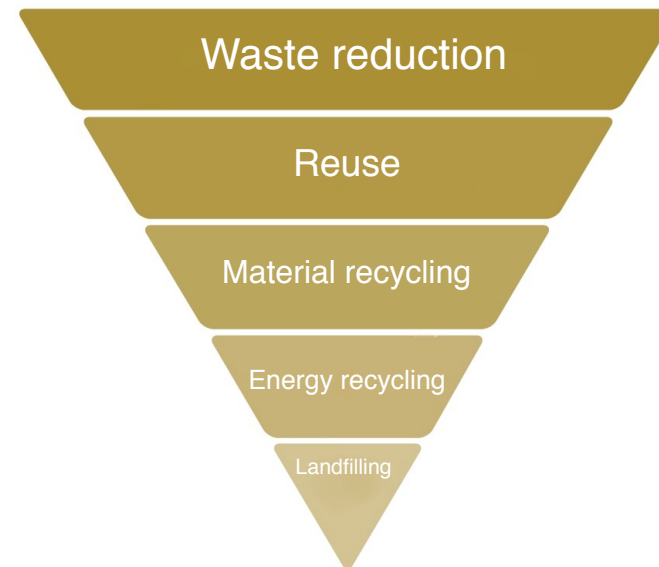


Figure 22: Norwegian waste reduction program source: Norsk Gjenvinning AS

facility without comparable examples elsewhere in Norway today ... *Groruddalen Miljøpark* is a pioneer within the recycling industry in Groruddalen and Norway (Norsk Gjenvinning 2014).

*Norsk Gjenvinning* works in accordance with the principals of the waste-pyramid and its priorities where the goal is to treat the waste as close to the top as possible. The most efficient way to increase efficiency in waste reduction is, of course, to reduce overall waste production. Next, one can increase the lifespan of an item by re-using it. Then one can break the item down into components and re-use material directly or lastly burn and re-use whole or parts of the item as energy. If none of these options are available, the product has to be wholly or partially disposed in a safe location. This is the worst scenario and puts the

material and energies that went into the production out of the material- and energy loop entirely.

Their neighbor Veolia is an international actor in both water and waste management and recycling, as stated on their website they specialize in the management of both liquid and solid hazardous and non-hazardous waste. Its expertise spans the entire waste lifecycle, from collection to recycling, in order to recover end products as materials and energy. Additionally, they work with energy, providing exclusive expertise enabling companies and municipalities to optimize the technical, economic and environmental performance of facilities such as buildings and heating or cooling networks (Veolia 2014).

These two companies are some of the biggest actors in recycling in the area, but not the only ones. Already there is opportunity to draw on the expertise of one or both of these companies in order to detail how the energy and material flows would work in practice, for example the laying of pipelines, as well as being a possible connection itself (Norsk Gjenvinning AS). For example using excess plant waste from the vertical farm in bio-gas production could yield excess CO<sub>2</sub> which could be re-introduced to the farm, as well as using CO<sub>2</sub> from the burning of other wastes.

Additionally, excess heat from the burning of wastes could be a great source of energy, especially in the winter-time, thus saving energy costs. The opportunities for cooperation in general recycling here between the developers of the vertical farm and local recycling companies are big, and may very well encompass additional structures for general local waste- and water management, but that is outside the scope of this study.

Lastly, Veolia's expertise in water management could help increase water recycling efficiency in the vertical farm. Holding to

industrial standards and high food quality ensures that the recycling of water in the farm should be test for quality, nutrients and toxins before being re-introduced. Veolia could help develop techniques to perform both testing and the separation of nutrient/toxin and water to lower total water-use.

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### 2.6.3 Science and education

To help improve the effectiveness of the farm it would be necessary to set aside some space in the building for doing research on the processes, growing techniques and related systems. As has been discussed earlier, this is relatively new ground and such a structure could in many cases be dubbed a prototype. To achieve lower costs and better utilization of resource one would have to monitor the system and help build data for later improvements or new structures. This is therefore a very important aspect of the vertical farm. It is to be both a food supply and a platform for later projects in food production, recycling and city/community planning.

Secondary to this, one should have adjoining presentation room(s) for showcasing the project, its place in the community and its use of different technologies. This could be used both for workshops and seminars, in concert with other companies and partners, and for educating school children. Additionally one could have one or more floors designed to allow tours.

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### 2.7 Alternative

Several warehouses, workshop and office buildings exist in the southern part of Breivoll. In cases were these buildings do not need extensive retro-fitting, to allow for large spaces and single-



room floors, they could be used as smaller vertical farms with shelf-systems. This could provide an alternative or supplement to a new specially designed structure for farming. The initial

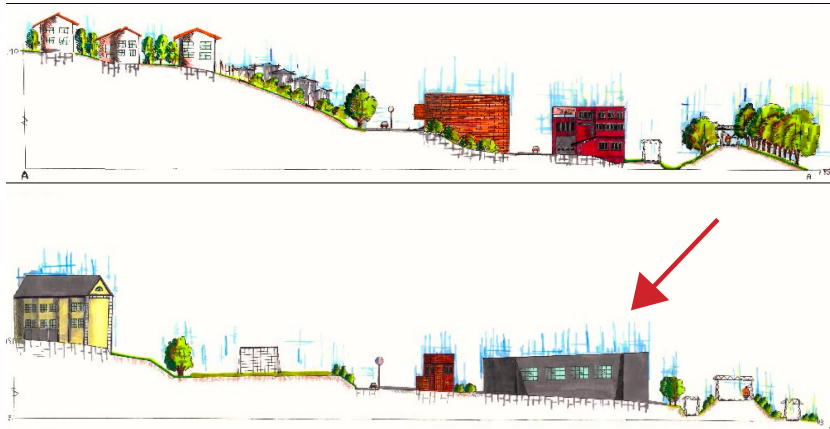
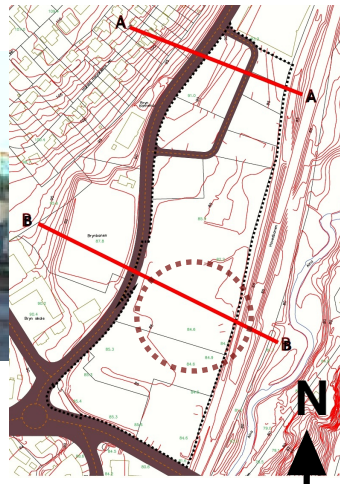


Figure 23: Intersection of southern Breivoll with warehouse Source: Author



Figure 24: The potential warehouse on southern Breivoll Source: (Grimstad, et. al 2012)



Map 12: Sections Source:(Grimstad, et. al 2012)

investment costs would be significantly lower, but would also likely have a much lower capacity. In addition, auxiliary functionality such as education, research and symbioses could be severely limited. The use of smaller retro-fitted buildings may not yield the extra space required, as in for example Plantagon’s design with a sun-facing production unit and “dark-side” office space.

It might therefore be natural to first consider warehouse buildings. At least two warehouses exist in the southern Breivoll which can more easily be adapted to vertical farming. The open space and high ceiling allow for shelf system hydroponics for example. This would leave more volume to the actual production unit instead of walls.

Figure 20 and 21 shows one of the potential warehouses. According to Grimstad *et. al* (2012) this building has a gray box construction. The plot is easy to transform, thus appears as a suitable location for a vertical farm.

### 3 Variables

A vertical farming project will likely in large parts be delimited and influenced by the following variables:

- Total project investment/cost
  - Scope of main project (food production unit)
  - Scope of auxiliary projects (recycling units and industrial connections)
- Possible local partnership and cooperation (i.e. Norsk Gjenvinning and Veolia)
- Investment in local infrastructure and cross-links and public spaces
- Investment in local subway station

These key factors are likely candidates for further investigation.

### **3.1 Scope and investment**

Firstly, it is the ambition and resource of investors that sets the premises for the project. I have outlined the possibilities throughout this thesis and it is the combination of these that decide the project and building scope. Going the direction of Plantagon, with a completely new and dedicated vertical farm, building costs will likely exceed 300 millions NOK. On the other hand one could choose to transform existing buildings and warehouses, it could even be rented space using a shelf system, as was done in Chicago. To fully investigate the possibilities of vertical farming it would be useful to invest in a new structure and advanced grow system. The balancing factor here is risk. If the national government were to invest for the purposes of research in national food production, overall risk could be reduced for the municipality and private investors. A likely scenario could be in-between the two “extremes”, for example one could use a warehouse as foundation for aquaponics (fish-plant loop) and auxiliary functions and build an annex for the main grow unit. Support systems could be planned for, but added in successive project stages.

The total amount of investment could also be influenced, both directly and indirectly, by deals of partnership or cooperation with local recycling companies. If expertise in recycling could be used and connections to recycling, waste and power industries could be added, the project could reduce investment risks and maximize possible profit. In this way one could potentially help gather more funding.

### **3.2 People and places**

Another important aspect to the location and scope of the project involves people, how they can access the vertical farm and how they can experience it. Good nearby access is important in order to enable people to visit regularly from around the city. This would both strengthen the project in terms of awareness, availability and interest and help increase the available market and potential customers. In addition, it can help fulfill principals of social sustainability which are very much a part of the municipal and local agenda. In other words, the easy access to local transport and inter-districts connections are important. It is also likely that situating the structure near the river green belt would allow a better view of it. This coupled with the cross-district links and public space improvements outlines possible locations for the structure. It is from these factors I have suggested a location, but these variables may change at a later date, in accordance with how the transformation of Breivoll and Groruddalen develops in general.

## **4 Summary**

### **4.1 Industrial character**

The area currently holds an industrial and commercial character. There are heavy structured warehouses, workshops and offices. It is surrounded by Fjellhus, Tveita, Alna river and nature park and the E6 highway. Breivoll and the river are split by the railroad

tracks going north along the river. There are some public transport opportunities, but improvements are required.

## 4.2 Plans for transformation

Especially interesting would be the construction of a new local subway station, which has been up for discussion in the media. It has also been proposed to construct bridges over the railroad in order to form cross-links along the east-west axis. Both of these actions would greatly increase the areas potential as modern and green mixed-zone district with a historical identity. It is here that a vertical farm could help establishing local green industry jobs as well as contributing to the local identity as a landmark. The municipality wish to revitalize the area. Using a vertical farm as focus area for local business and good public space may be a step in that direction. This may be achieved both by transforming buildings and constructing a new building.

## 4.3 Benefits of a vertical farm

Several key areas have been identified in which vertical farming could contribute, for example:

- Fresh and local food
- Better local environment
- Less transport
- Job opportunities
- Reduce resource use and increase recycling
- Helps reduce overall land use
- May strengthen local identity, public space and activity
- Strengthen awareness of food production
- May strengthen local economy

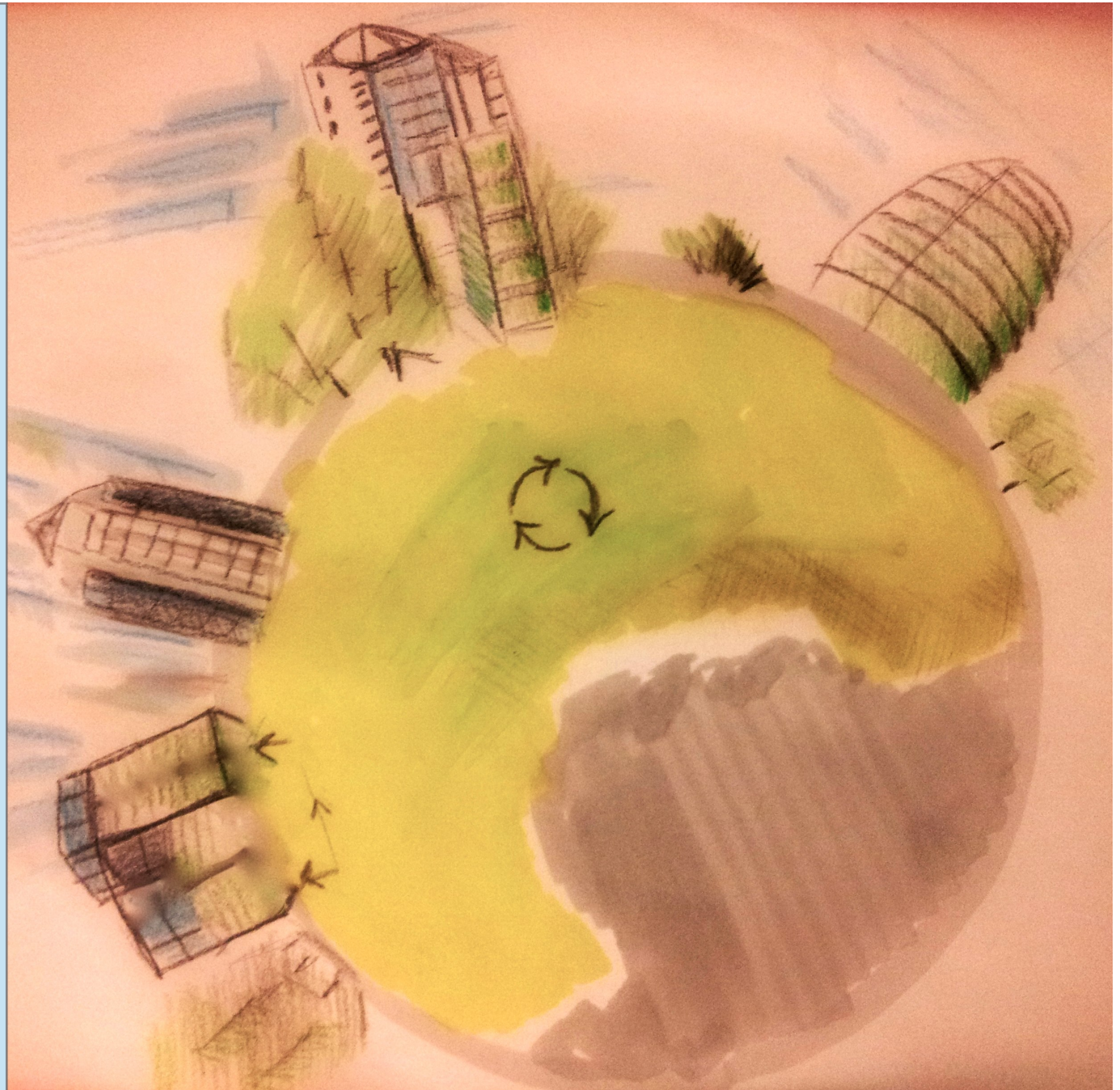
- May strengthen local education

These are not guaranteed benefits, but rely on a strong and coordinated plan in which multiple partners can help bring their own expertise. There are many variables to consider, especially considering not only environmental or economic, but also social dimensions. For a detailed plan of a vertical farm these would all be needed to taken into account to achieve maximum benefit and efficiency. Investments may be initially high, but the risks can be minimized with local partners and working with the municipality.



CHAPTER 4

# Conclusion



## 4 Conclusion

### 1 General critique

In particular I wish to underline my interviews and their scope. Both of my interviews were conducted after I started writing my thesis. To use this time and the knowledge of my interviewees to its fullest I could have prepared additional follow-up interviews and started them earlier. Especially Plantagon and Sweco could likely have provided additional information regarding more than one area, for example technology, planning and projecting, public awareness, business and politics.

Additional points deserving of attention:

- Wider study of the focus area in Oslo in an in-depth case-study
- Wider study of urban farming and current projects, especially concerning economic viability, and in this context also interviews
- Interview or other communication with national and local planning bodies.
- Further analysis regarding vertical/urban farming in planning theory and planning practice
- Investigated more examples of successful densification projects and hub development in Norwegian context, for example of Drammen, Aker Brygge in Oslo and other relevant current projects

## 2 Research question

*How can we facilitate and implement Vertical farms in Norwegian context?*

### 2.1 What is missing in today's planning system and densification strategy?

#### **Densification quality standards**

Densification has the means of reducing land use and help preserving valuable arable land or biodiversity. But with only this in focus there is a real risk of creating dense, socially inhibitive and poor functioning areas. In a planning context it is important to define quality criteria for achieving sustainability. This means defining qualities that help bring positive re-enforcing loops in the areas of environmental, economical and social sustainability. I have chosen examples of criteria from Butters (2012) in chapter 1 (table 1):

- Social variety
- Social security
- Social identity
- Economic flexibility
- Economic activity
- Land use
- Biodiversity
- Energy and recycling

#### **Methods of food production**

There is little debate around the methods of food production in the urban planning context. There are suggestions in the form of urban agriculture, but has until recently not been able to compete with the farming industry. In terms of self-sufficiency and food security Norway is still dependent on imports.



### **Local initiatives**

Transition movements are springing up all over the world. Among them are Omstilling Sagene in Oslo. They work towards a stronger community and local food, among other initiatives. They show that there is a demand for local and sustainable food, social activities and sustainable community. There is a bottom-up approach, perhaps it can be met from the top-down?

### **Policy support**

There is no policies currently adapted to handling urban or vertical farming. This means that entrepreneurs and developers will have greater risks in carrying projects in this area, potentially leading to longer planning and development periods and increased costs. Plantagon's plan in Linköping gives examples of problems which are transferrable to a Norwegian context. For example it was found that local building regulation severely limited the utilization of the property for its intended purpose.

Perhaps the introduction of alternate planning approaches are needed. The current approach is in large parts based on growth-based planning. Often this will lead to the strengthening of social inequities and environmental injustices to one group. Rydin's planning beyond growth-dependence diagram, in chapter 2, suggests an alternative approach to planning which may help focus on sustainability rather than market-forces. This approach focus on local assets: collective funding, social capital and public ownership as bottom-up flows of action. From the top-down government regulation and guidelines help control development. This helps gather all assets and criteria necessary for a development that is focused on sustainability.

## **2.2 Why do we need to include urban agriculture/vertical farming?**

### **Environmental sustainability**

Bringing agriculture into the urban domain in an effective way can help us greatly reduce our environmental footprint. Closed-loop vertical farms does not spill pesticides or nutrient run-off and helps protect the local environment. Firstly, it is as food production unit that that it may help reduce land usage. This in turn helps protect natural ecosystems as well as biodiversity. Additionally, the soil will not be worn-out and destroyed. Heavy agricultural load destroys arable land every year.

A vertical farm could also help reduce resource use by recycling near all material and energy flows in the system. Water usage has been reduced as much as 97% with comparable traditional farming.

Urban agriculture may help as water capturers to help prevent flash floods. Implementing green roofs are especially effective for this. One of the most important benefits of urban agriculture is transport reduction. Reducing transport distance from a thousand kilometers or more to one kilometer greatly reduces pollution form transport and waste of energy.

Looking for environmentally sustainable solution is an imperative also for Norway. While the local Norwegian environment are less polluted then many urban regions, basic patterns of consumption, waste and population growth suggest that the path of Norway does not in large part divert from the rest of the global community. In this globalized world it is also important to note that outside events often may have internal consequences. Local

environment also has great impacts on local social and economic opportunities.

### **Social sustainability**

There are several areas in terms of social benefits that could be strengthened with access to urban agriculture. It may encourage local activity, inspiring local production and local pride and identity. Green areas of the city may provide respite and recreation as well as sources of fresh food. However, it is here that vertical farming may add food safety to urban agriculture. No pollution goes into the system, and no pollution goes out.

Urban agriculture may also help support local business and act as a hub for cafés and stores taking advantage of the fresh produce and local activity. Vertical farms in concert with local business and good public spaces may help invigorate local communities.

Grow systems may serve as education tools for school classes and interested inhabitants. The system itself provides opportunity for research into effective food production, recycling and energy use.

### **Economic sustainability**

Vertical farms may provide varied jobs in the fields engineering, bio-technology, agriculture, construction, computers and food processing. It is flexible in its implementation, potentially growing almost any kind of food product. Can also be used for other organics used in clothes, medicine, biogas, waste management and animal feed for example. Further research may expand upon this and explore additional economic opportunities and functions. This may also likely help to increase the efficiency and functionality of vertical farming structures, and therefore help increase output and economic gain.

Producing our own food greatly increases food security and food safety. Costly transport schemes may be cut. Great amounts of nutrients and fertilizer for exhausted soil is not needed. It is freed to be used for other purposes by man or nature. This also prevents the degradation by the surrounding environment, thus help prevent the loss of other economic opportunities.

## **2.3 Where can we find already existing urban agriculture and how have they been implemented?**

There are actually several examples of vertical farming and urban agriculture being implemented many places all over the world. Especially in Japan, where we find that as much as a third of its agricultural production comes from urban farming. There are also attempts at using vertical farms for increasing agricultural output after the Fukushima disaster, which destroyed valuable arable land. Several hundreds small scale vertical farming systems are now up and running. The most common implementation of urban agriculture in Japan is still using traditional farming methods, but property prices and complex policy and economic support rules are decreasing overall viability for many of the farms. There are still issues in implementing policy support, but Japan is likely to continue urban agriculture and possibly expand on the vertical farming idea for the sake of overall efficiency. This is also being researched in South-Korea, where the government is directly sponsoring a vertical farming research project.

Singapore is actively seeking to expand its food production capabilities because of food import rates of over 90% and

consequently low food security. Here they have already implemented an A-frame rack system driven by rainwater. Output of this farm is roughly five times greater than the same area using traditional farming techniques and Singapore is looking to invest more in this field.

In the United States there are farming ventures which are doing good business. Chicago is an area where the local government laid the foundation and gave the support for local urban businesses, such as FarmedHere and The Plant. Warehouse farming systems using hydroponics and aquaponics are some of the main methods employed here. Delivery of fresh and local produce take place all over the nearby districts.

Implementation and use of technologies vary a great deal. From small converted plots and buildings in Japan to larger 40 000 square feet facilities near Chicago. Common factors are the need and demand for local fresh food and food security. The different approaches gives a glimpse of the combinational opportunities and customization of solutions to specific areas. Following Plantagon's mindset: overall plans for the vertical farm, with its methods and principles, are re-used and "mass-produced", while the specifics and different modules are custom-tailored to specific areas and locations. While Plantagon has not yet built their prototype in Linköping they are still very much an important actor for urban agriculture and are working towards awareness, standardization and policy changes both in Swedish, and European context. This work also holds relevance for a Norwegian context due to planning practice and theory similarities. They are also offering to act as developer, project organizer and consultants for vertical farming projects all over the world with the backing of the large international Swedish engineering company SWECO. This may help jump-start

projects in many regions, help build knowledge and expertise and increase success of project follow-through and completion.

## **2.4 Where do we start in the Norwegian context? (feasibility study)**

A vertical farm structure has the benefit of being able to produce practically anywhere. This removes restriction of soil and arable land. Important factors in placement are in terms of consumers and industrial connections. This makes vertical farming a potentially powerful tool in densification and transformation processes where suitable buildings may be re-used, the site is already localized in an urban zone and there are often potential partners and industries close by. Groruddalen, and specifically Breivoll, is very much in this situation: being close to the city centre and bounded by residential areas and good transport opportunities, available nearby industries, possibility of building transformation and connection to nearby blue-green structure, as well as political will for renewal.

State and municipal involvement may play a great role in deciding total scope of a vertical farming project. Public funds may be needed to attract private investors, and the municipality will anyway be important in terms of regulating and approving any plan. Planning this in concert with the municipality may aid in a proper implementation and reduce project risks. As discussed great potential benefits both local and national government goals and is therefore a likely candidate for serious consideration as direct efforts and studies on their part.

Further reduction of risks and maximizing of potential benefit can be gained by adapting rules and regulations in planning and

building to incorporating urban and vertical farming. This is also the domain of the government and it is the context of both development and regulation that the government can help themselves, business and community. In the study of Breivoll several plans and suggestions for local improvement also aids in the successful implementation of a vertical farm, for example linking the east-west axis over the railroad, improving local connections and public space and building a new subway station. The municipality is already an important actor in all of these efforts and this inter-project capacity may help increase overall success rates and reduce risks. Plans may be adapted individually and greater knowledge may be gained for specific projects.

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# Appendix

## Interview 1

### Interviewee background:

Dr. Dickson Despommier spent thirty-eight years as a professor of microbiology and public-health in environmental health sciences at Columbia, where he won the Best Teacher award six times. In 2003, he was awarded the American Medical Student Association Golden Apple Award for teaching. He has addressed audiences at leading universities including Harvard and MIT, and he has also been invited to speak at the United Nations. In addition, he has been asked by governments of China, India, Mexico, Jordan, Brazil, Canada, and Korea to work on environmental problems. Despommier lives in Fort Lee, New Jersey (Source: [www.verticalfarm.com](http://www.verticalfarm.com))

### Transcript:

**Helya:** You are the one who started the idea of vertical farming and you are the expert, but I was not sure how much you could help me when it comes to city planning.

**Dickson:** City planning is the reason why I want vertical farms, because, cities need to behave better. I will tell you why that is true. Cities are the reason why we need so much land to farm, because if you look at how much all of the humanity uses in order to grow its food, it is about the size of south America. Since half of us live in cities, it means half of south America is devoted to producing food for people who live in cities. So, now what if cities could produce, let us not be so ambitious, what if cities could produce 10 percent of what they needed? That is not a lot, for other smaller cities 10 percent of their food coming from vertical farms is not impossible to expect. This would save, on

the outside, about 340,000 Sq/miles of hard wood forest. If you look on how much forest is already destroyed, in just Brazil, it is about 700,000 Sq/miles. So if cities could produce 10% of their consume, you could repair half of damaged Brazil green forest. That's an incredible number.

That is why I think cities hold the key to ecosystem restoration.

**Helya:** What are the best arguments to persuade critics?

**Dickson:** Let's try starting with food insecurity. People die from eating contaminated food. Two years ago in our country (United states of America), we had 33 people who died from eating Cantaloupes. It is crazy. Every time you sit down to eat, you are dependent upon somebody else insuring the fact that the food is safe to eat. Some people do a better job than others in insuring that. But further away from your table, before food, the better the chance is that the food is contaminated with something. So city farms, being right next door to where you live, have a great and reduced chance of producing food that are safe.

People know about that argument. Another argument you can use is: You could have whatever you want to eat in any season of the year, because when you raise food indoors there are no seasons!

The final reason that you could use is: You can have as much food as you want because there is no limits for the amount of food you can produce indoors. Because all you need is another building. In a built environment there are a lot of empty buildings waiting for someone to use them. So if the amount of the food that you can grow is quite sizable, because there are no season and you can grow them all year long.

But the best reason ever is that the food is fresh. And it just tastes better. If they don't understand that, then you will have hard time convincing them. So what you need are some examples of indoor farms that they can go to and see for

themselves that this is a good idea.

Oh! By the way! You can make a living doing that.

**Helya: How long does it take before vertical farms start actually paying off? A project like this can cost a lot.**

Dickson: There is a wonderful example of that called Green Spirit Farms. They started out three years ago, in the city of Michigan, they began from scratch, they were using an abandoned warehouse. They rented the growing systems from a company. They used very little money establishing their vertical farms. They are using an often shared system called Omega Grow Systems. So they did not need to build anything, just rented them, moved them to an abandoned building and started to grow food and then went out and looked for customers. That is what they did. They were not risking very much. So now it is three years later. They are about to open the world's largest vertical farm in Scranton Pennsylvania. They have secured a 27,000,000 USD loan to do it, because they can convince anybody that wants to see the matrix, or how much food can I produce, how much can I sell it for, and what is my profit. They have already done that in the city Michigan with a little project. Now all they have to do is to scale it up for that and that is what they are doing. That is the proof that if you are smart and consult with right people you are going to be successful, and if you are not, then you will fail.

Other examples of making money is the FarmedHere in Bedford Park, Illinois. They have already been in business in two years, and they already are showing a big profit. They used an old building to start with. They did not have to build and act upon that. When you go on their website, it is done like a map. You will get from getting directions from one place to another, personal arrow that points down where you belong and a map of all the stores in about a 100 miles radius of where they exist that their products by. The number of arrows are so dense that you can

see them on top of each other. They are extreme profitable.

There is a little town in Sweden, called Linköping. They are about to build a very large vertical farm in that little town. 150,000 people who live there. They will be the first I guess Scandinavian country to have a vertical farm. But I hope not the last.

Japan has many, many, many vertical farms. They probably have 300 to 400 vertical farms. You can understand why that is true. They had a terrible event where they lost their nuclear power plant due to Tsunami. All the crop land got contaminated with radio active. They don't want to eat that food. In fact they could not trust food coming from any placme. So the government got behind this indoor growing system movement and also special incentives for those who were willing to take the chance to open up an indoor farm, and now there are hundreds of them, and multiple stories too.

They are not all multiple stories, the ones that are one story are called greenhouses. But there are many many versions that are multiple stories though.

Norway has a very rich government, as you know, and a reasonable population, with very wealthy people. You should be doing this!

You should start a blog, do it in both languages. A blog will educate people. Start a podcast. You will call people like me up and interview them and broadcast it on the internet. The idea started from a classroom. Tell them how easy it is to be engaged.

**Helya: Is there a cooperative environment or sharing of knowledge «open source», when it comes to the technology, or is it proprietary?**

Dickson: Everybody knows how to do it. It is a greenhouse operation, everybody knows how to make a greenhouse. There is no patent because it would prevent people from getting involved. The only thing there is patent for is the growing system.



Now you have to choose between manufacturers. It depends what you want to grow, and that is a matter of choice. You have to do a lot of research first around the area where you want your vertical farm to grow. You have to get your customers to commit into buying from you before you start to grow. Most farmers cannot do that. They cannot guarantee a crop because the weather is unpredictable. While indoors you create that environment. So you get to control everything. And as a result, you can promise based on known grocery systems and known productivities you can say how much you are going to grow, because you know how big you are.

You can sell them to restaurants, school cafeterias, hospitals, grocery stores. Those people are all ready to buy fresh products that they can trust, and that is what you are promising them.

**Helya: What kind of socio-economic possibilities are out there?**

Dickson: The answer will vary. Where ever you go the answer will be different.

**Helya: When do you see vertical farms being a part of our urban environments?**

Dickson: In Japan, it already is.

## Interview 2

### Interviewee background:

Joakim Ernback, Technical Manager, Plantagon

After graduating from Umeå School of Education, Joakim served as a teacher of mathematics, science and woodwork for eight years. Later in his career he worked at Armstrong World Industries as Production Supervisor and Project Manager. Continuing his professional development, Joakim done course work in Project Management and Economics at Umeå School of Business and Economics.

He has also been part of the build-up an Upper Secondary School focusing on apprenticeship training. During recent years, Joakim has been working on construction and renovation projects. Amongst others, he worked with implementing a new wall construction on the Swedish market. The inventor of this wall is the same person who invented the Plantagon Vertical Greenhouse. (Taken from Planatagon.com)

Joakim: When you speak about city planning today, food production is rarely taken into consideration, and we are trying to change that. Ulf Ranhagen. Yesterday we appeared in the European parliament and we spoke in front of the head of agriculture in the European parliament. So we are trying to bring food production up in the agenda.

Vertical farming is the future. You have to consider how to feed and be more self sufficient within a city.

At the moment, what I know is that Singapore, is the only country that has actually stated that vertical farm is going to be a part of

their future development. Because they import, I think about 97 percent of their fresh vegetables. Sky-Greens is the biggest vertical farm in Singapore.

Right now we are extremely focused on closing deals. There are some hard economic talks for realizing some projects. We are totally focused on construction right now.

We don't make drawing ourselves. We work with partners. Sweco, is one of our partners. They work with architecture and city planning.

The standardization institute in Sweden has contacted Plantagon to write new standards about how food is going to be produced inside cities. And a labeling project which is coming from our side hopes that the outcome of the standardization project is that Plantagon is going to be able to label the vegetables that has been produced within us. Because today since we don't grow our food in soil we cannot say that our food is ecological. We actually think that our products are more ecological than when you produce food in soil, because that needs a lot of transportation, which is not sustainable. So we would call ourselves beyond ecological.

A lot about Plantagon is actually communicating how to grow within cities and bringing the topic to the agenda. Building greenhouses is not the only thing that we do, that is our product. One cannot build test facility to see if you can grow vertical, no one would invest for that, so our strategy is to team up with strong partners and technological competence from Sweco and other big companies that will stand behind the concept and say that this will work. That is the only way to market a big greenhouse like Plantagon. If you want to bring the product to the market, there is two ways, either you can do it by branding, which we have done, and the other way is to grow the concept in

small scale and show the world that this works and you can buy it here.

**Helya: What happens with Linköping? As you mentioned earlier, there is only one type of vegetable that you are growing. I know that this project is a pilot project, but why only one type?**

Joakim: Actually we have not started building in Linköping. The reason for that is the permits to build. The municipality has to decide what is allowed to do in certain area, which is not yet exploited. Since this takes several years and it has to pass through all the legal parts within the city, this process is ending at the end of march. And by the end of March the people in Linköping or everyone in Sweden has to have a say on this, and if they want to make a complaint, they have to go to the jury and tell them that we don't like this and take the project into other terms. So this can take two more years.

**Helya: How long have you been working on this project?**

We started two years ago. We have bought the land and there is a ceremony that you can see on our webpage where our Chief executive officer Hans Hasle standing with the mayor of the Linköping and taking the first ground-breaking ceremony and I think that was two years ago. It is frustrating that it takes so long.

**Helya: How do we convince them, how do we tell people that vertical farms work, how do we find investors?**

This is an interesting topic for you, today when you talk about city planning, the regulation is not made for producing food within the city. For instance the thing that regulates the building permits, one major obstacle is that you can grow food on the roof tops, but the building code says that the building could only be a

certain height, which makes it impossible to utilize the surface on the roof. We need to change this in today's city planning system. Certain areas i.e. are banned for the productional food, this is the obstacle we are meeting in Linköping, the code for that area says that one cannot have a restaurant, or you can sell your products but you cannot have a shopping area. So we have been thinking about to create a small farmers market, and contact the local farmers to bring their products to our facility and sell them together with our vegetables. But since the building codes are so strict, this is not allowed. So if you want to produce food within a city you have to start really early in city planning to find out how it will be possible to change regulations in order to be able to produce food. One thing we do now is the standardization project mentioned earlier. This will prove that if we want to produce food in the cities and there is not going to be some health issues due to insects and diseases in the cities. That we are going to do this with perfect control and we will be using pesticides and have an extremely clean environment in order to protect food safety. When we talk about producing food in the city, everybody thinks that they are going to dig up a big ditch between a highway and grow food there, they don't see that as safe. There is too little knowledge about how to grow in hydroponic systems and closed systems. We need standards to be able to talk about food production within the city.

**Helya: Why Linköping?**

Actually it started out with that Tekniska Verken (municipally district heating 100% owned by Tekniska värken) they have waste incineration, and they have a biogas plant, everything located very close to the facility or the piece of land we have bought, So this company found out that they have excess heat that have too low temperatures, so they cannot use it themselves and they started thinking about how they can use this. Then they

thought that a greenhouse can use a lot of heat. And also for the biogas plant they get a lot of carbon dioxide which is also needed in a greenhouse. So they were looking at the internet and they so this really cool greenhouse which was Plantagon's and they made us a call. Otherwise there is no reason to build in Linköping because there is so much unused farm land and the population is not that big. I think Linköping is the Sweden's fifth largest city. It just makes no sense the greenhouse is going to be located in the middle of a field, not inside the city. But the thing would can make this liable is that we also are going to build office spaces and inside the greenhouse we are going to have a research centre. The building will be financed by the tenants and the research centre, so the income from that will make this project happen. This is not a greenhouse project, but is a real state project, so the greenhouse is just a bonus. As I said it doesn't make much sense building the greenhouse in Linköping, but with the cooperations and the companies close to Linköping, for instance SAAP a very big company close by, we are hoping to make this work out.

Plantagon is going to be a part of the research centre, several universities that we have agreements with like NTU in Singapore, Tanji in China, and Linköping university that has recently showed some interest, are going to be participating there. There are going to be also some companies that come in and do research within the greenhouse. The research centre is going to be together with Plantagon's networks, it is going to be a rehab to spread urban agriculture knowledge throughout the world and we hope that a lot of companies would want to participate. We are in the process of signing contracts right now on which company that is going to be staying in the building.

The network that we are creating is for the universities, but there is also going to be possibilities for companies to rent space in the research centre to sit on site to be a part of the development. The signing of the contracts with tenants will play a big role. But

we cannot have that before we have the building permits. Unfortunately we cannot sell anything that is not yet agreed to.

**Helya: How long does the consultation (Høring) is going to take?**

We are going to get the first results at the end of March, then legal thing within the municipality will be ready, but people of Linköping have to appeal.

The environmental party in Sweden doesn't like what we are doing, because they mean that Linköping is a farm land city and we should not bring this fancy thing to this city. They are legally allowed to say no and they are going to use this.

At the same time, they have found some rare birds in a pond that is located close by the land we own. The land we are using is an old quarry, so when they stopped using that, they just filled it up with water and some birds moved in. The biggest complaints we have received so far is that we are building this or the entire site or the block in the new part of the city is located too close to that lake and they would appeal that we cannot do anything that close to that lake with rare birds. And that could stop the whole project actually. There is also a big concern (they are right in this) that birds occasionally fly into glass structures and get killed. And having a green roof on our structure is too heavy, at the same time we want to use the roof to let in lights as well, but all the other buildings surrounding us could have green roofs, but this is nothing we could decide or by law tell people that when you build you have to use a green roof or so. So the main concern now is the pond with the birds nesting. We have stopped thinking that Linköping is going to be the first greenhouse Plantagon builds. We have bought a land in Singapore at the university NTU, we are going to build a facade on one of the existing buildings there. It is kind of a demonstration facility for Singapore. Plantagon is also owned by native american people, indian tribe called Onondaga nation. As one of our main owners, they have decided

to build a greenhouse themselves on their land to be more self sufficient. The reason they invest in Plantagon is that they decided that they don't want to be depending on having casinos and selling tobacco, they don't see that as sustainable. They have been looking for inventions that are sustainable and could provide their people with food. They don't want to have anything with the americans to do.

**Helya: Where do they live exactly?**

The Onondaga nation is just below the Great Lakes, close to Canada. It is as far up as New York State as you can get. The closest city is Syracuse.

**Helya: Do they have enough money to build a vertical farm?**

Yes, they make a lot of money on their tobacco. They have this deal with the American government, that they can sell things tax-free , so they buy tobacco and they have this tobacco farm, that they roll the tobacco and pack them with their own label. The highway passes right by, so people stop to buy cheap tobacco. Just like Norwegians who stop by Sweden and buy meat and cheese.

**Helya: How much does such a project cost?**

It is close to 300,000,000 SEK, if you are looking at the facility in Linköping.

**Helya: If a person like me wants to invest, or be a part of your franchise here in Norway for example, how much should I invest?**

If somebody would want to build a greenhouse, we do a pre-study first to find out what kind of structure we are going to build. One of the things that makes this project viable is that you need to find someone that buys the vegetables, so the commercial structure needs to be investigated. You could work with a grocery store that they buy everything that you produce, or you should look at how the local market works. If you are going to buy the greenhouse with office spaces, or a hotel on the north side of the greenhouse, you need also to get tenants so you get income from that. These are the first things we look at in the pre-study, all that has to be analyzed. This is a service that we charge for and we do this together with Sweco. The average 250,000 SEK, is the cost of this service. It includes drawing and financial plans and layouts of the facility and all the material one needs to start the project.

This process is described on our website, called business opportunity project.

Maybe you should talk to Petter Stordalen, he as built several hotels in Sweden, maybe he would want to invest.

Plantagon is a very strange company. It is both for-profit company and nonprofit organization. The company which is all for profit, which a company has to be today, gives away 10 percent of their shares to this nonprofit organization. The nonprofit organization gets to have 50 percent of the people in the board. You can be a member of the nonprofit organization and influence how to run Plantagon and see that we are doing the right things. You can see it as a football club, where you want the team to perform good, and you as a member can have a say in how to run the club.



Helya: Who makes the regulation plans for you?

Sweco is the consultant company that handles everything. They have made all the drawings, they make the plans, and do the communication with the municipalities.

Helya: How about Mats Hellström the Swedish former minister? How good has it been to have as the senior advisor?

He is doing a very good job. He is opening a lot of doors. He is one of the most important persons for us, he has been a great help in Singapore for instance. He knows a lot of people and knows how they think. As a former minister he has a very good reputation in Asia. It is extremely helpful.

Helya: How long has Plantagon existed?

The company started 2008. That was when our owners decide that we are going to invest in this. The inventor of vertical farm Åke Olsson now lives in Oppdal Norway, he came with idea in 2002.

Jan Dewit, he also works with urban agriculture.

# 1 Technology

There is no clear defined standard for what constitutes vertical farming. Therefore the technology involved in building or running a vertical farm will vary accordingly. At the same time it is necessary to adapt any solution to local conditions which in turn makes for an even more varied use of technology.

Any project can take the form of single-story retrofitted warehouses with multiple racks on top of each other, to much more expensive new constructions specifically planned for multi-story vertical farming. Below I am going to highlight key aspects of relevant technologies and how they contribute to increase efficiency.

According to Despommier (2011): “Most crops have a fairly broad range of tolerance with respect to temperature and humidity. This will enable the indoor farmer to mix and match a wide variety of plants and to grow them in the same room if desired, as long as their root systems are held at the optimal temperature for each species. In designing for the tenants, success goes to the farmer who can best manage temperature, humidity, and security. This is the “holy trinity” of indoor controlled-environment agriculture.” (Despommier 2011)

According to Despommier (2011) these are four themes that designers and engineers must include in any version of a vertical farm:

1. Capture sunlight and disperse it evenly among the crops.
2. Capture passive energy for supplying a reliable source of electricity.
3. Employ good barrier design for plant protection.

4. Maximize the amount of space devoted to growing crops.

Based on Despommier (2011) advantages of the vertical farm include:

1. Year-round crop production
2. No weather-related crop failures
3. No agricultural runoff
4. Allowance for ecosystem restoration
5. No use of pesticides, herbicides or fertilizers
6. Use of 70-95 percent less water
7. Greatly reduced food miles
8. More control of food safety and security
9. new employment opportunities
10. Purification of gray water to drinking water
11. Animal feed from post-harvest plant material (Despommier 2011)

## 1.1. Energy

In order to reduce external energy consumption it is important to include as many forms of renewable energy methods as possible. Dependent on local conditions one or more of these options may be used: Solar panels, Wind-turbines, Biomass Gasification, Municipal waste.

Solar panels may be viable in any location, but will have a greatly varying capacity dependent on location. It is also important that these solar panels do not block any sunlight from reaching the plants themselves, so most of the buildings sun-facing side would have to be free of solar panels. This limits the

amount of potential solar electricity, but can still be an important electrical supplement.

Another renewable energy source could be wind-turbines. On-site wind conditions determine the viability and effectiveness, if any, of this method. Different wind-turbines exist today to take advantage of different types and strengths of air flows. Locations and properties on hills or near the ocean may greatly benefit from wind-turbines. In certain locations one could even make use of tidal, wave or geo-thermal energy.

Probably the most important option is the use of biomass as fuel for plasma arc lights to produce clean hydrogen-rich gas. This gas can be burned to produce electricity. The biomass would be provided by the accumulated waste from the farm itself. One could also use biological waste to produce methane gas, which produces less carbon dioxide when burned than other natural gases. A study made by the Toronto-based student Gordon Graff concerning his vertical farm, Skyfarm, suggests that up to half of Skyfarm's electrical need can be met using this method. The rest could potentially be supplied by the municipality in the form of municipal waste which is often dumped and require landfills (Alter 2008). In other words one could even help the municipality rid itself of waste and generate needed electricity at the same time.

## 1.2 Lighting

Green houses around the globe often need artificial light to keep producing crops year-round dependent on their location and climate. This will also be necessary in vertical farms which are located in less sun-intensive areas and it is one of the key issues regarding sustainability and cost-effectiveness. Traditional green-

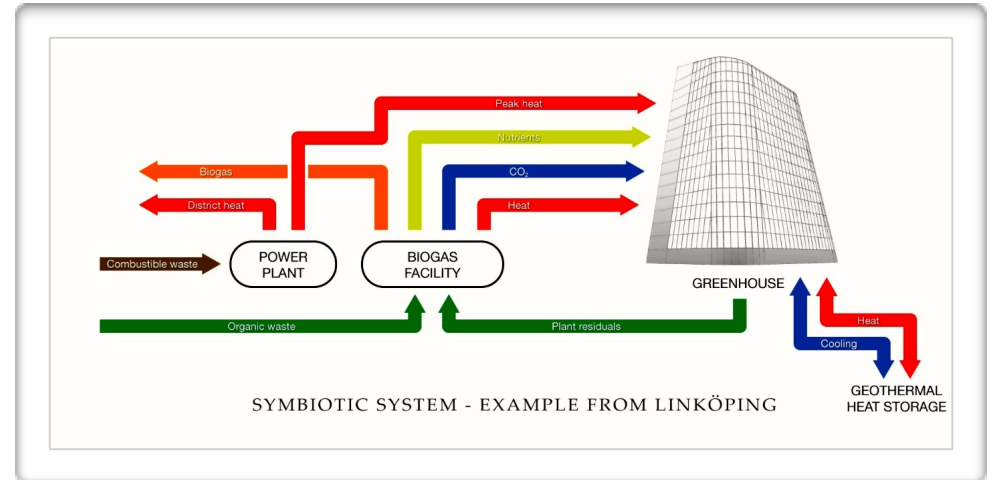


Chart 1: Business Concept Plantagon

Source: <http://plantagon.com/about/business-concept-2>

houses often use either incandescent, fluorescent or halogen lights, each with their own weakness relative to newer LED lights which can vastly improve energy- and cost-efficiency of grow-house lighting.

Incandescent and halogen bulbs both have similar technologies. They rely on a metal filament to conduct electricity across it in order to produce light. The filament burns as a result of the electric current. This means that much of the energy being used is converted to infrared energy instead of light (Benefits of LED grow lights 2013).

Fluorescent lamps are a great deal more efficient in that they convert a much greater part of the energy into light, thus producing less heat and more light. But the light produced is often at cooler end of the light spectrum.

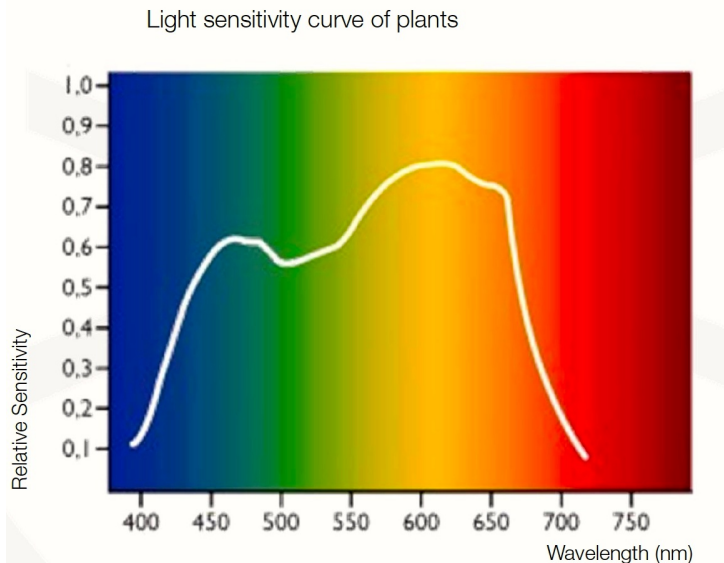


Figure 1: Light sensitivity curve of plants  
Source: SWECO & Plantagon (2014)

This means that plants aren't getting the right amplitude of light waves necessary for optimum growing conditions, which greatly reduces their rate of growth, as well as their maximum potential size. LED grow lights operate using a diode, which generates virtually no heat and can be changed to match any color within the light spectrum (Benefits of LED grow lights).

In other words, an even greater degree of the energy is converted into light and is at the same time more flexible in regard to useful wavelengths. This greatly increases efficiency as all the energy goes towards useful light.

In addition LED lights have a much greater lifetime than other lights. They can last up to 11 years before needing replacement.

Comparing this to a six-month lifetime for traditional bulbs we have a difference of more than 20 times longer life-expectancy for LED lights. At the same time the diodes of LED lighting are smaller and can be implemented in many different ways and places thus increasing efficiency even more. Lamps generating a lot of heat cannot be placed too close to the plants less they risk damaging the plant. Being able to place plants very near or even inside the canopy of a plant greatly increases the amount of light actually reaching the plant and not dispersing into every direction.

These are all figures concerning existing LED standard technology. We should not forget that the efficiency of LED lightning is probably going to increase even further as research into this subject moves forward.

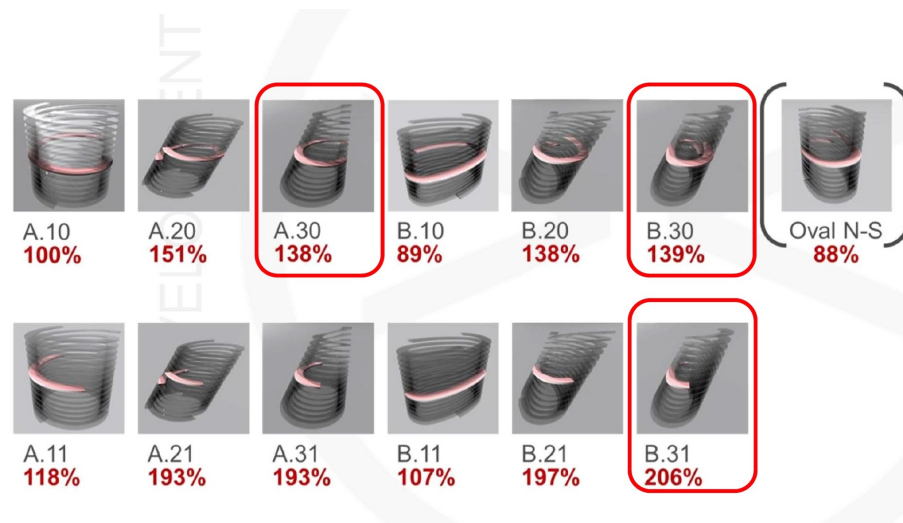
As an example we can use the relatively new Sol LED Grow Lights produced by Hydro Grow. Modern LED lights use one or more lenses to focus the light. Each time the light passes through a lens it loses a portion of its strength and energy.

Sol LED Grow Lights eliminate these light blocking layers, and instead use a custom-developed parabolic reflector to direct light. Unlike a lens, a parabolic reflector goes around a light source rather than over it to direct light in a set dispersion pattern. The Sol integrated LED instead uses 32 chips bonded together on a thick copper plate using a high-precision machine, which reduces the form factor of the LED, requires only one LED package, and eliminates the time and labor needed to solder 32 LEDs individually .

To ensure year-round high-capacity production it is therefore inevitable that we should include the use of the latest available LED lights. Though we should not forget that it is also necessary

to harvest as much of the local sun-light as possible. It is free energy and the building and its growth system will have to be adapted to using as much of it as possible.

Plantagon has made thorough studies concerning building shape, glass use and natural light. From the chart below we can see the various solar light yields for different growth structure shapes. Only a brief look at them can tell us that the shape of the building and growth system can greatly affect how much natural



▪ Solar gain on the cultivation surface  
 DLI, two days per month, 06:00-22:00, whole year, average cloudiness

STOCKHOLM 2014.02.28



Figure 2/ Source: Sweco, Plantagon (2014)

light is utilized. Therefore it also greatly affects how much energy is needed from artificial light sources, such as LED lighting. We can see that the building yields greater throughput of light if

focused in the direction of the sun. This allows auxiliary units to be placed at the “back” side of the building so as not to waste valuable energy.

### 1.3 Recycling

Reclamation and re-use of water is essential for any agricultural project. The degree of importance is of course related to the local climate, but it is in any case in everyone's interest to preserve as much of potential energy and resources as possible.

The specific methods used to recycle water depends on several aspects. The growth system itself is perhaps the biggest factor. Aeroponic and hydroponic can in this regard be seen as the two extremes in the amount of water present in the system and which will eventually need to be processed.

In any case, transpiration from plants will occur and humidify the air. In any closed loop system this enables us to channel the air into specific areas or chambers for dehumidification. The same method can be used if there are processes in the farm which creates grey water.

This is in cases where waste and waste water cannot be easily treated to reclaim water. A specific section, probably at the lower levels beneath the last crops, would contain plants expressly planted for soaking up the water and transpiring and thus cleaning and reclaiming the water as water vapor.

In cases where hydroponics or soil-based grow systems are used excess and waste water may be directly reused after being tested. PH levels, nutrients and toxins would have to be checked. In cases where direct manipulation of the water does not

ensure the proper quality it could be channeled directly to the grey water reclamation area.

Soil-based systems allows for the re-use of excess bio-waste in the form of compost into new soil or fertilizer. In the case were soil is not used it can be an income supplement in the form of plant soil sold over the counter. Any excess bio-waste and plant material can therefore be recycled either as energy, as explained earlier, or plant soil.

As a summary I will point out that all the water in the closed system need to be collected and checked for re-use. This means water in the form of vapor and as liquid. Physical means of capturing drip- and spill water must be in place, as well as means of capturing airborne water.

## 1.4 Integration

The photosynthesis requires both water and CO<sub>2</sub> to produce carbon hydrates as fuel for the plant. CO<sub>2</sub> occurs naturally in our atmosphere, but many plants can operate at higher levels of CO<sub>2</sub>. This enables them to increase their productivity. The amount of gain varies and some plants does not benefit from added atmospheric CO<sub>2</sub>.

This opens up for the possibility of using external CO<sub>2</sub> to boost production for many crop types. Nearby factories and power plants that can separate CO<sub>2</sub> may therefore function as providers of excess CO<sub>2</sub>. This helps reduce carbon dioxide emissions for the factory and boost production for the vertical farm, a win-win situation.

Plantagon also planned for the Tekniska Verken (Local government-owned power and utilities company) to treat organic waste coming from their prototype. Excess CO<sub>2</sub> would be channeled back into the grow system as described above, and excess nutrients would be separated and used in combination with “fresh” nutrients, if meeting quality standards.

Waste water may be recovered with the use of plants. A part of the vertical farm, or the entire project, could be dedicated to this process. As Dickson Explains: (...), plants obtain their nutrients by pumping water through their roots, up through their leaves, and eventually transpiring it out into the atmosphere. Remediation of grey water could easily be accomplished by taking advantage of the enormous amount of transpiration that could occur inside vertical farms constructed expressly for that purpose. Dehumidification of the indoor air is all that would be necessary to get back the water we produced by eating and drinking (Despommier 2011).

The plants themselves would not be edible, but they would soak up nutrients and grow. Excess foliage and bio-mass from these plants could be incinerated for energy, as a cleaner alternative to fossil fuels.

## 1.5 Grow systems

Growing inside buildings while still utilizing sunlight will require methods of redistributing the plants to even out differences in sunlight exposure. This is necessary to ensure that every plant follows the same growth pattern and therefore can be harvested at the same time and with the same quality. Below I will describe some of the different solutions implemented or planned.





Figure 3: Source: TNP [www.soshiok.com](http://www.soshiok.com)

Sky Greens vertical farm in Singapore uses rainwater to power its rotating A-frame. Every plant in each tray therefore goes through the same loop and sunlight is evenly distributed among them. For rain-laden climates this may be a viable option to save energy. I choose to start with this example to point out that seemingly low tech and small yield solutions may provide great advantages if applied in smart ways. It is this adaption to local conditions as well as utilizing every natural energy output to its potential. Each of these A-frame racks may revolve about 4 times per day. Additionally these A-frames carries a soil-based growing system which gives greater weight to each tray. Lastly there are more than 120 of these A-frames each using this

system. In total there is a lot of energy to be saved just by rainwater.

Plantagon has opted for a different solution. They plan to use trays? laid out on tracks that run along at 90 degrees angle to the window surface. The plant trays will start at the top of the building and slide down to the next floor when reaching the length of the track. When sliding down the trays switch track so that every tray will have roughly the same amount of light exposure. The track closest to the window gets the most exposure while the one furthest from the window gets the least amount of sunlight exposure.

Omega Gardens plans on building a vertical farm based on their own model in the Vancouver area, Canada. They have opted for not using sunlight, but a wheel-based frame system where the hub contains a lamp giving the plants at the edge the light it needs. The wheel rotates to distribute light evenly and runs through the water at its base to hydrate the plants. These wheels are placed in shelves in the cylinder shaped insides of the building and distributed with robotic arms. This is an example of a more high-tech solution considering the robotic arm wheel distribution system. They also have smaller mobile containers with growing wheels easily transported where they are needed (Vert-Gro 2014).

Hydroponic systems can be stacked as well. VertiGro has a system of polystyrene pots stacked on top of each other. Each pot would be smaller in the bottom to allow the plants to spill out on the side. These stacks would also rotate to distribute the light evenly (Vert-Gro 2014).

Aquaponics is the combination of hydroponic plant growth with aquaculture, or fish breeding. This is a very interesting field

which to a greater degree takes advantage of natural ecosystems to produce food, both proteins from the fish and carbon hydrates from the plants. The plants produce excess bio-waste which provide feed for the fish and they soak up excess nutrients in the water, therefore cleaning it and oxygenating it. The water is then sent to the fish which deposit ammonia in the water. This is then broken down into nitrite then nitrate by bacteria. This nitrate and CO<sub>2</sub>-rich water is then used as nutrient for the plants, thus completing the cycle. This method of growing is perhaps the most sustainable in that it provides most of its own nutrients and is, at the very least, partially self-cleaning. For examples of successful aquaponics businesses, we refer to Colorado Aquaponics and Green Acres Aquaponics in Florida.

## 1.6 Plantagon in details

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### 1.6.1 Partners

Plantagon works closely with their partners and advisors to facilitate the development of vertical farming. Among them we find former Swedish minister Mats Hellström, which according to my interview with Plantagon has been a major asset in creating a network, facilitating agreements and “opening doors”. Other senior advisors include:

- Madeleine Cæsar, Interaction academics/business
- Fredrik Billing, Interaction academics/business
- Richard von Essen, Business development
- Mia Kristiansson, Business development
- Thomas Malmer, Academia/R&D
- Mikael Kullman, Global business development
- Mats Rønne, Brand management

SWECO is their primary technical partner, here is an excerpt from Plantagon’s website:

The Sweco Group is a strategic ally to Plantagon with the responsibility to develop detailed solutions and productive ways of manufacturing the greenhouses. Sweco is Sweden’s largest consulting company in engineering, environmental management and architecture. With a staff of 5,600 and offices at 60 locations nationwide and overseas, they work on projects in more than 30 countries every year – in Europe, Africa, the Middle East, Asia and the Americas. The vision is to be Europe’s leading knowledge-based company in the fields of consulting engineering, environmental technology and architecture. Today, they are the market leader in the fields of water and environmental technology, architecture and installation and has a strong market position in industrial structural engineering, energy systems, project management, hydro-electric power and civil engineering. Sweco’s areas of expertise include forefront competence and experience in sectors such as Water & Environmental Technology, Power Systems, Hydropower and Nuclear Waste, Transportation Infrastructure and development projects in Pulp & Paper, Healthcare, Pharmaceuticals and Retail & Logistics. The company is listed on the Stockholm Stock Exchange (Plantagon.com).

Included as a strategic partner is, of course, also the inventor of Plantagon’s vertical farm concept Åke Olsson. Other notable partners include: Saab, Tekniska Verken, SymbioCity and Combitech.

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### 1.6.2 Goals and philosophy

Plantagon’s business concept is based on developing innovative solutions to meet the increasing demand for locally grown food in

cities all around the world. They minimize the use of transportation, land, energy and—using waste products in the process but leaving no waste behind (Plantagon 2014).

Plantagon believes that as modern people we must strive to find good solutions in food production that use synergies in the hinterland between technology and everyday life. They mention that there are today too many uncontrolled flows of endless resources in our agriculture, peak phosphorus is also an issue in today's societies. Based on Plantagon, issues mentioned above point out the need for solutions that capture phosphorus before entering rivers and seas.

Plantagon argues therefore that urban agriculture, considering it being close to urban resources, can integrate production to these flows of resources. They mention that the possibility for using locally produced nutrients by itself, is a reason for having urban agriculture.

They point out that for the city planners who do not understand the link between the resources (energy, water, sunlight, carbon and many more), urban agriculture and livestock keeping, it is easy to stop developing urban agriculture.

Plantagon states that traditional farming in general has been considered as a risk factor. It is therefore that planners have suggested to keep agriculture outside cities due to unsolved questions like dangerous bacteria, different zoonosis or the leakage of nutrients imply an advantage to rural (far away from cities) agriculture.

*Urban farming supports the market with products that do not need to be transported.*

“Cities already have the density and infrastructure needed to support vertical farms, and super-green skyscrapers could supply not just food but energy, creating a truly self-sustaining environment.” (Chamberlain 2007)

- “Mega—Cities need food production within to avoid paralyzing congestion.
- Especially important is the demand for organic food close by.
- Cities need to be green to keep up biodiversity.
- Many cities have grown organically from farming villages; local history is important for city-dwellers identity. Farming should be tangible.
- Cities need a diversity of jobs and competencies to have a sustainable labour market with low unemployment, farming jobs and a new dimension.
- Farming in an urban environment can give impetus to develop new methods for agriculture through all the competencies, research embedded in a city environment—compared to traditional rural ways or ‘industrial’ large ranches.
- Sustainable waste management and water treatment can give good food inputs and nutrients for urban agriculture, which can become part of an ecological system.” (Chamberlain 2007)

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### 1.6.3 Concept

The helix

A key part of the Plantagon design revolves around the helix form. It was this that formed the basis of the development and the following concept. It was the idea of starting with food production, then expanding the concept until a whole building has formed — form follows function. It later was adapted as a spiral-formed growth system running along the sun-facing side of the building, not the entire building structure as originally

envisioned. This developed because of their research into light and light coverage in different structure types and set ups.

The hydroponic trays will slowly move along many tracks running parallel to the window surface. Once reaching the length of the track it will swing inwards and slide down to the next floor. In the process of sliding down they will also change tracks to balance the amount of light given to each tray and plant. This is to ensure a proper industrial setting which allows for precise and efficient food production.

### **Hydroponics**

They also intend to use a hydroponic system for growing the plants. Substrate trays will allow a small stream of water and soluble nutrients to reach the plants. The closed system allows all of the water to be recycled. The water and nutrients will have to be measured and tested before returning it to the flow of water nutrients to ensure a proper and even distribution. This involves at the least PH testing, nutrient concentration and toxins testing.

The use of hydroponics allows for a greatly reduced water consumption as no water goes to waste either as water vapor or run-off. In this manner, it may also never bring excess nutrients or toxins to the surrounding natural environment. In addition it allows for a much greater control of the growth of the crops.

### **Integration and recycling**

Plantagons current project in Linköping were on the request by Tekniska Verken. They produce extra heat and CO<sub>2</sub> in the their bio-gas facility want this excess to not go to waste. This could be provided to the Plantagon vertical farm as energy for heating and plants. Excess bio-waste from the farm could in turn be used as “fuel” in a gasification process to produce bio-gas. Integrating the

cycles of each plant could greatly increase efficiency in terms of resource use and environmental impact.



**Norges miljø- og  
biovitenskapelige  
universitet**

Postboks 5003  
NO-1432 Ås  
67 23 00 00  
[www.nmbu.no](http://www.nmbu.no)