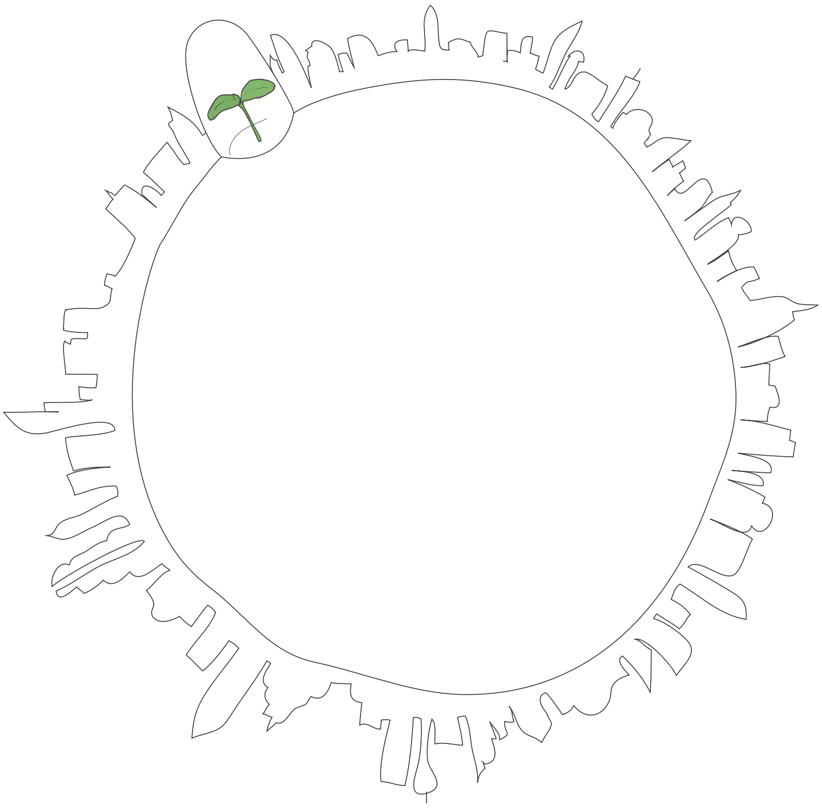

Urban Growth

Analysis of crop consumption and development of a conceptual design to increase consumer adoption of vertical greenhouses.

Master of Science Thesis in the Master Degree Program, Industrial Design Engineering

EBBA HEDENBLAD
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CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

The Master Thesis "Urban Growth" aimed to facilitate the implementation of innovative ways to produce food industrially in large cities by analyzing the consumer relation to food production, investigating possible interventions, and developing conceptual designs that could increase the consumer adoption. The project was carried out at the department of Product and Production Development at Chalmers University of Technology, and was performed by the Industrial Design Engineering students Ebba Hedenblad and Marika Olsson in collaboration with Plantagon International AB.

In order to meet a growing urban population along with an increasing food demand, a sustainable productivity improvement is necessary. Plantagon offers vertical greenhouses to be placed in the urban landscape that will allow an increased productivity through an automatized and industrial cultivation. This new type of food production could result in a closer relation between producers and consumers, and hence imply an expanded insight in and transparency for the production process. The project was initiated by a comprehensive user study that investigated the consumer relations to the innovation by mapping out the needs and demands of crop consumers in Swedish cities. Several factors, such as skepticism for greenhouses and industrially produced food, were identified as crucial to consider in the implementation of the vertical greenhouses.

With a foundation in theory about adoption of innovations and new food production methods, interventions to meet the consumer requirements were developed and analyzed. The intervention of providing the consumer a possibility to try the technology was recognized as most suitable for the project and was further developed into a mini cultivation system. The *Plantera* is an automated system for the cultivation of a plant that opens up for user interaction, with pedagogical meaning, to explain the benefits of industrial greenhouse production.

Key words: Industrial Design Engineering, product development, mini cultivation system, urban farming, hydroponic cultivation, adoption of new innovations, Plantera, Plantagon.

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Gothenburg 2013,

Ebba Hedenblad & Marika Olsson

Table of Content

1. Introduction

"Urban Growth" is a Master Thesis project that has been executed in collaboration with the company Plantagon. This chapter introduces the report of the project and includes a description of the background, the project purpose and goal, the delimitations as well as a report outline with a short description of how to read the report.

1.1. Background

Along with an increasing food consumption per capita (UNEP, 2012), the estimated population in urban areas is expected to grow with 2.6 billion people the coming four decades (ESA, 2012). Because of this extremely rapid increase in demand for food, the production and consumption of provisions is a crucial issue today and is forecasted to be an important concern in the near future. An energy-efficient production and overall decrease in negative environmental, social and economical impact of food production will be required, as well as an increase in overall productivity, in order to balance supply and demand. (FAO, 2009)

1.1.1. Plantagon

A newly established company (2008) named Plantagon, based in Stockholm, is developing a new solution for vertical greenhouses and industrial food production. The solution is patented and intended to be used in so-called megacities (>10 million inhabitants) with large structures that have a high demand for food. In these cities, the solution is meant to incorporate more effective land-use and embrace the local infrastructure.

Plantagon has acted as a source of information through interviews and meetings for the initial analysis of the project, rather than being a client with specific needs and demands for the concept development.

1.1.2. Project background

To succeed with Plantagon's new type of food production it is essential to know the consumer's relationship to the greenhouse, its technology, and the food that is produced. It is also important to know how design can influence this relationship to support adoption of the new technology, and make the food both accepted and requested.

The company is projecting the first greenhouse, based on this technology, to be built in the city of Linköping in Sweden. The purpose is to create a reference building that can be used as an example in the further spread of the buildings and incorporate different functions into the greenhouse, such as a research lab and a tourist center.

The target group of Plantagon is mainly stakeholders within municipalities, real estate, and construction. With these contacts they can achieve agreements to project the construction of greenhouses in large cities in Sweden and worldwide. However, the target group for the Plantagon greenhouse vegetable production is in this project *vegetable consumers in urban areas of Sweden*.

1.2. Project aim

The overall project aim is to facilitate implementation of new and innovative ways to produce food. It is also to, by conducting user studies in Sweden, gain a deeper understanding of future potential consumers of vertical, urban and greenhouse-produced vegetables. Further on, the project is aiming at increasing the potentials of achieving beneficial product experiences from the combination of food and technology.

1.3. Project goal

The project goal is to make a thorough analysis of and investigate the consumer relation to urban greenhouse production and based on this result develop conceptual designs to facilitate the future implementation of the Plantagon technology in large cities.

The research questions below, being the point of departure, summarize the overall direction and the goal of this Master Thesis project.

- What prerequisites are there for the specified target group's adoption of an industrial and high technological urban food production in vertical greenhouses?
- How could the awareness of the relation between sustainability and the vertical greenhouse be increased and how would this affect the consumer experience?
- How can we with design control the consumer experience and facilitate the implementation of the concept?

1.4. Delimitations

The project's research phase will encompass a thorough and broad study of consumer habits, needs and wants. This will, together with relevant theory, act as a basis to find passible ways of how design can facilitate the implementation of Plantagon's concept of a vertical greenhouse. The solutions will act as a starting point for the phase of concept development, hence, concept refinement such as development towards production or marketing will not be taken into consideration since a greater focus has been on the initial development phases.

Although vertical greenhouses are destined for megacities in the future, the geographical context in this project is limited to Sweden and Swedish cities. The company is, as mentioned, aiming to build the first greenhouse in Linköping, and the boundary has been set thereafter.

The project will focus on the products Plantagon will offer and not on urban agriculture in general. More specifically, the focus will be on the products people interact with, meaning the food produced in the greenhouses and/or the greenhouse buildings as such.

1.5. Report outline

This report explains the complete implementation of the project "Facilitating implementation of urban food production". The basic structure is chronological, but must not be read from cover to cover in order to be fully understood. The division of the chapters offers the reader to focus on sections of specific interest.

Chapter one introduces the project with background information, aim and delimitations.

The second chapter is describing the project collaborative company - Plantagon - by introducing the organization, the brand, the vertical greenhouse, and the reference building.

The third chapter, of theoretical background, presents underlying theory of the global food situation and the industrial cultivations of crops that are of importance for the project.

Chapter four is containing the theoretical framework of the project. It includes theory behind adoption of innovations and the methods used as well a description of how the methods were implemented in this project.

The fifth chapter describes the major result of the data collection and analysis.

In chapter six a conclusion, with research summarizing aspects and illustrations, and guidelines for the concept development of the seventh chapter, is presented.

Chapter seven introduces the concept development phase of the project by describing the process from brainstorming of ideas to the development of the chosen concept. The final result – Plantera – is visualized and described in chapter eight.

Chapter nine includes the discussion with insights and thoughts on the complete project. The discussion is concluded with suggestions for further development and recommendations for Plantagon.

The tenth and final chapter contains the conclusions of the project.

2. The company

In the following chapter the company and project partner Plantagon is being described. The description is accounting for a broad range of aspects, such as organization structure, logotype, values, and the vertical greenhouse, that all have, during interviews, been discussed with employees at Plantagon.

2.1. The organization

Plantagon is an organization based on a special business model named *The Companization*, which is developed by the founder Hans Hassle. The organization model is described as a hybrid between two legal units that are working for the same cause and are legally bound to support one another. One of the units is a profit-driven limited company called Plantagon International AB and the other one is non-profitable association called Plantagon Non-profit Association. (Hassle, 2012; Plantagon, 2013)

The Companization is meant to "combine commercial and non-profit driving forces in one and the same organization" (Plantagon, 2013). Both the association and the company have the ethical frameworks "The UN Global Compact"[1] and the "Earth Charter"[2] in their articles of association and statutes. The two organizations, their board members and leaders are committed to financially and socially review their compliance to these articles with the aim to "bring moral questions to the otherwise purely economic forum" (Hassle, 2012; Plantagon, 2013).

Plantagon link the business model to the global political and economical state of today. "Today some of the largest individual economies are private, owned by global companies and not nation states" Hassle (2012) claims. This means, according to Hassle, that the owners of corporations and their boards have enormous responsibilities in determining future directions of the entire world. The idea is, according to Plantagon, thus to explore how to make money while doing good causes and using the power of money and public support to achieve both general benefits for society and economic progress. This is where the Companization model steps in; it is designed for people "that see no reason to choose between money and doing good" (Plantagon, 2013). Another mission of Plantagon is to offer services in food security and to sustainably produce food directly to consumers, either in western parts of the world or to citizens of the third world.

For more information about Plantagon's organizational structure, see Appendix III.

2.2. The brand

The brand of the company is based on a logotype as well as on several values and goals, all of which are described in this section of this chapter.

2.2.1. Logotype

The logotype of Plantagon (Figure 2.1.) is designed in relation to the company's underlying idealistic principles.

Figure 2.1. Plantagon logotype

The ring symbolizes all time, the left angle bracket symbolizes everything from the past that has happened until now, the right one symbolizes everything that will happen in the future and the space in between is where human mankind is at the moment. The symbols in the middle are not connected to the ring because there is no answer of what this connection should look like. The questions the logotype is aiming to address, is what responsibility humans will take for the future and how this will affect us.

1 United Nations Global Compact, 2011. Overview of the UN Global Compact. [online] Available at: <http://www.unglobalcompact.org/AboutTheGC/index.html> [Accessed 5 March 2013].

2 The Earth Charter Initiative, 2012. The Earth Charter [online] Available at: <http://www.earthcharterinaction.org/content/pages/Read-the-Charter.html> [Accessed 5 March 2013].

Figure 2.2. Plantagon mission - Feeding the city

2.2.2. Mission and visions

The company uses several statements that act as missions and visions. The most prominent one is to "*produce and sell food at the same spot"*, a vision that is to be fulfilled through the vertical greenhouse.

The mission is *"Feeding the city"* (Figure, 2.2.), and to participate in the work for *food security*; enough food and good food for as many as possible is one of the company's main driving forces.

2.2.3. Values

The six words below, describing what the company is aiming for and want their vertical greenhouse to be associated with, are values the company consider important in the communication to consumers.

- The company wants to consider the consequences on the surroundings to always take *responsibility*. Giving one example, Plantagon does not want to outrun already established farmers with their vertical greenhouse.
- *Action* is the core aspect to communicate, "We do things".
- Thinking in a *long-term* perspective is a fundamental aspect in the organization; future consequences of actions done today must always be considered.
- The company aims to be a transparent organization, *sharing* insights and strategies as much as possible without interfering with competitiveness. Plantagon claims to be prepared to share its power with everyone.
- Finding *sustainable* solutions for the future with an emphasis on food security is one of Plantagon's goals. This is realized by, for example, involving industrial symbiosis and offering vegetable production with less transports and intermediates.
- The aspects of running a *local cultivation* are connected to the greenhouse and its crops; the core is to produce and sell at the same spot, i.e. in the middle of large cities.

2.3. The vertical greenhouse

The company's main product is the vertical greenhouse. It contains new technology and production processes, and is designed to be a part of the urban landscape. The overall design of the system and the technology of growing vertically separates Plantagon from other greenhouse producers.

2.3.1. The helix

The helix is the core of the greenhouse, stretching vertically through the building and carrying trays of crops in three parallel tracks from the top to the bottom. In order to keep the crops in sunlight as much as possible, the trays will move at a faster pace when in shade than in sunlight. On each level of the helix, there will be robots that move one tray forward at a time. The technology behind the robots is an important innovation patented by Plantagon, which makes the optimized cultivation process of the greenhouse possible.

2.3.2. The design of the building

The general idea with the vertical greenhouse is to design the building to optimize production yield and to encourage a sustainable development of the surrounding environments. To achieve this, many variables have to be accounted for and optimized, both in the building as such but also in the system that connects the building to its surroundings.

From the start, the design of the greenhouse was a sphere, but from studies of the solar movement it has been shown that to optimize the building and the helix in regards to mainly light, different buildings are needed for different environments. Therefore, two main greenhouse models has been designed; a sphere for tropical climates and a half moon shaped cross section for tempered climates (Figure 2.3. & 2.4.).

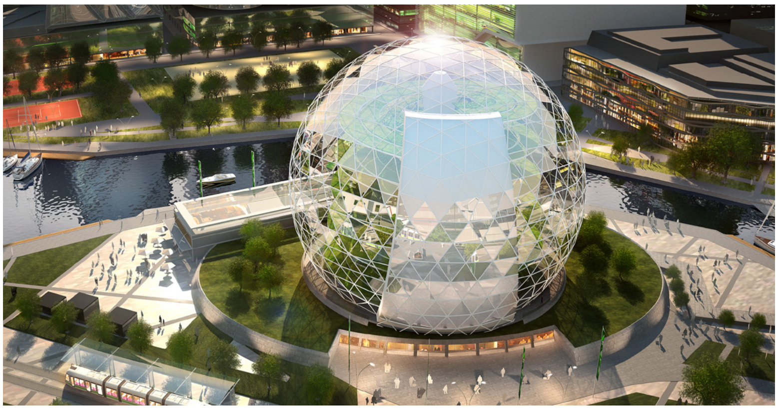


Figure 2.3. Spheric greenhouse

Figure 2.4. Half moon shaped greenhouse

The design is thus chosen on technical principles to optimize the process. However, the aesthetics and the design of the building are very important for its role in the city and among the inhabitants and have thus been considered. The half-moon shaped building is tilted towards the sun for functional reasons, to some extent, but mainly to clearly communicate that the greenhouse uses direct solar light, which has been shown to please consumers that believe the sun is important for vegetable cultivation.

As a complement to the solar inflow, LED-lights will be used. This technology is very energy efficient, has a relatively low heat supply compared to sunlight and allows a controlled lighting environment. Today, artificial lighting is so efficient that sunlight is not needed to the same extent. As long as the plants receive wavelengths, artificial or not, in the interval of 400 - 700 nm (also called the Photosynthetic Active Radiation), there is no proof that a broader spectrum like sunlight containing all the wavelengths, will give more flavor, nutrients or other benefits. However, since Plantagon has decided to use sunlight anyway, this may decrease the need of artificial lighting and thus the overall energy consumption.

2.4. The reference building

The first greenhouse that is planned to be built in Linköping by 2015 will contain different functions. To ensure financing, the building will contain two separate parts, one with offices and one including the greenhouse. Examples of other functions that will be incorporated, is an urban farming research department and facilities to market and display the technology. The main reasons behind including these functions are to achieve another income source, to create a symbiotic relationship between different roles and to provide information and education to the society.

The site for the greenhouse is situated outside central Linköping. The partners involved in the process of building and running the greenhouse is Combitech, Sweco, Saab and Tekniska Verken, however, the building will be owned and financed by Plantagon itself. To achieve a symbiotic industrial relationship, the greenhouse will be built next to a biogas plant run by Tekniska Verken; a company owned by the municipality delivering e.g. electricity, water, long-distance heating, biogas and waste management to Linköping and surrounding communities.

During an interview with Stefan Jakobsson[3] the role of Teknsika Verken was further explained. In the biogas plant, organic waste will digest and a heat surplus at around 50 degrees Celsius will be emitted in the process. This heat is difficult for Tekniska Verken to use efficiently today, but can be used in the greenhouse to heat up the air with a heat exchanger from the biogas production. To ensure the power supply fully in the building, it will also be able to use long-distance heating and cooling functions from Tekniska Verken.

2.4.1. The process from seed to harvest

Within the greenhouse, crops will be cultivated using a hydroponic growing technique (see Chapter 3.X) with advantages of increased control, yield and cleanliness. Hydroponics is also used in order to eliminate the need of transporting large amount of soil to and from the building.

Plantagon has chosen to use pumice as a growing medium, mainly because it has a beneficial capillary effect and can be used for several years within the greenhouse system. Pumice is a volcanic rock and the result from the cooling of volcanic lava in water. It has good air porosity that can absorb nutrients and render them available for plant absorption (Nationalencyklopedin *pimpsten*, 2013).

Cultivation process

The cultivation process, is divided into three steps, mainly to minimize the risk of contamination. In the first phase of the cultivation process, during the steps

3 Stefan Jakobsson (Manager Business Development, Tekniska Verken) interviewed by the authors 8 March 2013.

of germinating and starting the growing process, humans will be involved. The second phase, from a seedling to a fully ripened crop, demands a more controlled environment with minimized direct human involvement why robots will hold a key function. Due to the cleanliness, it is possible to avoid the use of pesticides. The final phase is the harvesting, where humans will be involved again. None of the process phases will be completely sterile because ecosystems will emerge and contain microorganisms, which however could be positive for the yield.

Further on, the seedling that has been seeded in a pre-germination chamber, will be placed in a pot with holes in the bottom, containing pumice. The pot will be placed on a tray, which in turn is sent up in an elevator to the top of the building, where it is placed on a track to be slowly transported down the helix. At the bottom, the now ripened crop will be harvested, and the trays as well as the pots will be disinfected and prepared for replanting. The process for a tray to move down the helix and a seedling to grow to a crop that is ready to be harvested, will take approximately 45 - 60 days.

Due to the art of the process, the only possible crops to grow are non-perennial ones that can be harvested in its whole; therefore it is impossible to grow e.g. tomatoes or strawberries. Furthermore, the cultivation cannot be classified as organic according to the European Union's statutes on greenhouse cultivation, requiring that the substrate is biological active, i.e. soil and not pumice (Winter and Ascard, 2010).

Since no soil will be used, the plants will receive mineral salts from the water and nutrient solution added. The watering system has not been entirely set at the moment of writing but the general idea is that water and nutrients from a controlled and closed loop will be filled in the trays within intervals. The water that is not absorbed by the medium will be poured away and reused.

Choice of crop

Since the Swedish greenhouse will be a reference building to the future ones that are to be built in Asia, Plantagon has decided to initially try out the one in Asia popular and nutritious crop - pak choi (Figure 2.5.).

Pak choi, also called celery cabbage, is a Chinese type of salad that can be eaten raw or heated (Nationalencyklopedin *sellerikål*, 2013). It is a crop with the length of 10-15 cm with white succulent leaf stalks and softer and thinner dark green leaves.

It has its origin in China and Japan, and was introduced in Europe in the 1980s. According to Fredrik

Figure 2.5. Pak choi

Önnevall[4], pak choi is often mistaken as Chinese cabbage howsoever there are some differences between the two crops. In the recent decades, with increased availability of refrigerators, the more sensitive one - pak choi - has taken market shares from the more durable Chinese cabbage that can be stored for longer periods without refrigerating. Though, Önnevall explains that this has its reasons, since pak choi has a more convenient shape and is richer in flavor than its "precursor".

4 Fredrik Önnevall (Journalist) interviewed by the authors 21 February 2013.

3. Theoretical background

This chapter presents and summarizes research that has been used as a background to investigate the consumer relation to crops produced in the vertical greenhouse. It puts the greenhouse production in a larger context that is necessary to be able to address the project's research questions. It covers the fields of The global food situation and Industrial production of crops.

3.1. The global food situation

To vertically produce food in cities is viewed by Plantagon as one measure in its mission to provide enough food and good food for as many people as possible. Accordingly it is relying on an existing and predicted demand for space efficient and local ways of producing food in urban environments with minimized environmental impact. The following section investigates if current theory points towards such a demand for new and different ways of producing food.

The global food situation is an issue in today's society. The vast majority of people suffering from malnutrition live in developing countries, where about 850 million people or slightly fewer than 15 % of the population are estimated as undernourished (FAO, 2013). How this issue will evolve into the future in relation to the world demographics, is a highly debated subject. It is foreseen by some that it will be a crucial issue the coming decades and that we must develop our production and/or change our consumption to meet an increasing food demand (FAO, 2009). To get a common definition and a tool for these issues the term *food security* was defined by World Food Summit of 1996. Food Security exists when "all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (WHO, 2013).

Notable is that the forecast for food security the coming decades recognizes that economic growth including productivity increases will help to fight the deprivation and malnutrition. There will, according to the forecasts, be a food security gap also in the year of 2050 but it will not be as severe as today. It is expected that the number of undernourished will fall from 868 million in the years of 2010-2013 (FAO uses three year averages in its calculation of undernourished people) to 370 million by 2050 (FAO, 2009; FAO, 2013). To reach this improvement FAO (2009) estimates an increase with 70% in the overall food production from 2005 to 2050. Higher yields and intensity in cropping is expected to cover 90 % of this increase, while the rest comes from land expansion (FAO, 2009). However, FAO (2009) suggests that production increases are not sufficient to ensure food security for everyone, the access to food of the needy and vulnerable groups in the society must also be improved. It is stated by FAO (2013) that to succeed with ensuring nutrition to the most needy, they must both be reached by and participating in the production growth processes. In addition to this, as much as 75% of the poor in developing countries live in rural areas and most of them depend on agriculture for significant parts of their livelihoods. It is further claimed that "agricultural growth involving smallholders, especially women, will be most effective in reducing extreme poverty and hunger when it increases returns to labor and generates employment for the poor". (FAO, 2012)

In the forecasts of the future food security, the impact of urbanization is an important aspect. The reason for this is that urban dwellers are in general net buyers of food (buys more than sells), which affect the supply and demand balance and make them vulnerable to price fluctuations. Furthermore, if the cities fail in absorbing the increasing number of inhabitants, slums may develop and threat the food security further. Since slums are low-income and overcrowded areas that often lack infrastructure and basic services, this phenomenon may create an increasing number of urban poor that are vulnerable to changes in food prices (Matuschke, 2009). The population in urban areas is expected to grow with 2.6 billion people the coming four decades, and urbanization is forecasted to continue with an even higher pace with

70% of world population living in urban areas in 2050 compared to 49% in 2009 (ESA, 2012).

In addition to this, some studies stresses that agriculture is very sensitive to climate changes and higher temperatures may reduce yields from the increased productivity and encourage weeds and pests (Padmavathy and Poyyamoli, 2011). Finally it is concluded by FAO (2009) that food security is a very complex issue and that there are different opinions, questions and expectations to be found.

3.1.1. Environmental impact

There are many variables affecting the total assessment of the environmental, social and economical impact, agricultural production and consumption has. It is therefore difficult to determine what method or strategy that is more or less beneficial for an overall sustainable development (Foster, et al., 2006). For example, evidence determining if locally supplied/consumed food results in a totally lower environmental impact is weak. There are too many unknown variables and it is actually assumed today that for some food, global sourcing is actually better for the environment, depending on local factors such as water supply, energy access and weather conditions. Another example observed by Foster, et al. (2006) is that the environmental impacts of car-based shopping are greater than the transports within the food-distribution system and even if the airfreighted products have a severe impact the proportion of these products are very small. Nonetheless, today's industrial agriculture has had and still has a great environmental impact where the main issues are according to Padmavathy and Poyyamoli (2011) degradation of water and soil quality, negative effects on the ecosystem services and biodiversity, global warming and use of natural resources, and direct health hazards for humans and animals.

3.1.2. The Swedish crop market

Since Sweden is not a developing country with cramped mega-cities, the vertical greenhouse would have to meet other demands here.

Sweden's vegetable production is to a high extent steered by the climate, but even though the use of greenhouse productions is increasing, many vegetables are still imported. The arable land in Sweden accounts for approximately 7 % of the total land area (FAO, 2001). The rate of self-sufficiency for fruits and vegetables is 20 %, but differs a lot between product groups and seasons. For example, while Sweden is 92% self-sufficient for carrots, products like bananas and citrus-fruits are 100 % imported. When it comes to the domestic production of vegetables and fruits, 35 % is greenhouse produced. The most important vegetables for greenhouse production - cucumbers and tomatoes - are actually stagnating, while potted lettuce and herbs are increasing their market share. The areas for vegetable field crops have remained more or less the same for 20 years, even though a structural change has occurred and increased the cultivated area per grower more than the double (Jordbruksverket, 2008).

The geographic location of the production is mainly located in the southern parts of Sweden. 62 % of the field crop area for vegetables was in the year of 2005 located in Skåne and Blekinge (Jordbruksverket, 2008).

Organic food demand

The organic market in Sweden has grown the last couple of years and the overall organic market share is 3,5 % of total foodstuff sales (Ekoweb, 2012). A Swedish market characteristic, is that organic products are predominantly sold through supermarkets, which therefore - especially the larger ones - have a relatively wide range of organic fruits and vegetables (FAO, 2001).

Among the leading retailers in organic crops, limited and irregular supply is seen as the main constraint for further expansion of the market. In order to increase the market, not only are more suppliers needed, but also suppliers that can provide their products during more than one season. (FAO, 2001)

3.2. Industrial crops cultivation

There are many different ways to grow crops although the basics of plants remain the same. The vertical greenhouse farming will use a technique called hydroponic cultivation. This is a method that is widespread and gaining ground for the industrial greenhouse production all over the world. Nevertheless very few consumers know that crops they consume are grown this way. This section aims to describe the basics of cultivating a plant and investigate how hydroponic cultivation is used today, and what challenges the industry acknowledges.

3.2.1. Basics of cultivation

A plant can be divided into four different parts; root system, stem, leaves and flower. All of these are essential for the plant and are needed for its growth. The *root system* attaches the plant in its growing medium and absorbs water and mineral salts that is in contact with the fine root hairs through semi-permeable cell walls. The *stem* connects the roots with the leaves and conducts water and nutrient elements. Within the *leaves*, the photosynthesis takes place; chlorophyll transforms carbon dioxide and water to simple sugars in the presence of sunlight. The leaves also serve a cooling purpose since they have pores, which are the gate for carbon dioxide and oxygen and from where the water evaporates to the atmosphere. Lastly, the *flower* is made for reproducing. (Harris, 1992)

Necessary for a plant are 14 essential nutrients: six macro substances and eight micro substances. Macro substances are needed to a larger extent than micro substances, and if one is lacking, the growth of a crop will be negatively affected. (Jordbruksverket, 2004)

3.2.2. Hydroponic cultivation

Several different elements and conditions play part in making cultivation more or less successful. One of these conditions is the growing medium. The perhaps most commonly known cultivation medium, soil, is to a great extent (in industrial farming) replaced with other mediums. This is something made possible by using hydroponic growing techniques.

The definition of hydroponics is by Encyklopedia Britannica (2013) "the cultivation of plants in nutrient-enriched water, with or without the mechanical support of an inert medium". The term derives from the Greek words hydro and ponos, where hydro means water and ponos means labor. The use of water culture for growing crops has a long history, but the commercial introduction of hydroponics can be linked to 1930s Professor William Frederick Gericke that promoted nutrient solution to be used for agricultural crop production. (Harris, 1992)

Hydroponics can be divided in two main categories; water culture and soilless/aggregate culture employing solid mediums. There are several types of substrates used as solid medium and also many different techniques for irrigation. For sub-irrigation the nutrient solution is delivered from below and absorbed upwards. Gravel sub-irrigation is the most efficient type of hydroponics for commercial purposes, and is practiced by many commercial growers. It means that the nutrient solution is percolated through the gravel type medium (e.g. through pumice as in the case of Plantagon) and the excess solution is collected for recycling. For top-irrigation, the water is delivered from above and absorbed downwards. (Harris, 1992)

There are many differences that likely will affect and differentiate the result from a hydroponic cultivation compared to a soil-cultivation. The hydroponic one allows a more controlled environment than growing in soil, since it is easier to control the level of nutrients and the PH value in a water based solution. Hydroponics may also result in a more uniform and better yield as the optimum combination of nutrients can be provided for all plants. In soil, many factors such as temperature, oxygen level, moisture and microorganisms affect how the soil-fixed nutrients are made accessible to the plants, since the nutrients are being dissolved in water through erosion and mineralization (Bierman and Rosen, 2005). Another benefit of hydroponics is that it offers a cleaner process, because no animal excreta is used, the medium is sterile and because of the possibilities to control that no harmful substances such as heavy metals have access to the plants. (Harris, 1992; RIRDC, 2001)

The use of hydroponics in industrial agriculture is widespread and growing. Its advantages are marketed as (compared to traditional cultivation in soil) a less labor-intensive way to manage larger areas of production, higher efficiency in controlling pest and diseases, lower demand of water and chemical usage, higher yield and a possibility for all year round production (Harris, 1992). In a study performed in 2001 (RIRDC, 2001), examining hydroponics as an agricultural production system, its role today and future trends, it was found that Australian growers felt a reluctance to market their produce with a hydroponic label. This is also the case in several European countries, e.g. Holland has a production covering more than 50 percent of all fruit and vegetable cultivation in the country. One reason of the reluctance towards hydroponic cultivation revealed in the study, is that there is an increasing pressure for vegetables that are produced without chemicals and in harmony with nature and that there are perceptions in the society that a hydroponic production is not natural and *"dependent on the use of chemicals"*. The writers of the study highlights the importance of using quality based marketing, e.g. flavor, appearance, freshness, or changing and increasing the understanding consumers have of the beneficial qualities of hydroponic produce, so that the production method does not become a problem for the producers.

3.3. Conclusion

Obviously there will always be a demand for food; the question is though where the vertical greenhouse will fit in the supply-and-demand balance. Will there be a clear need for urban produced food that pushes the adoption of the greenhouse, or will it be necessary to spread this new production idea and even create the need for it?

As a conclusion from the theoretical background it is possible to say that there exist a food security issue in the world, however it is of a complex nature and it is difficult to distinguish the specific interventions that would improve the situation today as well as how the future will evolve. Nevertheless, it can be concluded that the future food supply depends on an increased productivity and that the vertical greenhouse can be seen as one of these efficiency measures to be taken. This production method aims to have a very low environmental impact and will be placed right in the urban landscape, and could therefore be better than the environmentally harmful agriculture that exist today. However, the people in most need of more and better food are the poor, often living in slums. This makes it important for Plantagon to try to reach out to these areas in order to fill a food security purpose, something that puts high demands on the distribution system. The matter becomes even more complex with the poor rural inhabitants' incomes being highly dependent on rural food production. Hence it is a difficult compromise to increase the productivity in the city without negatively impacting the traditional rural farmers.

An interesting conclusion to be made from the theory regarding the Swedish vegetable consumption is that, since Sweden to a very high extent imports its crops, the consumers can have a relatively sparse knowledge of and relation to the production simply because it is situated geographically far away. This could mean that a local production method would be well embraced just because it is local. However, it could also due to ignorance create skepticism to producing food industrially, even if it is very common in other production countries supplying Sweden with crops today. Nonetheless the trend in Sweden is at the moment an increasing demand for organic produced food, and the industry needs more suppliers that can provide organic products throughout the seasons. This indicates an interest in sustainable crops that could favor Plantagon on the Swedish market.

4. Framework

In this chapter the theory used as a foundation for the design process, as well as all methods and tools used throughout the project are being presented.

4.1. Adoption of innovations

New ideas for growing food will, as all new ideas, need some time to be adopted into a social system. This section aims to investigate what aspects that could affect the rate of adoption of innovations in general, and if there are any specific aspects to consider when it comes to new ways of producing food.

4.1.1. General adoption of innovations

It is difficult to incorporate a new idea in a social group even if the advantages of the innovation are obvious. Plantagon has a vegetable production facility with a new kind of technology and, in addition to this, they bring the before rather remote vegetable production into the city. This makes it possible for consumers to meet both new technology but also already established production methods that before only have been known by staff working in the greenhouses. Due to this, Plantagon's production and outcome can be seen as an innovation that has to be adopted by individuals in a social context.

There are often years passing from an innovation being first introduced to it being adopted widely. The diffusion of innovations is thus an important area to consider when trying to spread an innovation. The innovation development process in an organization is often driven by technological information exchange with competitors, governments etc. It is also driven mainly with anticipations of the potential adopters' problems and needs, which is why the process faces a high degree of uncertainty. In addition to this, many innovations result from research and are thus, from the beginning and throughout the launching, relatively scientifically packaged. (Rogers, 2003)

Innovation Diffusion Model

To handle this uncertainty, Rogers (2003) presents an innovation diffusion model. In this model, diffusion is described as the communicative process by which information about a new idea is created and shared over time to the members of a certain social system in order to reach a mutual understanding. Diffusion is thus, a social change that occurs from the consequences when new ideas are invented, diffused, and adopted or rejected.

In the diffusion model, an innovation is described as an idea, practice or object that is perceived as new by an individual or other unit. A technological innovation usually has at least some degree of benefit for its potential adopters. However, this is not always clear for the intended adopters when they first learn about it. Instead they often hold an uncertainty about possible consequences if they would adopt the innovation. Therefore, individuals seek and process information to reduce uncertainty about advantages and disadvantages of innovations, and typical questions asked by the individuals are: "What is the innovation?", "How and why does it work?" and "What will its advantages and disadvantages be in my situation?". (Rogers, 2003)

Further on, the model suggests that several characteristics of innovations can explain different rates of adoption:

- *Relative advantage* - the better an innovation is perceived, compared to the idea it supervenes, the more rapid rate of adoption.
- *Compatibility* - the more consistent an innovation is, with an individual's values, experiences and concerns, the higher rate of adoption.
- *Complexity* - the more difficult to understand and use an idea is, the lower rate of adoption.

- *Trialability* - the higher the possibility to learn, by trying the innovation, there is, the higher rate of adoption.
- *Observability* - the easier it is to see the result of an innovation, the higher rate of adoption.

Since diffusion to a high extent is a communicative process, the channels of communication become crucial in the adoption of the innovation. These channels represent the means by which a message gets from one individual to another. Mass media channels are usually the most rapid and efficient channels to inform about a new idea. However, interpersonal channels involving a face-to-face exchange are more effective in persuading an individual to accept a new idea. Research has shown that most individuals judge the innovation on subjective evaluations conveyed from individuals like themselves, with for example similar economic status and education, which already has adopted the innovation. Diffusion is a very social process that involves interpersonal communication relationships. It is also notable that interactive communication through the Internet is becoming increasingly important. (Rogers, 2003)

The structure of the social system also has a high impact on the diffusion since it impacts the communication abilities and since the system norms and leaders can form peoples' attitudes to the innovation. Naturally, the people intended to adopt a new idea affect the rate of diffusion as well as the strategy needed to increase adoption, and the characteristic differs; some individuals are relatively early in adopting new ideas compared to other members of a system. Rogers (2003) concludes that it is possible to generalize members in a social system into groups with relatively similar characteristics amongst the other members. These categories are: *innovators*, *early adopters*, *early majority*, *late majority* and *laggards*. The procedure of the different categories adopting an innovation can be described as a S-shaped curve. Typically, a few individuals, the innovators, adopt the innovation first. The curve climbs when more individuals adopt the innovation, and levels off as fewer of those who haven't adopted it, remains (laggards).

Adoption decision process

Individuals' decisions about an innovation can be described as a process with several actions and choices. In this process the individuals are dealing with an uncertainty that is inherently involved in deciding about a new alternative. The nature of this process is described by Rogers (2003) as containing five stages; knowledge, persuasion, decision, implementation and confirmation.

In the *knowledge*-phase, individuals acknowledge an innovation's existence and understand how it functions. Important in this phase is the notion that individuals tend to expose themselves to ideas that are in accordance with their interests, needs as well as existing attitudes, and ignore others. However, Rogers (2003) suggests that for many ideas the innovation may create a need for it. Further on, he describes three types of knowledge: awareness knowledge, how-to knowledge including "how do I use the innovation" and principles knowledge meaning information about the principles underlying how the innovations works. Rogers (2003) also claims that *"it is usually possible to adopt an innovation without principles-knowledge"*, but misunderstandings and trouble in judging may occur.

Persuasion is a formation of a favorable or unfavorable attitude towards the innovation, and a stage in the process that involves a great deal of "affective thinking and feelings". An individual wants to know what happens if the innovation is adopted, to reduce the uncertainty. Following, the *decision*-phase is an engagement in activities that lead to a choice to adopt or reject a new idea; adoption is a decision to make full use of an innovation. One way to handle the underlying uncertainty about an innovation's consequences is to try out the new idea. In fact, most individuals do not adopt without trying on a more or less small-scale basis to determine the innovation's usefulness. However, some innovations cannot be divided for trial, therefore they must be adopted or rejected in toto. It is further suggested by Rogers (2003), that methods to facilitate trial of innovations, like free samples of a new idea, will usually speed up the rate of adoption. *Implementation* is to put an innovation into use and is a step requiring a behavior change. Lastly, *confirmation* is when individuals seek reinforcement of the decisions.

4.1.2. Adoption of new food innovations

A new food innovation puts the technology behind in a very personal relation to an individual that is to eat the produce, which naturally impacts its adoption. In an article about trends in food technology Belton (2001) reasons about how adoption of new innovative food production is affected by cultural, ritual and personal dimensions. First of all, to put food in one's mouth is something very intimate and what you eat actually becomes a part of you. Perhaps the notion of this and the economical ability to be selective has created a trend in today's society of highlighting the source of the food, and actually forming a new vocabulary around it. Here Belton (2001) claims that terms as "natural", "organic" and "free range" perhaps relate more to the ritual in how the food has been produced than the actual content. It is thus, further suggested by Belton (2001), possible to see that attitudes to food are very much related to consumer's worldview rather than a merely scientific assessment of the foods nutritive value.

Another important aspect to consider when discussing new food technology is regulations. It is argued that, by Lobb (Mazzocchi and Traill, 2007), trust in labeling and regulations can overcome some concerns consumers have. For example, they suggest that *"perceptions of unnaturalness"* alone will not create public rejection of a food technology since trust in regulations and labeling can overcome the concern. Different technologies also create different worries; in a review of seven food technologies, those that were characterized as "bioactive" created special concerns since they were related to uncontrolled use, ethical problems and unpredictable effects.

Even if the society has regulations, they risk becoming hollow with the food industry experiencing an increasing number of food safety crises. As a consequence of this, consumers are subjects to a large amount of information about food hazards from media, governmental and consumer organizations. Problems related to this are according to Lobb (Mazzocchi and Traill, 2007) in-ability for consumers to make an assessment of the risk, increased uncertainties, lack of trust and doubts of new food technologies. Research in Sweden has shown that consumers want to reach a higher control of food safety by preparing the food from the start by themselves, but since they don't have the time nor the knowledge to do so fully, food safety becomes a worry for them (Wikström, Hedborn and Thuresson, 2010). It is further stated by Belton (2001) that consumers tend to create safety concerns both from the process and the outcome of food production; aspects such as wellbeing of workers, pollution and effects on the environment, as well as one's personal health are considered when judging new food technologies.

Skepticism about new technology in relation to food production has been identified in different studies (Bruhn, 2008). A reason to this doubt might be that consumers (research conducted in Europe and USA) associate a low technology approach with health as well as environmental sustainability. Likewise, in a survey in the United Kingdom, Germany, and France it was found that the perception of personal benefits and environmental friendliness were the most important factors affecting likelihood to purchase products processed by an innovative method.

In a research study in Sweden stretching over several years (Wikström, Hedborn and Thuresson, 2010) it is concluded that Swedish consumers have worries about food concerning treatments, additives, production conditions as well as that industrially produced food is not nutritious. It is further notable that commonly consumers do not know details of how food is grown, harvested, processed or distributed, and that they actually don't ask for new technologies (Bruhn, 2008). Instead the consumers expect the food industry to deliver products that are beneficial for their health and the surroundings. It is also notable that price is a very important aspect; (Wikström, Hedborn and Thuresson, 2010) concluded that Swedish consumers have difficulties in evaluating the relationship between price and quality and often make their decision based on primarily price. However, other aspects are also important and perhaps starting to challenge the price. In an article about consumer perception and choice of minimally processed vegetables (Ragaert, et al., 2004), it is concluded that convenience is a driving force in today's vegetable and fruit market, leading to the conclusion that innovation should be driven by providing high-quality and fresh products and still maintain convenience and health benefits.

Another important consideration in the adoption of food produced with new technologies is that the information consumers receive, highly affects their attitude and knowledge (Bruhn, 2008). As Rogers (2003) suggests, when an individual decides about controversial or complex questions, he or she will likely be influenced by trusted people or organizations that knows more about the underlying technology. This is also highlighted by Bruhn (2008), whom is also claiming that endorsement by experts having respect in the specific social context, can increase the acceptance of food produced with different methods. The information channel used, should mirror the target group and with benefit be varied to reach different consumers. In addition to this, the information dimension should be advanced to include a two way process to reach communication with the consumer. It is suggested by Bruhn (2008) that effective communication involves listening, identifying, and responding to consumer questions and relating this to the innovation.

4.2. Methods and implementation

In this section the theory and implementation of the different methods that have been applied throughout the project are being described, and are presented according to when they were initially applied.

4.2.1. Planning and structuring

The initial phase of the project included planning and structuring. A Gantt chart was created to achieve an overview of deliveries and the different phases, and acted as a structure throughout the project (Appendix I). A planning flow chart was formed to enlighten the different phases in the project as well as the need for iteration (Appendix II). The visualization of the flow chart link the different phases of the project to each other and was used as a communicative tool, simplifying the description of the project process for Plantagon. A more detailed planning with weekly and daily deliverables as well as meetings and appointments were also created to structure the most current activities.

Gantt chart
A Gantt chart is a simple method to, in the early phase of a project, map activities and time against each other to achieve a quick visualization of the project's time limits and the start and end of different activities. In the chart activities and time constitutes the y- and x-axis of a regular coordinate system. Each activity represents a horizontal line and the length of it represents the durance. (Johannesson, Persson and Pettersson, 2004)

Flow chart
A flow chart is a graphical diagram, describing a process using geometric figures linked to each other with lines or arrows (Mind Tools Ltd, 2012). The chart may through its implementation describe the relation between processes or tasks to determine which of these must be completed before entering the next project phase.

4.2.2. Data collection and Analysis

Data collection is aimed at gathering information from users, experts and relevant theory. Further on, the data is analyzed with different methods in order to find underlying reasons and relations.

The user studies should focus on identifying spoken as well as non-spoken user needs, giving information for product specification, and allowing a common understanding within a development team. The aspects of who the consumer/user is, why the product is needed, where the product shall be used, and what the current product consumer relation is, should be encountered for during the data collection. (Ulrich and Eppinger, 2008)

In order to map user needs and demands, an extensive user study was performed in the project. It was initiated with a survey and finalized with in-depth interviews.

Questionnaire-based survey
A questionnaire-based survey is a structured survey built up by a list of questions with fixed or open-ended responses. The method allows an easy and fast data collection processing and analysis, and is multifaceted in a manner that it can be used in all phases of a product development project. It can also reduce bias that can come from the direct contact with an investigator. However, the method is not very flexible, and it can be difficult to create engagement among the respondents and achieve enough responses. Questionnaires often encounter a low return rate, which is a problem since it could mean that the sample of people answering is not representative for the population investigated. It is suggested by Jordan (1998) that people that complete a questionnaire often are those with relatively extreme standpoints.

A survey was performed to get a holistic overview of consumers' thoughts and views of vegetable production and consumption. The survey was Internet based and covered nine questions concerning crops and vegetable purchasing habits; all of which had fixed answer alternatives with room for comments. The formula was sent out through a social forum to some 500 people and had 100 respondents. Mainly, the respondents were in the ages of 20 - 35 and approximately 50% of them are living in Gothenburg and 95 % are living in a Swedish/European city.

Unstructured interviews
The qualitative data collection method in-depth interviewing allows the user to elaborate relatively freely about a subject and provides an understanding of the consumer emotions, attitudes and reasoning. This is thus a good method to acquire understanding of how and why individuals' attitudes towards a subject have been formed. (Lantz, 2007; Kvale 1997)

There are two important dimensions to consider when choosing participants. First of all, the number of interviews necessary to identify most of the consumer needs have to be decided. Naturally this depends on the context, but even so there are different opinions in the area. Griffin and Hauser (1993) propose a span between 20-30 interviews in order to identify 90-95% of the consumer needs, while Kvale (1997) proposes a span of 15±10. Moreover, Guest (Bounce and Johnson, 2006) suggest that 12 interviews are enough if the target group is relatively homogenous. A similar conclusion is made by Nielsen and Landauer (1993), suggesting that six participants can identify 80% of the main usability problems within a system, and with twelve the amount of needs usually levels of at 90%. The adequate number of interviews can also be identified by, instead of anticipating it, detecting the saturation point when further interviews do not signal any new needs (Ulrich and Eppinger, 2008). The second dimension is the qualitative, that encompasses on what criteria the participants should be chosen, and to achieve a valid result the participants should be representative in regards to the investigated population. (Jordan 1998)

To achieve a deeper understanding of the consumers' attitudes, values, emotions, and behaviors towards crops grown industrially and in greenhouses, an in-depth interview study was performed. The aim was to interview twelve respondents, but one of the interviews was cancelled. Since a saturation point had been reached the study finally encompassed eleven respondents, ranging between the ages of 20 to 65 and evenly distributed between the genders (Appendix VI). The selection was chosen on the basis of being theoretically representative for the target group and consists of individuals living, studying and/or working in the city-centers of Linköping, Malmö, Gothenburg, and Stockholm. The interviews took between 35 minutes to more than one hour to complete, depending on how much the respondents elaborated around different topics. All interviews were individual, but followed a predefined question formulary (Appendix V) in a semi-structured way. Some of the interviews were performed with two interviewers, where one mainly took notes, and some with only one.

Literature studies

The purpose of literature studies can be to describe a current state of knowledge but also to collect knowledge within a specific field (Bohgard, et al., 2008). In this project, the initial phase of the literature study was reviewed on a rather broad basis to achieve a holistic approach as well as a clue of already existing data, regarding e.g. consumer habits and vegetable consumption that could be used in the analysis phase. Later on, a more narrowed literature study was performed, in order to confirm the data from the user studies and learn more about adoption of new innovations, which was to be used as a theoretical basis for the concept development and evaluation of the project.

Research reliability and validity

Research reliability is a measurement tool to determine the consistency of a result. The consistency concerns whether the same results are produced from different samples of a population and to which extent an instrument measures the same way each time it is used under similar conditions and with the same subjects. Validity refers to if the degree of a result from a study is generalizable to a population, as well as if the instruments have measured what they were intended to. Further on, validity also concerns whether the interpretation of the findings is correct or of more or less high quality. (Hernon and Schwartz, 2009)

System mapping

In a design process a higher level of abstraction is important to understand the product in a system, and how it is affected by and affects other parts in the system. System mapping can thus, be applied by using pen and paper and investigate and visualize the different parts and their relations. System thinking emphasizes that the "whole can differ from the sum of the parts" and that important insights may come from the understanding of interaction and relation of parts, functions and stakeholders. (Gharajedaghi, 2011)

Different systems have been used throughout the project, to achieve a deeper understanding of the context and to keep a holistic approach. In the initial phase, such a system was mainly used to understand the context, parts and stakeholders that affects Plantagon's relation to the customers (Appendix IV), while systems later on were used to analyze and communicate results from the data collection. The system mappings have initially been conducted by using pen and paper to relate different parts to each other. However, to make the result more communicable they have been translated and refined in different software programs.

Clustering

Clustering is a method that is used to group and sort large amount of collected data. It is realized by relating and grouping the data based on some characteristics that is chosen for the specific project. One way of performing the method is to have quotes from interviews written on paper, to sort and group them, and lastly name the groups with appropriate names relating to what the notes in the specific groups explain. The method is a bottom-up analysis that by departing from the details, combining and developing them, conclude in a holistic view of the result (Hycner, 1985).

In order to group and categorize the large amount of data that came out from the survey and interviews, two clustering sessions were performed and later on merged into one. Quotes from respondents were printed and grouped in several and different compositions (Figures 4.1. & 4.2.), in order to find the most appropriate ones describing the main problems and needs.

4.2.3. Design requirements

To create a tangible and communicative link between the result from the data collection analysis and the conceptual design process, the two methods of mood boards and personas were applied to create design requirements.

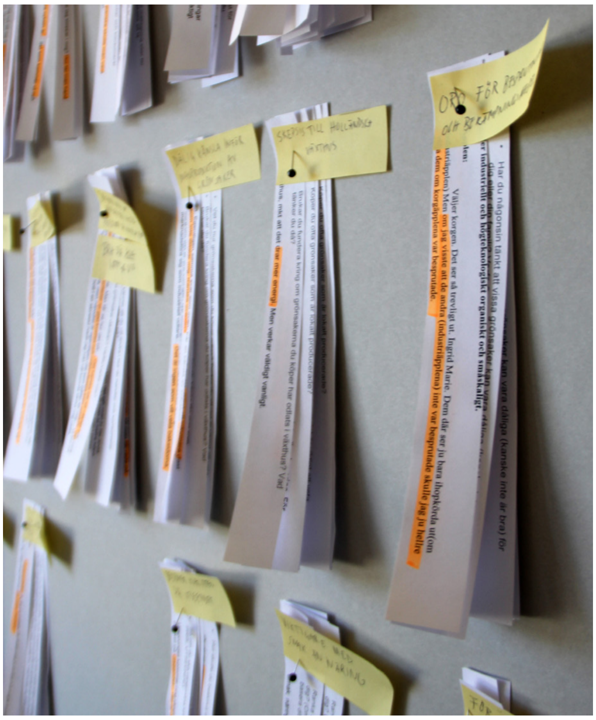


Figure 4.1. Clustering groups

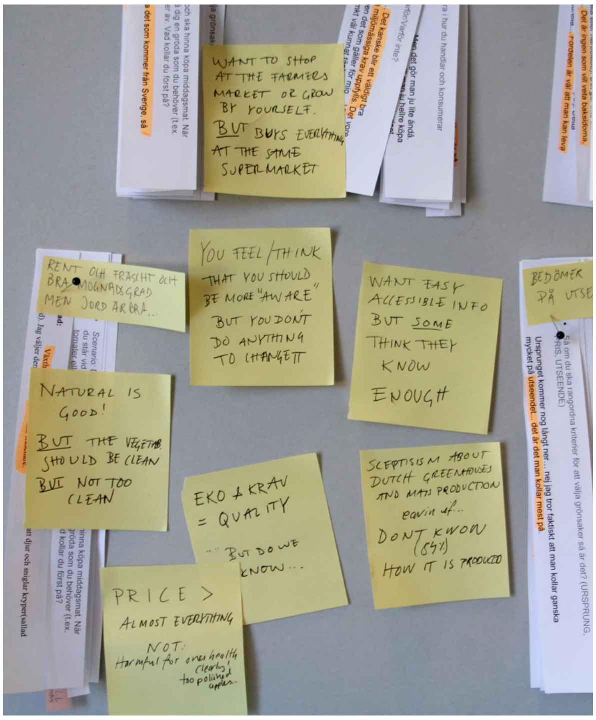


Figure 4.2. Clustering notes

Mood board

A mood board is a collage technique used to describe ambiance and feelings, as well as other more intangible values for something. It can be built with images, texts, colors etc. with the aim to document and communicate intangible values. Mood boards can be used to describe different situations; as a tool in ideation and in a later stage of a design process as guidelines to steer the work in the right direction. (Baxter, 1995)

In order to specify and be able to use and discuss Plantagon's values, an initial mood board was created. The mood board, describing what Plantagon wants to communicate to consumers, but also what the consumers likely should associate Plantagon with, consist of a combination of words and images (Appendix VII). In addition to six predefined Plantagon values, three words identified as important in the consumer communication were added. The mood board was created for the purpose of being an analysis tool, but also to simplify communication with Plantagon in confirming the interpretation of the company.

Persona

A persona is a fictive user profile that is thoroughly composed and is used as a representative for a larger group of user goals, needs and personal characters. The purpose is to convey knowledge about the user and the context, and to offer a common image of the specific product's users. Giving the persona specific characteristics like age, accommodation, habits and name can vivify it. (Goodwin, 2005)

Naturally the number of personas that should be used varies with different projects. Adlin and Pruitt (2010) suggests that roughly three to five personas are suitable. It is further stressed, that the personas should be relevant in relation to product and business goals, it should be clear what information they are based on and they should be "engaging, enlightening and even inspiring to your organization". A persona should thus pinpoint the important and relevant user data that are related to the product being created.

To be able to communicate the result from the user study performed in this project and to use it in the concept development phase, four categories of consumers were identified. Within each one of these categories one persona was created to describe the characteristics of the users, in that specific category. The personas that were created are constructions combining several identified user characteristics in order to include as many users as possible, which means that the majority of the users don't hold all of the characteristics each persona include, nor to the same extent. The personas were created both to communicate initial findings from the research and to, during the concept development phase of the project, have thorough descriptions of the users that could be used as support and guiding.

4.2.4. Conceptual design process

Different methods and tools have been applied to spur creativity and to ease the idea generation.

Brainstorming

The purpose with brainstorming is to generate as many ideas as possible, hence quantity is more important than quality and the ideas can vary a lot. Further on it is encouraged to think outside accustomed habits and ideas, an unrealistic idea can be a way to another solution. It is thus important to not criticize ideas from other participants, but rather further build on them or use the ideas as sources for inspiration. The method is often realized in groups where simple sketches or small texts are visualised on a paper and shared with the others in a team. (Michalko, 2006)

In order to generate an extensive number of ideas, several brainstorming sessions were held, and mainly conducted by simple sketches with pen and paper. Some of these sessions were structured with a clear problem description and goals, while some were more unstructured.

Focus group

A focus group consists of a number of participants gathered to discuss a particular subject. A discussion leader is setting the agenda of the discussion, which should be rather loose in order to allow for the participants to steer the discussion in wanted direction. The focus group can be used in any instance of the product development process to gain new and often unanticipated information about issues or opportunities. (Jordan, 1998)

In the concept development phase, a focus group was used to evaluate early concepts and get insights that could spur new ideas. The six participants, including the two from the project group acting as moderators, are all student peers at the Industrial Design Engineering department at Chalmers. A brief summary of the project was given and a question describing what the aim.

Benchmarking

To identify gaps in the market and to be inspired and learn from others, benchmarking is a valuable method. It can help a company to identify strengths and weaknesses in relation to a competitor, but also act as a way to get new ideas. There are several ways to benchmark; a rather cost-effective and easy to-implement method is to collect and analyze data from the public domain about existing and comparable products and/or processes. Another way is to conduct interviews or surveys to map out consumers' opinions to existing comparable products. (Stapenhurst, 2009)

Benchmarking of different urban farming products and services was conducted in order to be inspired, but also to discover potential gaps in the market for the concept development. Mainly the web was used to search for existing urban farming solutions, but also opinions about certain food consumption related products and/or services from the deep interviews, were utilized as an inspiration source.

Sketching and modeling

Sketching is a good way to force loose thoughts to substantialize, to simplify communication about ideas as well as to try thoughts and assumptions. A physical model can act as an evaluative and generative tool in in the same way as the sketching but with the advantage that the practical handwork can allow for other insights and ideas. It also allows the designer to evaluate volumes, haptic and forms in a superior way.

Sketching has been used extensively in the project to test and communicate ideas and concepts. The rapidness of sketching was considered very suitable for the project, however, primarily in the early phases of the idea generation. Modeling was applied in order to construct a simple cultivation system, mostly to easier understand the complexity and difficulties of such a system, but also to easier grasp what is needed to make it work and what is not.

Storyboard

As an aid to offer a common and visual language about a product and its context, storyboards can be used. It is realized by using sequential images, with or without text, which describes a situation where a user commonly interacts with a product. It is important to consider that a storyboard can be used for different purposes dependent on its visualization. A storyboard can e.g. be sketchy and open evoking comments and reactions, or detailed and closed being more convincing and focused on transmitting facts. The visualization depends on the purpose and in which process phase the method is used. (Van der Lelie, 2006)

The storyboard was used in the concept development phase as an evaluative and communicative tool. By creating a story around a concept it was possible to investigate the consequences and relations the concept would have. The storyboard was sketchy in an initial phase but developed in order to be able to communicate the user experience of the concept.

Computer Aided Design (CAD)

Using CAD is to build 3D-models with software. CAD is a great tool to visualize and explore a design, and can thus be assistive in developing and evaluating of form, colors, materials and textures, but also to prepare a concept/product for manufacturing.

CAD has been used on a conceptual generative basis to experiment with and evaluate forms but also as a finalization tool to visualize the final concept.

5. Result - Data collection & Analysis

The result and analysis of the user study is in this chapter presented and described in detail.

5.1. Survey

The aim of creating and executing a user survey was to investigate general vegetable consumption habits. The focus was to ask what consumers actually know about crops and crop production and to what extent this knowledge is important for them, but also to learn more of how consumers relate to new technology and greenhouse production. Using a survey as an initial user research method was important in order to initiate the identification of different problem areas, on which the further research and concept development should focused upon. The survey resulted in statistics that have been listed in charts and hundreds of quotes clustered within each of the nine different survey questions that can be seen in this section.

5.1.1. Question 1

- Do you know where the vegetables you buy at the supermarket are produced?

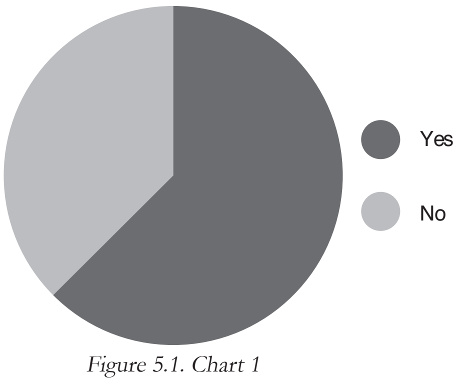


Figure 5.1. Chart 1

It was found that 63 % of the participants know where the vegetables they buy are produced (Figure 5.1.). Many of which are stating that it says on a sign or the package, and that they check the country of origin from time to time. Some of them explained that they know this and want to know because they need something to base their choices on: e.g. *"I do this because I'm interested in how long they been transported and some countries have less regulations about use of fertilizers"* and *"Sometimes, depending on what kind of vegetable. Have opposing feelings towards nutrition from eastern Europe since their history of environmental issues"*. Some of the "Yes"-respondents seems, however, somewhat uncertain of the credibility: e.g. "*Trying to keep an eye on the country of origin by looking at the label. But that can perhaps not always be trusted…"* and *"Only because I read the information given from the supermarket. But if it is credible, I do not know"*.

The most common reasons of why consumers don't know where vegetables come from can be related to laziness, lack of interest and stress: e.g. *"I guess I am too stressed while doing grocery shopping"*, *"I don't really care. Tomato, Tomaato"*, *"It probably says on a sign but I don't look"* and *"They don't tell me"*.

5.1.2. Question 2

- Do you care about where the vegetables you buy at the supermarket are produced?

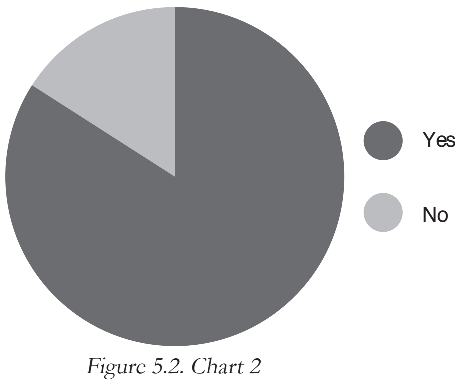


Figure 5.2. Chart 2

84 % of the participants care about where the vegetables they buy are produced (Figure 5.2.), but "only" 63 % of the respondents stated that they knew the

answer of the question (see 5.1.1.). Several comments indicated that most people wish they knew more than they actually do and this might explain why there is a difference between the answers of this question and the previous one. One of the respondents added one comment that could add to the explanation: *"I do but I don't know enough or have enough info to know how it matters"*. Perhaps knowing the origin is not enough for some people to know why to choose one box of tomatoes instead of another one.

Amongst the respondents answering "Yes", several reasons were mentioned. Locally produced crops with less transport, in order to benefit local farmers and minimize CO_2 emissions, seem to be one of the main aspects to consider. However, also other reasons such as human rights, politics and fertilizers were brought up in the comment list: e.g. *"(...) For me, it depends on season. Prefer Swedish food. Avoiding Israel of political reasons"*, *"How long they been transported and use of fertilizers (synthetic ones) - CO_2 emissions, use of fertilizers contributes to higher eutrophication etc."* and *"I don't want to support countries, which is not fulfilling the human rights"*.

The 16 % of the respondents that answered "No" added less complex comments; some seem to not know at all why they should care while others can't afford to care and a few claimed to trust the supermarkets to choose fresh and not poisonous crops for them to buy. Some of the respondents seemed nevertheless to want to care and said e.g. *"I wish I could say yes, but my behavior indicates a no"*.

5.1.3. Question 3

- Do you know how the vegetables you buy at the supermarket are produced?

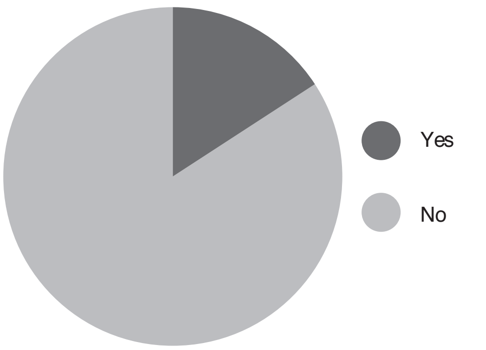


Figure 5.3. Chart 3

It was shown that 84 % of the participants don't know how the vegetables they buy at a supermarket are produced, and 16 % are stating that they know (Figure 5.3.). This is clearly a difficult question because fairly many of the respondents are explaining that they know some but seem unsure of how correct their assumptions are. Only a few explained confidently the answer of why and how they know: e.g. *"Grew up on the country, and after 7 years part time in a grocery store it´s obvious for me"*, *"I have seen some documentaries, and also been on location where some are produced."* and *"Earth -> Seed -> Water + Nutrients -> Plant -> Tomato"*.

The respondents are more or less blaming their lack of knowledge on the fact that the food stores don't show information about this on signs or packages. Most of the respondents are arguing that there is not enough information about this available, and claims more; e.g. *"Interesting. There should be more information on the package, like there is information about how the hens have it when producing eggs. (Think greenhouse / free land / under lamps and so on)"*. In the present situation the information seem to be both too difficult to find and too time-consuming to deal with.

5.1.4. Question 4

- Do you care about how the vegetables you buy at the supermarket are produced?

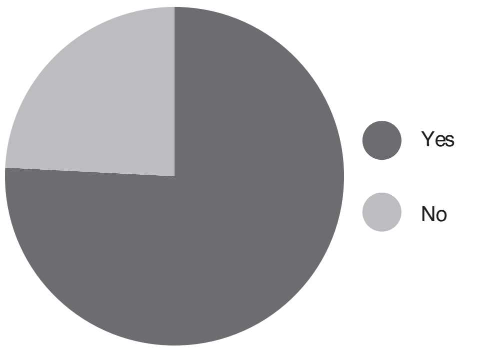


Figure 5.4. Chart 4

As many as 76 % of the respondents stated in this question that they care about how the vegetables they buy are produced (Figure 5.4.). Comparing with the 84 % that don't know how they are produced in the previous question, there is a clear gap between the answers of the two questions. Though, is "caring about" equal to "want to know"? Reading the comments gives a hint of it; many are concerned of e.g. the environment, human rights and personal health, and knowing the answer to how crops really are produced and the consequences of that seem to be one way of helping the consumers to make choices that could calm their worries. *"I try to eat sustainable food both for my health's sake and the nature"*, *"Because I don't want to consume "unnecessary" chemicals, I don't want to help fund slave-like conditions/child labor and, according to my presumptions, I want my consumption to affect the environment as little as possible"* and *"Cheap ways to produce foods equals cheap food, but it's usually the nature that pays the price. Don't like that!"*. These sentences are three examples of comments from respondents that indicate both existing concerns and wishes for more information.

All of these comments include pieces of information that require heavy headhunting today, the respondents wonder if it even is possible to find all this information somewhere or if they really have to base our choices on assumptions To overcome this, some of the respondents are stating that buying KRAV or Fair Trade-labeled products is however giving some kind of quality check of the production and is something to rely on for the present.

Most of the "No"-men clarified the importance of price and time and two of them explained the reasons of their attitudes and priorities: *"Although I know that perhaps I should care... But I don't. Lazy attitude. I try to trust that the vegetables are produced relatively "normally" at agriculture farms"* and *"I guess because I prioritize other conscious choices in the grocery store like not buying meat. And because price and quality are more important to me than production methods"*.

5.1.5. Question 5

- Which crops do you believe are the most nutritious, crops grown on a field or in a greenhouse?

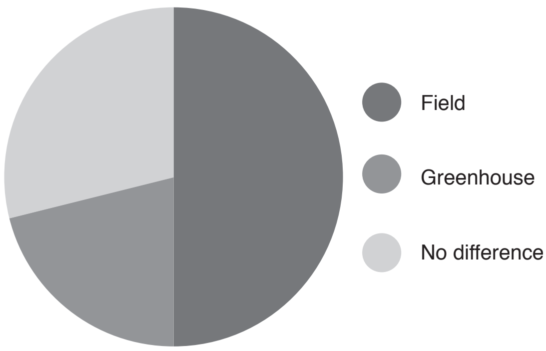


Figure 5.5. Chart 5

50 % of the respondents believe that field-grown vegetables are more nutritious than greenhouse produced vegetables. Many of which declare that it feels more natural and "right": e.g. *"(...) The crops are not being "rushed""* and *"The sun is giving the plants more energy than in a greenhouse"*. 29 % said they believe that there are no differences in nutrition between the two choices (Figure 5.5.), and stated questioningly that several conditions such as production method, production place and type of vegetable must play part in this; for example, one of the respondents said: *"It shouldn't make a difference if the gardener knows how to take care of the soil and use the right fertilizer etc. The right conditions might not be fulfilled in fields either. Optimal if less pesticides could be used and environmental condition controlled in greenhouses. Control over harvesting, even with climate change"*. A lower amount of the respondents, 21 %, believe that greenhouse-produced vegetables are more nutritious, and commented that it must be easier to screen the environment in greenhouses so that the crops can grow in a more effective and controlled way.

5.1.6. Question 6

- Which crops do you believe are richer in flavor, crops grown on a field or in a greenhouse?

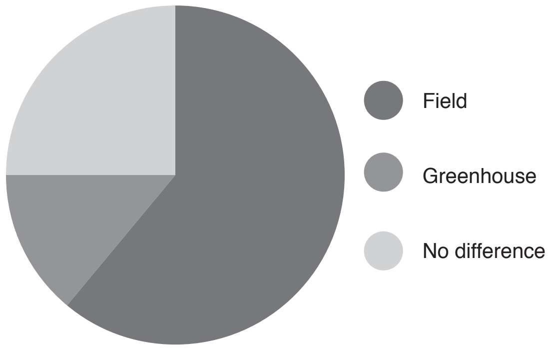


Figure 5.6. Chart 6

Regarding the level of flavor, 61 % believe that field-grown vegetables are richer than those grown in greenhouses (Figure 5.6.). Some respondents said *"Difficult question. The only greenhouse vegetables I've eaten are mass-produced and they are harvested before they are ripe and then transported, while "field grown" are usually home grown or grown nearby, which means they're harvested when ripe and therefore are richer in flavor"*, *"Greenhouse crops are said to grow too fast?"*, "*Think some flavor disappears in the process, without the worms, dirt and rain"* and *"Because of the natural sunlight"*. As partly can be seen here, many of the respondents are trying to describe that they don't know the answer of the question and that they are guessing. However, even though they are unsure of the "correct" answer many of them are giving the exact same reasons anyway. What is interesting here is that many are connecting rich flavor to soil and sun. The respondents are not only unsure of what is right and what is wrong, amongst the answers of this question a lot of speculations can also be found, e.g. *"I think it depends. A lot. On in which country you grow the crops, which seeds you use and how you treat your crops while growing"* and *"No idea. I don't think there is a difference"*.

Only 14 % believe the flavor is richer for greenhouse vegetables, partly because the environment is controlled and optimized: e.g. *"Don't know. I imagine the plants in a greenhouse might get more attention and might therefore have a more intense flavor"*. It seems like people do not know enough about what is happening in greenhouses making them skeptical against that type of growing.

5.1.7. Question 7

- Which crops would you rather buy, crops grown in soil or only in water with nutrients?

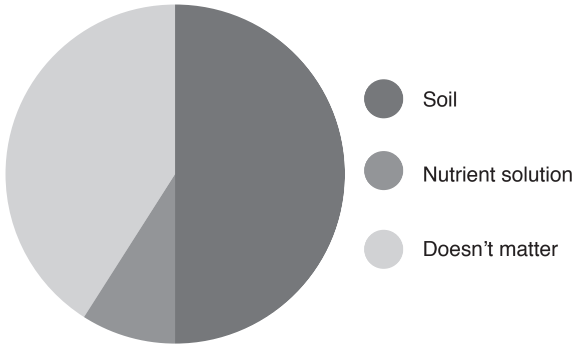


Figure 5.7. Chart 7

50 % of the respondents would rather buy crops grown in soil and 41 % says it doesn't matter, which means that only 9 % believe in the nutrient-grown vegetables (Figure 5.7.). This is clearly a difficult question, because the latter and least chosen alternative is something that many have never heard of. However, having 41 % of the respondents to clarify that the taste, quality and sustainability is more important than how the crops are grown, is interesting e.g. "*Whatever is most ecological and best for biodiversity I would prefer. If you can prove that it is better to cultivate crops in greenhouses I will go along with that. It is sad to lose the small scale farming though, but perhaps it is dead/gone already?", "If it gives equal quality, I do not care"* . This means that fairly many are interested of trying new techniques, if they can be convinced that the end result is "as good as" or better than the conventional ones.

The 50 % that chose crops grown in soil stated for example the more natural, the better; e.g. *"It feels more natural. But I guess it depends on what the final products contain, if there is a big difference"* and *"Don't know why, but it seems better or at least more traditional and thereby better?"*.

5.1.8. Question 8

- Suppose that crops grown in water with nutrients have exactly the same amount of nutrients as crops grown in soil, which crops would you rather buy?

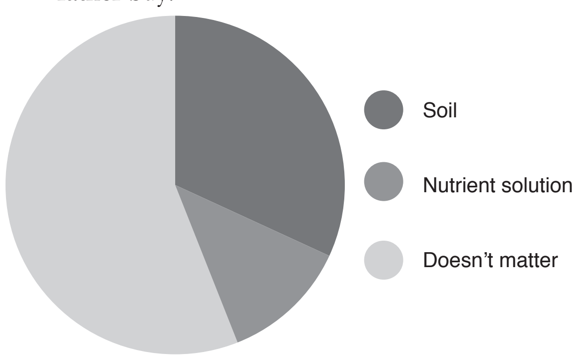


Figure 5.8. Chart 8

When stated that hydroponically grown crops are as nutritious as those grown on a field 32 % said that they would rather buy crops grown in soil, whilst 56 % said, "It doesn't matter" (Figure 5.6.). Comparing with the result from the previous question, a few more are here willing to buy crops grown in a nutrient solution because that *"(...) Seems good for space utilization"*, and less stated they still want the soil-grown and as much as 15 % more of the respondents said "It doesn't matter".

The largest group of respondents gave somewhat the same comments as in the previous question, e.g. *"If they are equal then I don't think it matters. The lack of fields in the world today, with all its inhabitants, could be well of if this was the case. Then we would have a better possibility to feed the inhabitants in the world"* and *"Whatever is best for the environment and cheapest"*. Though, the reasons regarding the soil were still pinpointed, e.g. *"Why would I rather want to eat crops grown in a "nutrient solution"?", "Nutrients are not the only things found in soil that I think help plants grow and give them flavor. Soil has a complex natural biology that as far as I know has not been replicated yet including microorganisms"* and *"They feel more real and less artificial"*.

5.1.9. Question 9

- If money and time didn't affect you, where would you prefer to get/buy your crops?

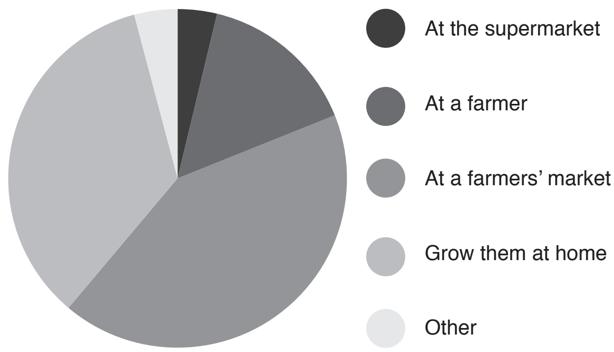


Figure 5.9. Chart 9

In the last question when the respondents were asked where they would prefer to buy their crops if money and time were not issues, as many as 42 % would buy them at a farmers' market and 15 % at a farmer (Figure 5.9.) The comments were e.g. *"I can talk to the farmers, find out how the crops are grown and what they are sprayed with", "Because I have no interest in growing them myself, but if I buy them from a nearby farmer, I know how they are grown and I can make sure that I buy vegetables that are harvested at the right time and not transported from other parts of the country/other parts of the world"* and *"Then I know that the "farmer" has good work terms, the co2 impact is at a minimum and so on"*. 35 % explained that they would like to grow them at home: e.g. *"Because then you will be more aware of what you eat and how much effort and care it is needed for its growth"* and *"The idea of being self-sustained when it comes to food is appealing to me"*. There are many similarities between the three biggest group of respondents and an indication of a pattern of wants and needs can be found amongst the comments as seen above. However, not all appreciate other routines than the most conventional ones, 4 % would still buy their crops at a supermarket mainly because of the convenience. One of the respondents added an interesting comment to that: *"I shop everything else there. Where I shop is less important than the quality",* indicating that not everyone appears to associate a closer connection to the vegetable source with quality.

5.2. In-depth interviews

The main goal of interviewing consumers was to learn more about their thoughts of crops in regards to consumption, sustainability issues and greenhouses. Since the survey had a general focus on personal knowledge regarding vegetables, the interviews were steered to focus on a more detailed direction in personal interests of and relation to crops.

The interviews resulted in a lot of qualitative data that has been clustered and structured into six main questions including prominent and characteristic interviewee quotes, all of which can be seen on the following pages.

5.2.1. Question 1

- Which needs for information regarding vegetable consumption do consumers have, and how should additional information be displayed?

The situation of today seem to be that the consumers often lack references and tangible reasons for their preferences and make their choices on gut feelings rather than facts. At the same time many are insecure about the knowledge they posess. During the deep interviews the test subjects often referred their point of view to some sort of inherent knowledge that they didn't know the source of, for example TS6 said *"I know that GMO crops are not good for you but I don't know why"*. At the same time several had rather intangible feelings as their argument when choosing crops, like TS11 when stating, *"It feels better if it is locally produced... You think that better crops like locally produced have more flavor"*. It was also clear that media has a great influence, since they based their preferences on things they have heard or seen from the television, newspaper or radio; TS8 explained *"I heard a radio show, you should eat vegetables in season"*.

A pattern discovered in the interviews was that people do not actively search for information about vegetables and that they prefer receiving the information without too much effort. Some of the interviewees want to know more about vegetables if the information would be presented clearly, whilst some feel they don't need or could handle more information. For example TS6 expressed an overload of information; *"No... Maybe I should but really, maybe I should set a limit for how much information I can handle in my head every day"*. The need for more information requires one that is easy to embrace and access. *"I would like to know more (...) but it is nothing you would like to find out by yourself if it is not served to you"* TS10 said, and TS8 uttered a demand for more information about flavor and quality but *"not a long damn story"*. The main information demanded were identified to be production method, a marking of local production, environmental impact and flavor, here explained by TS1; *"Maybe I want to know if it is locally produced and its carbon footprint"*.

The interviewees expressed that the information about environmental impact regarding crops are in many cases contradictory and hard to apply in ones daily shopping routine. *"It's not so easy to do anything about that information, it is pretty contradictory"* TS5 said about knowledge retrieved from discussions and lectures about ecological produce, pesticides etc. It is clear that people are not sure what choice is the best, and TS11 explained *"There are so small marginals deciding what is the best (...) ecological bananas are also uncertain"*. In this case, as for information in general, the interviewee expressed a need for distinct and concise information that makes their shopping easier and their conscience lighter.

5.2.2. Question 2

- What is the consumer awareness of their vegetable consumption's impact on sustainability and how does it affect them?

In almost every interview performed the test subjects in some way highlighted the environmental impact as an issue connected to their vegetable consumption. It is clear that people in general consider, on a more or less deep level, many and vast sustainability areas like climate change, arable land issues, dangerous chemicals and often address that this is something important that should be accounted for, e.g. TS7 expressed it like *"The environmental aspects are really the most important if you think in a long perspective"*. However, there is a gap in what the consumers want to know and do and what they actually know and do; price, time constraint and convenience are examples of obstacles between consumers and a more sustainable vegetable consumption; *"I would like to think less about price, instead consume what is most sustainable"* TS10 said. Another issue is the knowledge gap and insecurity about whether the information is trustworthy or not, and how different aspects should be prioritized. TS5 expressed a knowledge gap that several others of the interviewees seem to have as well *"I would like to know* *more about environmental impacts, on all levels not only pesticides but about greenhouse gases and arable land"*.

When discussing industrial production in general and the Plantagon project specifically, an awareness and positive attitude to rationalized processes and efficient area use emerged in some of the interviews. The test subjects, that argued about this, were in general more interested and had more knowledge about industrial production and sustainability, such as studies in the field or a personal interest: e.g. *"It is damn good if you can rationalize cultivated land"* TS1 explained and *"Tomatoes you buy in the winter are obviously cultivated in greenhouses, and you have to accept that in order to produce enough"* TS7 uttered.

5.2.3. Question 3

- What are the consumers' emotions and opinions regarding food production?

It turned out that the interviewees prefer local production and crops that comes with a story or a personal connection. The reason for this seem to be that they believe they know the conditions better and hence can trust the information more and make a better choice, if they have a connection and can relate to the production place: TS4 described consequently *"Is it a text about a farmer outside Kungsbacka I would probably trust that information pretty much, but is it a text about organic mangos from Kenya I am not sure there is reliability in that, I don't know how it is over there"*. In relation to this, an aversion towards many middle-hands was discovered in some interviews; *"I trust the information more if I know the origin rather than if there has been 13 intermediates, if I just know its origin I could make an active choice"* (TS10). However, the least complicated reason for appreciating personal details and origin is that it offers a more tangible experience, here described by TS9: *"More fun to buy stuff when it says where it comes from"*.

There seem to be a link between the obvious positive attitude about local production that is mentioned above and the word "natural". In the interviews the word was highlighted as positive among all the interviewees, and not seldom also associated to what is seen as local production. Though, the definition of the word varied some: a few mentioned that all crops per definition are natural, but the majority connected the word to soil - *"I like when the carrots have soil on them without plastic bags"* (TS3) - and to fields, no chemicals, growing outdoors and in its own pace, *"ripen in its own pace, it is right below the sky and it gets what it needs, no extra nutrients in the soil"* (TS2).

When talking about local production and what that means, all of the interviewees expressed favour to Swedish crops and many also equaled Swedish with local; TS8 said, *"In the region, Västra Götaland... No I change my mind, Swedish is local"*. The argument for choosing Swedish is that it is experienced as safer; *"I want it to be Swedish, feels safer"* (TS3) and *"I imagine they are better"* TS9 said about Swedish apples. Another reason for choosing Swedish and locally produced is because the consumers believe it is better for the environment, Sweden and the local neighborhood; *"I buy locally produced because it is less environmental impact, 80% climate and 20% local patriotism"*. However, often the decision to consume locally produced have rather intangible reasons like *"it just feels better"* (TS6).

Regarding the opposite - industrial and/or mass production of vegetables - there are mixed attitudes apparent. Few of the interviewees highlighted any positive aspects regarding industrial farming, but some of them explained the necessity of optimizing and feeding the world even if they themselves still prefer to eat small scale produced crops. In most other cases this type of production appeared to be connected to environmental issues and a large energy consumption, whilst some just have bad feelings about it: *"I get a feeling of industrial mass-production that doesn't please me"* (TS7) and *"You can not market yourself as an industrial farmer, nobody wants to know the downsides"* (TS11). Above all, the interviews elucidated a widespread scepticism towards greenhouse productions in general but more specifically greenhouses in Holland; for example TS8 said *"Rather Spanish and Italian because in Holland everything is cultivated in greenhouses. I don't think that tastes as good"* and TS4 blurted *"Distasteful! It sounds like the greenhouses in Holland, some chemicals that is absorbed by the plants"* about growing crops in nutrient solutions. Though, regarding how much the consumers really know about Dutch greenhouses is uncertain. What they know about the greenhouses seem to have reached the consumers through mass media, *"I hear a lot of bad things about Dutch greenhouses on the television, energy guzzlers!"* TS10 said.

5.2.4. Question 4

- Which are the main important criterions for choosing vegetables and how does the consumer evaluate the vegetables based on these?

The arguments the consumers base their choices on in the grocery stores seem to be very much steered by the perceived freshness and cleanliness of the vegetables, as well as habits and personal preferences. Another important aspect seem to be the level of ripeness, which should fit the consumers' plans of when to use the crops. Regarding taste TS10 said, *"You buy something for the taste"* and TS2 reflected *"I don't buy a green apple if I want a pink lady"*; two arguments that gave a hint that the flavor is fairly important for consumers. A crop's nutrients are however only somewhat important, the interviewees' answers differed more for this specific question; some consider it very important while some does not consider it at all, e.g. TS1 expressed *"Merely eating vegetables at all, is healthy"*.

Touching and visually examining crops by looking at, weighing, squishing and turning the crops in the hands is how a consumer evaluate a crop. This is something everyone does more or less consciously to determine; is it ripened enough, is it clean and free from vermin, and is it tasteful? TS11 expressed the decision-making in stores: *"The appearance comes first, it sets the quality, and even if I would check the origin first I would check the appearance as well"*. It also appeared in the interviews that past experiences help the consumers to make the choices and that many have certain visual characteristics that they search for when looking for crops connected to quality, e.g. TS10 said, *"It should be fresh and distinct in color and form"*.

These aspect are however not free from conflicts or worries in the consumers' minds. A question that was commonly discovered in the interviews were: Is avoiding vermin by buying clean and fresh vegetables most important amongst the consumers, or is it the naturalness of having vegetables from fields and partly covered in soil? This is illustrated by the quote of TS6:*"I don't want bugs and don't want to rinse them, I am a bit lazy but I think it tastes better when it has grown in soil with sun and everything"*. Consumers in general seem to be sparsely informed about the positive and negative aspects of these two sides which adds up the worry; too clean crops might for example not only mean that they are cleaned from dirt, they might have grown in greenhouses or been sprayed by pesticides. TS1, for example, reflected on too clean apples: *"They look so sprayed, but if I knew they were not sprayed it would not be a problem"*.

Lastly, the price is very important in the purchase of vegetables, perhaps the most important factor. For some of the interviewees with lower incomes it overrides all other criterions and TS1 explained: *"For me it doesn't matter if the crops have some small faults, I rather take cheap ones"*. Another dimension of the price aspect is that it can be connected to quality for some consumers, a too low price indicates that the quality is not very high and make the consumer suspicious, for example TS11 said: *"Very, very cheap - then I think they have used very much chemicals to have as high yield as possible"*. This indicates that there is a clear connection between price and production method in the minds of the customers. TS11 further explained, *"Stores where the price seems the most important I perhaps trust less than for example a business that has ecological groceries"*. Furthermore, there seems to be a conflict for many of the interviewees between price and organically labeled products, like TS3 expressed it: *"My boyfriend wants ecological crops but I think it is too expensive sometimes"*. The consumers want to buy organic crops but choose the non-organic one when the price difference to the organic option is too high. This seems to be a rather common outturn - *"Sometimes it is very expensive and then I would buy the tomatoes from Holland anyway"* (TS6). However, almost all of the respondents expressed a feeling of guilt and a worry that they didn't act correctly in the consumption of vegetables anyway, e.g. *"Maybe you should be more aware and think further than what is the cheapest"* (TS1).

5.2.5. Question 5

- How do consumers fit vegetable consumption into their lifestyles?

The test subjects expressed an enjoyment for harvesting and eating crops they have grown by themselves seemingly due to several reasons. The crops are considered to be fresher and taste better, and another important aspect is the feeling and the overall experience of growing by yourself, as well as harvesting and eating your own produce. For example, TS2 said, *"The best is to pick a vegetable from the garden plot, it is fresh and it feels like it tastes better"* and TS11 explained, *"It is fun to see things grow"*.

When it all came to an end, though, the interviewees most of all claimed they want cheap, convenient and time-efficient methods for consuming their crops; *"It is most important that it is quick"* and *"I don't walk that far"* TS11 and TS8 declared. Moreover, some could consider having crops chosen and delivered to the home by someone else if the price tag is reasonable, while others expressed a strong wish of choosing the crops by themselves when shopping.

5.2.6. Question 6

- What are the consumers' opinions about Plantagon and the greenhouse that is to be built in Linköping?

Knowledge about Plantagon among the interviewees was not very widespread at the time of the interviews. The ones that had no prior knowledge were given a description of the project, and its underlying purpose, whereas almost everyone seemed positive about what they heard and expressed a wish to observe how the greenhouse project evolve in the coming future. In Linköping the situation regarding knowledge about Plantagon was certainly another, since the local newspaper of Linköping, Corren, has been writing about Plantagon and the greenhouse project in some articles. Information has therefore been naturally spread around the city and its surroundings, revealing mixed feelings among the citizens.

Discussing the project elicited many questions among the interviewees, both out of curiosity and worry; for example TS7 asked *"What happens with the residues?"*, TS5 had questions about the cultivation process *"I would like to know the entire cycle, what comes in and what comes out"* and TS3 wanted explanations regarding the choice of pak choi *"Is there something special with that crop, it sounds strange to build such a large building just for that"*. An anxiety regarding that the project would not work and that this would affect both Linköping as a city and the citizens, was revealed during some of the interviews in Linköping. These interviewees asked, what happens in case of a failure, would taxpayers have to pay and will the credibility for environmental technology decrease. TS11 also added an overheard criticism concerning building a greenhouse on the predefined area of land, since that is an *"extremely fertile cultivated land"*. In spite of the fact that all these questions seem rather negative, every interviewee added some positive reactions to the discussion. Excitement and expectancies of the greenhouse possibilities were pointed out, and a hope of the greenhouse being positive for Linköping as a city was also stated: *"Maybe it will be a place for excursions, somewhat exotic"* (TS6).

6. Conclusion - Initital research

The initial research with expert interviews, theoretical background, and user studies is in this chapter summarized with three important communicative aspects and two system illustrations. The final part of the chapter is describing the four personas, created as guidelines for the next phase and chapter of the project - the Concept development.

As a summary of the initial data collection and analysis, several communicative tools were applied. Three factors identified as crucial in the company communication, were compiled and two system illustrations describing the situation of the company's potential future consumers, their relation to Plantagon and their basic demands, needs, wants and appreciations of experiences were created. These summarize the main research result and can act as a material to see how and where possible interventions can be made in order to facilitate the adoption of a vertical and industrial greenhouse production.

6.1. Communication aspects

Three aspects - trustworthy, natural and high technological - were identified as important to consider in the communication to consumers of crops produced in the vertical greenhouse.

In order to convince vegetable consumers that Plantagon crops are good and sustainable alternatives than what exist on the market today, Plantagon needs to communicate *trustworthiness* to the consumers. The reason behind this is that the findings from the user studies show that consumers have worries about their food consumption and that it is hard for them to know what information or which sender to trust. In addition to this, several studies show that there exist a need for more trust in the food sector both due to the complexity and lack of transparency, but also since several food scandals have affected the consumers. By claiming trust, Plantagon indicates that they have control of the farming process, it outcomes and its consequences, e.g. that cultivation is not emitting harmful chemicals and that they are offering high quality crops. Plantagon already acknowledges trustworthiness as being crucial in their communication. Cooperating with Sweco, a big and well-established consultant, can give, according to Plantagon, credibility and might convince the consumers that worry regarding the technique is not necessary.

To show that the Plantagon crops have equally high or higher quality than crops that have grown in nature or more nature-like conditions, it is important to consider the term *natural*. The findings from the user studies clearly indicate that the degree of how much a product expresses naturalness is something that is very important for consumers when adopting new food. It can also be related to that food is something very closed linked to our well-being. It is thus important to communicate that using new ideas of how to cultivate crops - with vertical greenhouses in the urban landscape and a hydroponic and highly controlled growing technique - does not mean that harmful substances and dangerous processes will be used to make artificial outcomes.

The vertical greenhouse is obviously very *high technological* with a closed environment, robots, and a climate that is adapted to fit the crops all year around. The question is however what the consumers think of this aspect; is it perhaps beneficial to make an effort to more or less camouflage the high-tech factors? For example, it is already decided that the greenhouse will be directed towards the sun to communicate to consumers that the sun is a part of the cultivation, even though artificial lighting can replace natural sunlight. On the contrary, it could be more beneficial to show that high-technology in relation to food is something favorable and interesting; tt is believed, with a basis from the user studies, that it actually exists an interest in knowing how food is produced, but it also exists a lack of trust for industrial and high-technological food production. A positive experience from high-technological production could thus, be beneficial in creating adoption of the Plantagon vegetable production. In relation to this, it is also possible to see that the greenhouse technology could actually create more interest in farming and local production for groups that are interested and fascinated by technology and innovations, but not cultivation nor growing.

The two latter words - natural and high technological - are somewhat contradictory, but bringing them both together is an interesting challenge and might in some way also be a necessity. The question is; how can a company connect to the nature and naturalness and unite this with an urban scope using modern technology. A combination of these two words could perhaps fuel trust, which could make these three factors a winning combination worth being considered by Plantagon.

6.2. System illustrations

Two illustrations were made as visualizations of the general result from the research. They can be seen as descriptions of the requirements the vertical greenhouse production will meet and have to address, but also as discussion platforms and foundations to be used to find the most appropriate way of how to continue the project. The question of how to engage the consumers and with design create a tool that could ease the implementation of a vertical greenhouse remained unanswered in the research phase of the project, however the two illustrations launched some indications of where the project was heading.

The first illustration – Requirement Circle – is describing the target group's requirements for consumption of vegetables found in the user study, as well as in the theory regarding food consumption. It was discovered that the needs and demands actually stretched from basic necessities to wishes not being claimed (Figure 6.1.). Basically, this means that the consumers are not expecting all requirements to be fulfilled, and that some of them are highly prioritized. A categorization of four different groups was created: a basic demand is something a consumer prioritize and demand, a need is something the consumer not necessarily demands but literary needs, a want is something a consumer is looking for but not necessarily needs nor demands, and lastly an appreciation of experiences is something a consumer might not even know that he/she wants and is not expecting to be fulfilled.

The requirements are difficult to categorize with strict borders, but are related to four different sectors of a circle that together is creating one unit. Some of the requirements are less appropriate to bring about in the conceptual phase of the project than others. These are requirements closely connected to the inherent quality of the end product/vegetables and shopping situation and, accordingly, these cannot nor will not be as prioritized in the coming concept development. Examples of these requirements are: to purchase low price but fresh and tasty vegetables and to consume crops with an organic label.

When further analyzing the result and placing it in relation to the vertical greenhouse production, three areas - communicating, involving and simplifying - were identified as possible approaches for addressing the consumer requirements illustrated in the Requirement Circle for the vertical greenhouse. The three areas in the illustration *Communicate, Involve & Simplify*, see Figure 6.2., can be seen as highly interrelated and dependent on each other and the concept development aimed at embracing all of them. Within these areas, several factors identified as critical and tangible were added, and altogether this evolved into a system describing both possible relations between Plantagon and the consumers, and an overview of conceivable approaches that the project partly could involve.

6.3. Personas

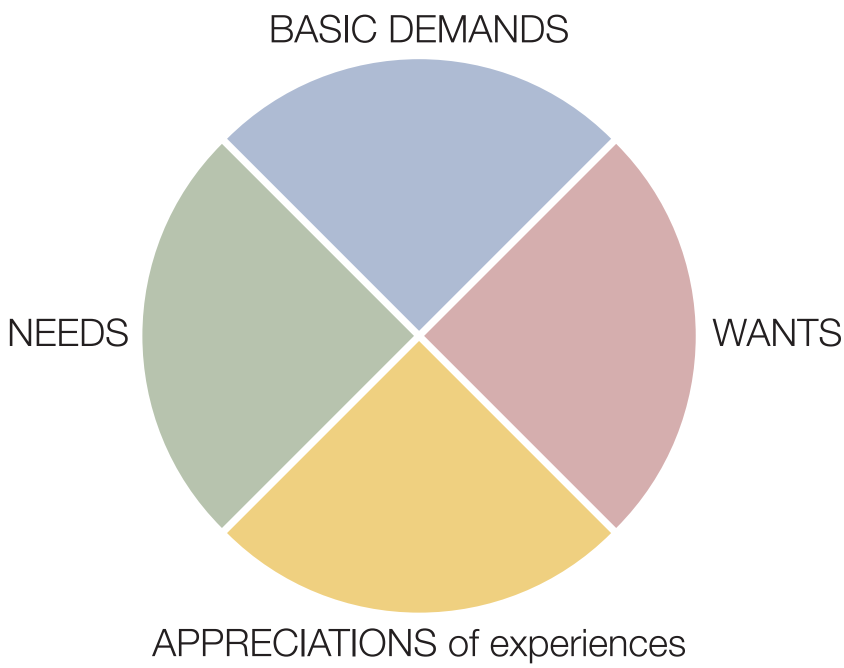
The consumer characteristics identified in the user studies were concretized into four personas that should act as a foundation for the concept development.

The personas are based on the information gathered in the user studies. Each persona is describing one of four consumer segments and is mainly structured to give a hint on personal descriptions of typical consumers and how these behave regarding vegetable consumption.

6.3.1. Gilbert the Gourmet

Gilbert (Figure 6.3.) is 52 years old and lives in central Stockholm with his wife and a 17 years old son, the two elder siblings has recently moved out. He works as a bank-clerk since 20 years and have recently started to work less hours to have more time with the family and his hobbies, cooking and spending time in nature.

He buys his vegetables where he buys the rest of his groceries, in a well-sorted supermarket just 150 meters from the family apartment. He often buys ecological products since he thinks these crops taste more and he often spends a lot of money to make sure he gets the best quality. One of Gilbert's biggest interests is to cook; he often makes extravagant dinners for the family. *"Good commodities are the essential in cooking"*. He often wishes he had more spare time during the weekdays, then he would go to a farmers' market and get the finest crops for his cooking.



Low price
Fresh and tasty
Simple and time-efficient consumption

Friendly for environment, ones health and society
Sure of making correct choices
Consume crops from reliable sources (e.g. KRAV and local prod.)
Consume natural crops

A feeling of nature
A personal connection to origin
A story of origin

Clear and easy-to-embrace information
Support to handle information overload

Figure 6.1. Illustration Requirement Circle - from the necessity to the exceptional

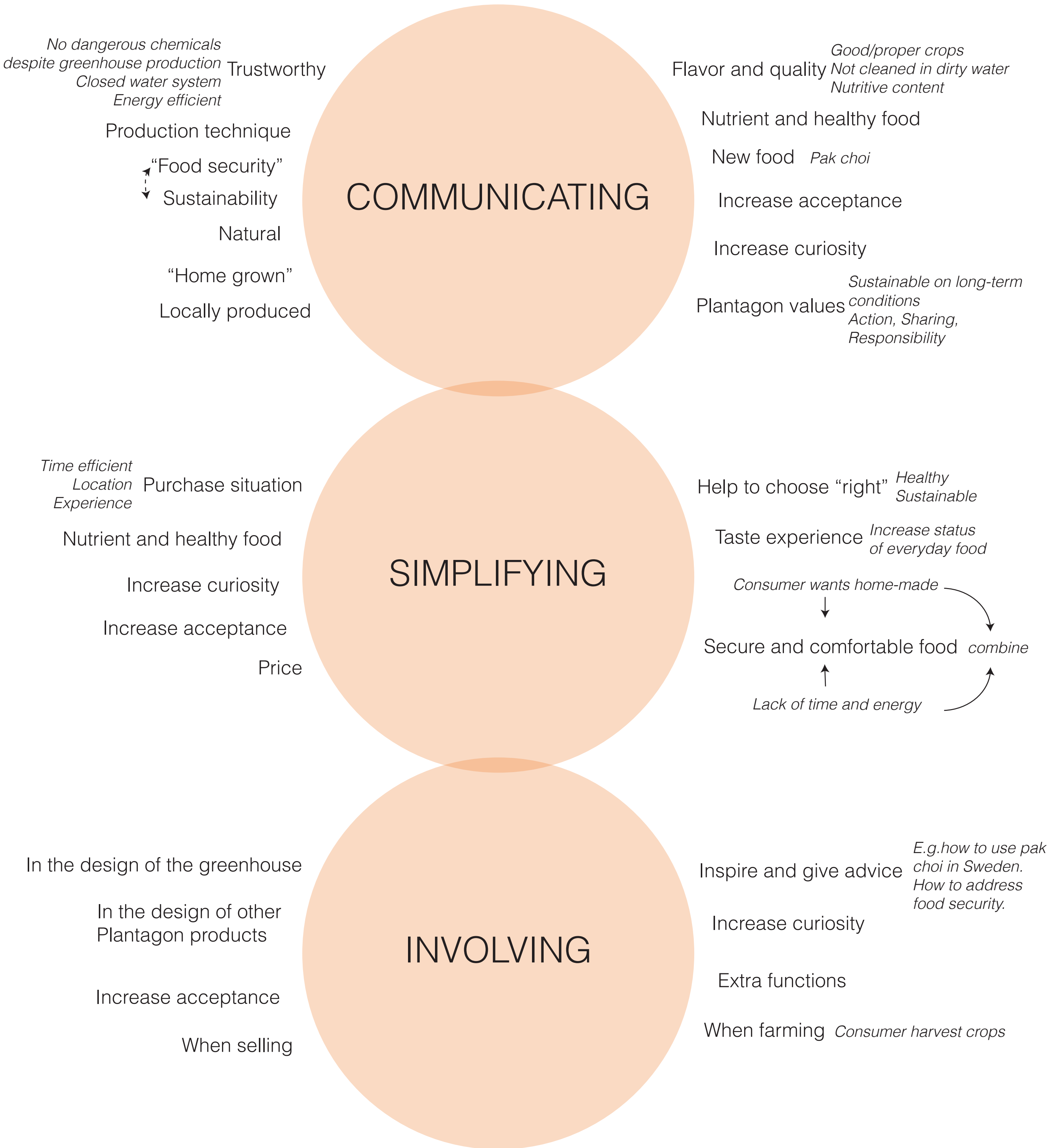


Figure 6.2. Illustration Communicate, Involve & Simplify - approaches to simplify the adoption of the vertical greenhouse production

Figure 6.3. Gilbert the Gourmet
Figure 6.4. Cecilia the Conscious

6.3.2. Cecilia the Conscious

Recently Cecilia (Figure 6.4.) opened a coffee shop in the heart of Majorna in Gothenburg. She just turned 45 years old and lives in a two-room apartment with her Golden Retriever Chef.

She tries to buy organic products, but sometimes she thinks the prices are too high. She often gets a feeling of guilt when choosing an non-organic vegetable instead of an organic-labeled one. Cecilia is interested in societal and environmental questions; issues about the environment have always been close to her heart and therefore she knows a great deal about agriculture and food production.

She likes to try new recipes with new ingredients and frequently she get ideas from her friends or from blogs she is following. Since she is a vegetarian she uses a lot of different crops in her cooking.

6.3.3. Louise the lazy

Louise (Figure 6.5.) is a 25 years old student that lives in a student apartment in Linköping. Her major is Sustainable Energy Systems and when she is graduating in a year she would like to work at an energy company.

Louise does her grocery shopping in the small supermarket just outside her building, often two to three times a week. She is a quick shopper, just take what she always uses and that is quick and easy to prepare. Her vegetable consumption is sparse because she thinks it takes too much effort to cook vegetables and that they are too expensive to fit her strict student budget.

Overall, Louise spends most of her time in school; she knows a lot about and is very interested in sustainable development and is following trends in technology and new green innovations. She sometimes thinks that it doesn't matter how she herself consume or act, since the question about sustainability is so complex and contrarious that *"it is impossible to make the correct choices anyway"*.

6.3.4. Isak the Indifferent

Isak (Figure 6.6.) is 32 years old and lives in the center of Gothenburg with his girlfriend and their 3 years old son, Tom.

He works as a salesperson in a clothes store, something he loves doing. Clothes, street fashion and the social aspects of the job is what he likes the most about it. Since Isak is working between 9am and 6pm most days, he is the one leaving Tom at nursery every weekday morning.

Isak is not very interested in cooking; he does what he has to do and takes every opportunity he can to avoid doing it. Therefore, he doesn't have much knowledge about vegetables, or about any food products for that matter. He has no interest in where and how vegetables are produced, so when he is the one shopping for the family, he buys whatever is on the shopping list that is sold to an affordable price. From time to time he thinks that he should perhaps care more about sustainability and be more aware than he is, but since shopping is something that is boring and only needs to be done, he quickly changes his mind and the thoughts disappears within seconds.

Figure 6.5. Louise the Lazy

Figure 6.6. Isak the Indifferent

7. Concept development

The content of this chapter is a description of how the process, of strengthening the relation between consumers and the vertical greenhouse by using design, was realized. The chapter is initiated with presentations of the idea generation and evaluation of ideas, and followed by descriptions of the benchmarking, concept generation, and further development.

The consumers, described as four personas in section 6.3., need to be convinced that a vertical urban greenhouse production is something they should adopt. In order to achieve this persuasion, and thus simplify the implementation of Plantagon's greenhouse, there are many possible interventions to be made. In the concept development part of this project, design has been used to develop a conceptual "persuasion tool".

Departing from the project question "How can we with design control the consumer experience and facilitate the implementation of the concept?" and the results from the research phase with user and literature studies as well as the two conclusion illustrations from section 6.2., several general design guidelines were developed as a foundation for the concept development phase.

In order to push for a quick and vast diffusion, the final solution should to as high extent as possible:

- Communicate the relative advantage of a vertical, and industrial greenhouse production.
- Communicate that the produced food is not artificial.
- Communicate that the merge of technology and food is something positive.
- Not increase the overload of information regarding food consumption.
- Facilitate the spread of information about the vertical greenhouse.
- Increase the understanding of how food is produced in the vertical greenhouse.
- Reduce how complex the innovation of a vertical greenhouse is to understand.
- Allow for the consumer to try and learn about the technology behind the vegetable production and the outcome of it.
- Increase the consumer's feeling of safety in regards to the produced food, e.g. by decreasing worries for dangerous chemicals in the processing of crops.
- Increase the consistency between the innovation and the potential consumer's values, experiences, and concerns.
- Increase the consumer's feeling of control in what he/she is eating.

7.1. Idea generation

Several idea-generating sessions were held in order to create different ideas that could fulfill the demands of easing the implementation of a vertical greenhouse. In the initial sessions the ideas formed were out-of-the-box in order to investigate as many directions as possible that could fit the project aim. The method brainstorming (see Sec. 4.2.4.) was primarily applied with a starting point from the guidelines described above, and the illustration Communicate, Involve & Simplify (see Sec. 6.2.).

The early idea sessions resulted in a collection of simple sketches, and the ones having the most potential to be developed further can be seen in Figure 7.1. All ideas were solely quickly designed and to leave room for changes in the next development phase. In the following categorization six areas of ideas are being presented.

Specific label

A specific Plantagon label could be added to the vegetables in order to promote, inform and help the

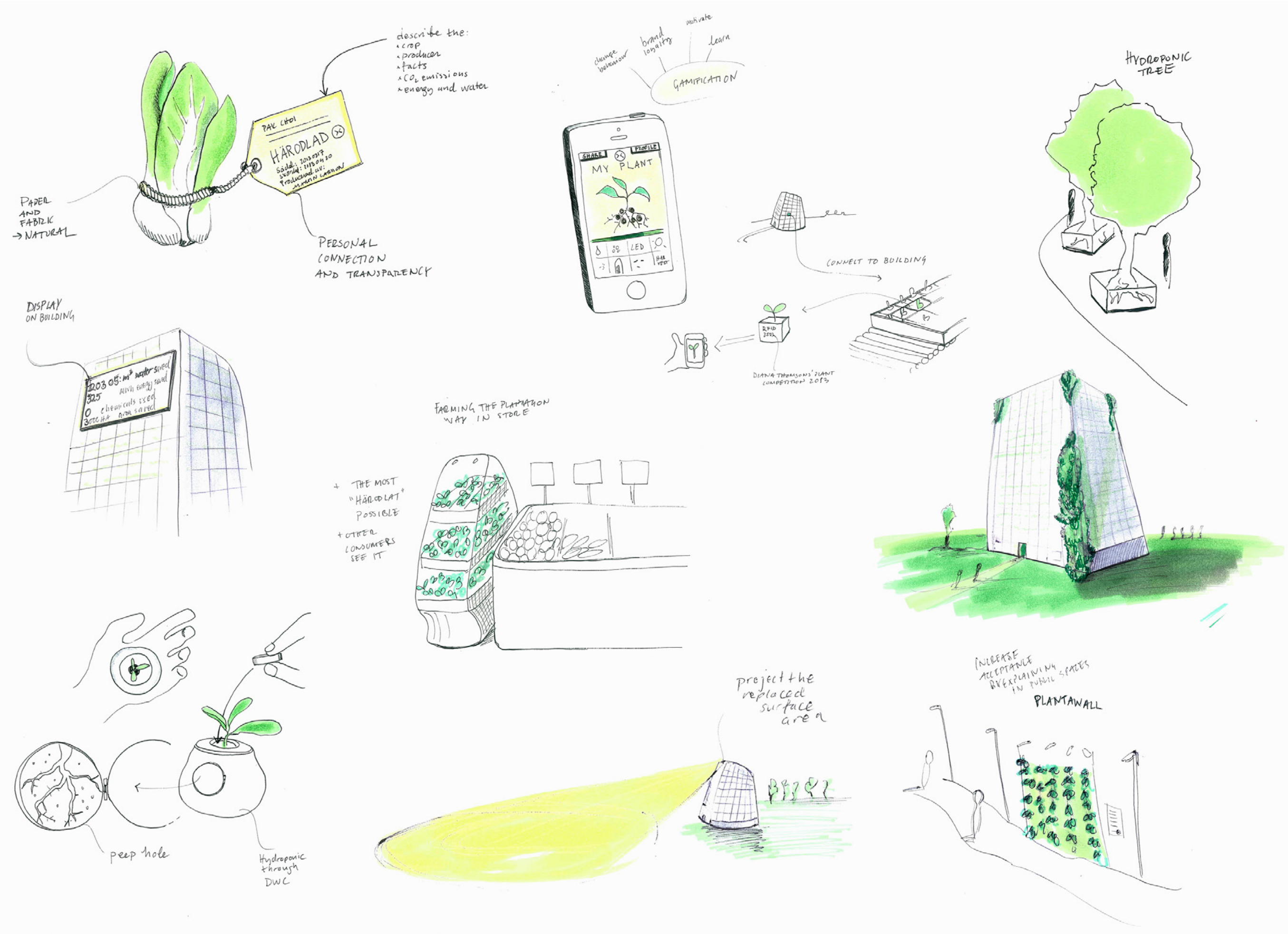


Figure 7.1. Early ideas

consumer at time of purchase. From the research, it was detected that labels are important factors in the purchase and can overcome barriers as e.g. skepticism towards a new technology. The label should promote local cultivation and create a personal connection to the producer, but should be clear in the message without holding too much information. Preferably, it should also hold some standard marking that is easy to detect.

Game connected to Plantagon

One idea was to develop a game where the main goal would be to nurture plants based on Plantagon's technology. This would allow the user to try out Plantagon's way of farming, to inform and, by including sharing options with peers about the results in the game, to create a face-to-face exchange of information about Plantagon. This could also be a complement to other information channels in order to reach different type of users.

Building design ideas

Since the building is such a clear landmark and is meant to incorporate production and sale at the same spot, the design of the building and its surroundings are crucial for the consumer adoption. Many ideas regarding the building were created, most of which either serve the purpose of expressing certain values or to inform. One idea is to "greenify" the building, since that can communicate more clearly what's inside the building, the sustainable aspects Plantagon stands for ,and being a way to create a expression of naturalness, farming, and personal connection. Another idea is to let the building project the farming area that is saved, by growing vertically, on the surrounding ground. This would allow a clear message of one of the building's advantages and be a "fun" and interesting way to get attention.

Plantagon production in supermarket

Producing and selling Plantagon crops at the same spot, directly at supermarkets, would optimize the consumer convenience. The idea is to have a small imitation of Plantagon's production at the supermarket that would allow the consumer to know how the crops are produced as well as create attention and interest.

Mini cultivation system

Several of the ideas are directed towards letting people try the technology, both because it has been shown from the research that there exist an interest in growing and producing your own crops, and because that is a way to increase knowledge and acceptance of an innovation. By letting consumers use Plantagon's technology in a small-scale system that can be used in schools, offices or at home, an understanding of the effectiveness and the positive result from the Plantagon production may be increased. Several ideas, covering from smaller systems more focused at playing to larger ones focused at giving a considered yield, were elaborated.

Cultivating in public spaces

In order to reach as many potential consumers as possible and to create a conversation in society about Plantagon and vegetable productions, public spaces can act as a channel of information. The idea is, by growing decorative plants in the Plantagon way on walls and buildings or by adding a small greenhouse on meeting and open places, to communicate the message to more people.

7.2. Evaluation of ideas

All ideas were evaluated and discussed in order to find the best and most appropriate track to develop further. The evaluation was based on finding the ultimate idea that facilitates the implementation of the vertical greenhouse according to the guidelines listed in the beginning of the chapter. The selection was, furthermore, also matched with the scope of the project and the competences of the project group.

In the evaluation within the project group, it was concluded that personal trying of an innovation deliver on many of the guidelines. Personal trying can for example give meaning to a new idea by creating a personal connection, allow for an individual to learn how a specific technology works and observe its result under one's own conditions, reduce worries, doubts and the perceived complexity. It was therefore evaluated as one of the best tools to push for a more rapid rate of adoption.

To discuss the different ideas with people outside the project group, and open up for insights from "open and fresh minds", a focus group session was held. The discussion was initiated and steered by the following question.

- How can we convey the purpose and create a positive experience from high technological and industrial cultivation in vertical greenhouses?

Initially, the group was encouraged to together and loud brainstorm ideas around the question; the

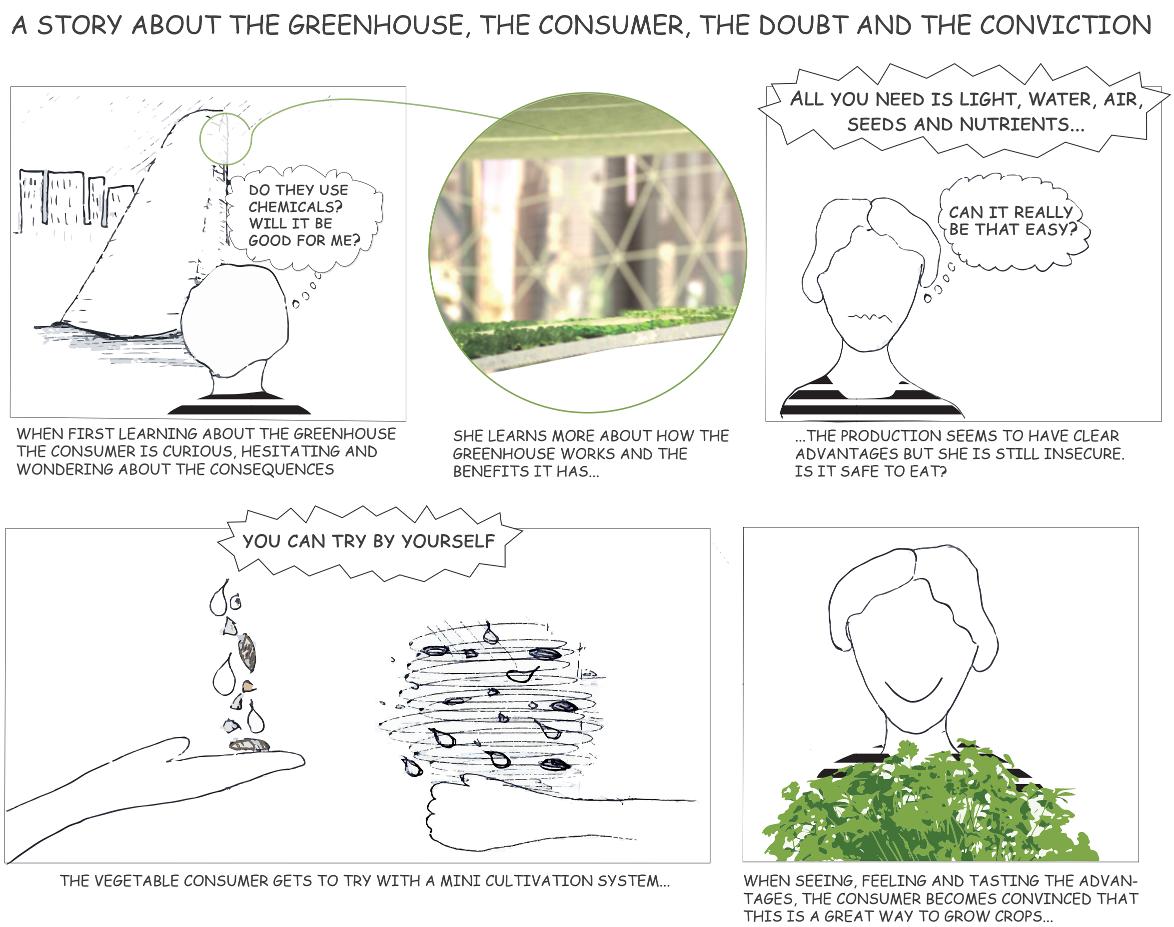


Figure 7.2. Storyboard - description of how to increase adoption of a new idea

moderators took notes and helped in driving the discussion. The idea of a mini cultivation system emerged after a while, something that had been the initial purpose of the moderators, in order to test this specific idea further. The students added valuable thoughts regarding many ideas, but specifically regarding the concept of a mini system. It was confirmed that a cultivation system could facilitate the implementation of a new way of producing crops, but also that it is a product that creates interest.

A storyboard was created to evaluate and communicate how the mini cultivation system increases adoption (Figure 7.2.). The cultivation system should be a product that allows an individual or group of individuals to use Plantagon's technology on a smaller scale and grow plants in for example a home environment, at an office or a school. New criterions were to be developed to maximize the concept's persuasion abilities, by linking it clearly to the Plantagon greenhouse form and value expressions, as well as its underlying technology.

7.3. Benchmarking

To learn more about small-scale cultivations and set the requirements of a cultivation system, a benchmarking session was implemented. The session included both a search for other home cultivation systems on the Internet and an experiment with the technology where a window farming system was built and put into function.

It was discovered that a wide range of home cultivation systems already exists, and it was possible to distinguish two groups:

- "Build your own"-systems (e.g. Figures 7.3. & 7.4.) can be built using only simple tools and objects that can be found at home or at a regular supermarket. These systems are somewhat tricky to construct, require weekly attention and have problems with formation of alga. The price differ between 170-700 SEK.

- "Ready-to-use"-systems, e.g. Click-and-Grow and Herbie (Figures 7.5. & 7.6.), are often easy to use and require only a few minutes of attention every two or three weeks. In order to minimize the maintenance on these systems to avoid alga, the water is often in a closed container without light input. The systems are a bit more expensive, 550-1400 SEK, and sometimes they include a cultivation lamp to improve the environment for the plants and increase the yield.

7.3.1. Hydroponic cultivation experiment

The simple pet-bottle system from the organization Window Farming (WindowFarming.org), was decided to be the one to be built as an experiment at Chalmers. Instructions were found at the organization's web page, and most parts and devices were bought in a store specialized in hydroponic cultivations in Gothenburg.

The construction of the window farming system was executed without any major problems (Figure 7.7.), even though it required access to working tools and was executed in several steps only roughly described in the instructions. The actual growing process within the system was more troublesome, since it demanded more monitoring than expected.

Once the system was assembled, seeds were put in wet rock wool-cubes and the cubes were placed in the bottles (Figure 7.7.). Water was added to the system and was running through it alone, until the seeds had grown to seedlings. Nutrients were added to the water when the seedlings were a few centimeters and the system ran like this 24/7 without any pauses. The result after approximately a week was, unfortunately, slouching plants. A troubleshooting process was executed and detected that the failure was likely due to overwatering.

The result after three weeks was a major spread of alga in the tubes, the water container, and the rock wool cubes (Figure 7.7.). In addition to this, chalk residues in the water had left white spots on the window and on the bottles. The transparent tubes and

Figure 7.3. & 7.4. "Build your own"-systems

Figure 7.5. Click & Grow

Figure 7.6. Herbie

Figure 7.7. Hydroponic cultivation experiment

water container were the source of the issue since the light inflow had allowed a photosynthesis process to start and a following spread of alga.

The conclusion of the project was therefore - anyone can a build and have a window farming at home, however the running of it requires more attention than predicted. More instructions on how to keep the plants alive are wanted and preferably a system that requires less attention with a timer to control the pump. It was concluded that a large amount of interest is needed to really succeed with it.

7.4. Concept generation

The idea of a mini cultivation system was put through to the concept development phase, where several different solutions on the system were developed and evaluated.

7.4.1. Requirements for a mini cultivation system

For the further development and evaluation of concepts, a requirement list was compiled. The most crucial demands for the devlopment of the concept are listed below, and the entire requirement list with detailed specifications is to be seen in Appendix VIII.

- The dimensions of the system should be designed in regards to the dimensions of a regular windowsill as well as to being easy to handle.
- The system should offer beneficial growing conditions for plants.
- The design of the mini cultivation system should minimize the required maintenance to a few minutes every three or four weeks.
- The maximum end price for consumers should be comparable to similar and existing products around 1000-1500 SEK.
- The system should aim for a low sustainable impact and should thus also minimize the power consumption when being used.
- The system should to a high extent apply and communicate the usage of the same technology as the vertical greenhouse.
- The form expression should comply with the vertical greenhouse.

7.4.2. Initial concepts

Departing from the initial idea of a mini cultivation system, and with the additional input from the benchmarking and the requirement list, three initial concepts were designed. Below, brief descriptions of the concepts as well as pros and cons that emerged during project group discussions are presented.

Concept 1 - Drip system for several plants

This concept (Figure 7.8.) is highly inspired by the window farming system and is built on a hydroponic drip technology. Several plants are vertically aligned in the window and the water is, by using a pump, led up in a tube to the top plant. By gravity and highly permeable medium, the water is dripping down through the plants to finally come back to the water container.

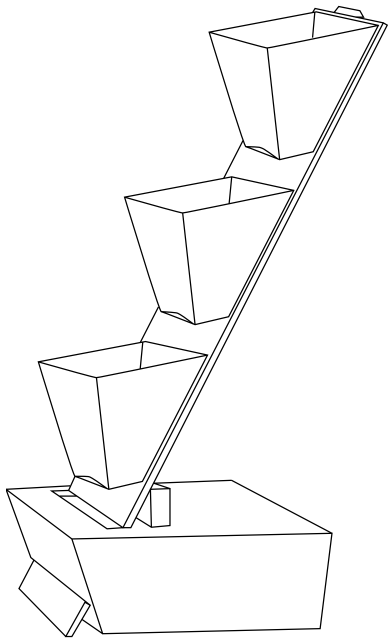


Figure 7.8. Concept 1

+ The system is vertical, which has a direct and natural connection to the vertical greenhouse cultivation of Plantagon.
+ It maximizes the number of plants that can be grown on a small surface of the windowsill.
+ It is educational, since it is possible to follow the water through the system.
- It requires a high lift power of the pump, which in turn requires more power than what is needed for a lower system.
- It has a high risk of algal production, since the water is exposed to light.
- It requires fairly many parts such as tubes that can obstruct the overall expression of the system.

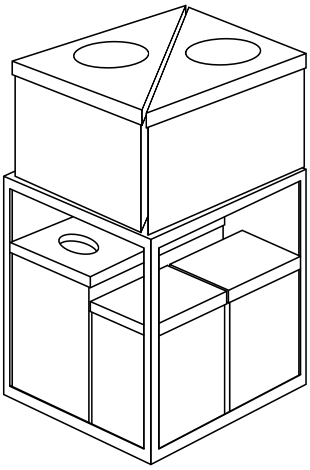


Figure 7.9. Concept 2

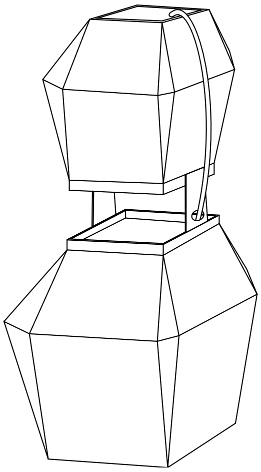


Figure 7.10. Concept 3

Concept 2 - Standalone system

The second concept (Figure 7.9.) uses a hydroponic technology called "deep water culture"; the roots and growing medium are submerged in a nutrient solution that is aerated by an air pump in a closed container. The system is low and allows only one or a few plants in order to not take up too much space from the windowsill.

+ The system has a relatively simple construction with only a few parts that allow safe and easy maintenance.
+ The water is contained in a reservoir excluding light to discourage alga production.
- The overall product structure is not directly linked to Plantagon's vertical greenhouse
- It is inefficient in use of space.

Concept 3 - Drip system for one plant

This concept (Figure 7.10.) applies the same drip technology as in Concept 1, however this is a smaller version with tubes and a pump holding only one growing container.

+ It has a simple construction
+ The concept is educational, since it is possible to follow the water through the system.
+ The system is somewhat vertical, which has a direct and natural connection to the vertical greenhouse cultivation of Plantagon.
- The system is not vertical enough to get a clear and direct connection to Plantagon's vertical greenhouse.
- It has a high risk of algal production, since the water is exposed to light.
- It is inefficient in use of space.

7.4.3. Concept selection

The evaluation and concept selection of which track to further develop was made within the project group and in collaboration with the academic supervisor at Chalmers. A part-time presentation at the company was also held. The evaluation was to a high degree based on the decisions and the requirements and guidelines derived from the scientific basis and user studies. Discussions regarding important aspects to consider, e.g. already existing solutions, degree of technology complexity, targeted users, and suitable price range, were held and acted as a foundation for the decisions made.

During the concept selection discussion, none of the three concepts were put through as a whole. Instead a blend of qualities from the different concepts and new input, were therefore decided to be included in a new design, to reach an overall higher compliancy with the needs and requirements.

7.5. Further development

A structured way of developing the solution further was initiated and four basic aspects - communicative properties, initial form development, user aspects, and functions and components - were set up as partial goals to go through in a step by step design phase along with a final brainstorming session.

7.5.1. Communicative properties

The overall appearance of the concept is closely linked to its functionality, but also critical in the communication to the user. It was important to elaborate around what communicative messages the product should transmit, and how it is possible to steer the user's interpretations of the product to match the expectations of it. According to Monö (2004), semantics deal with what different product characteristics communicate. A product sign's message can have different semantic functions that can be categorized into four groups, all of which have been incorporated in the design development of the cultivation system. Concisely, the overall form should through different design characteristics *describe* the purpose of the system and *express* something significant for the concept. The design must *exhort* the user to interact with the product and to nurture the plant when needed, and the product characteristics have to help the user to *identify* and correlate the system to Plantagon and the vertical greenhouse.

To elaborate around the wanted communicative characteristics, the development of aesthetics departed from the Plantagon form language. According to chief architect Alessio Boco at Sweco[1], the building

1 Alessio Boco interviewed by authors 23 April 2013.


Figure 7.11. Close-up of spheric greenhouse

planned in Linköping has a simple form and will be a strong symbolic landmark. This simplicity comes from the fact that the building is, to a high extent, rationalized around the growing process whereby the form follows the function. Specific reappearing elements, on the greenhouse building and in the overall branding of Plantagon, which are important expressions for the company, are the circle, the sphere and a triangular pattern (Figure 7.11.).

As concluded in section 6.1., it is desired that the company should consider the aspects of trustworthy, high technological and natural. Consequently, the concept has to balance natural with high technological in its communication to consumers in the same time as explaining that the sender behind the mini cultivation system is trustworthy. When elaborating around the explanation of the greenhouse by Boco and the three communicative factors, two desired expressions were evolved specifically for the mini system - *simplicity* and *dynamicity*. The form language shall thus have a semantic function of expressing simplicity and dynamicity both due to the target group's needs and wants, but also to increase the identification with the vertical greenhouse. The simplicity captures the "form follows function"-view with no superfluous decorations or ornaments. Furthermore, the combination of simplicity and dynamicity should merge the shifting and organic aspect of nature with the clean and strict high-technological side. The trustworthiness is captured by the simple and dynamic expressions, since it elevates the function of the system yet communicates strength and flexibility.

The design of the mini cultivation system should be identified with the vertical greenhouse and be designed to trigger the correct reactions in order to simplify the usage. The form language of the system will necessarily be highly dependent on the overall function, since much technology and water needs to be housed without taking too much room on a windowsill.

7.5.2. Initial form development

The communicative properties were defiined as a basis for the form development sessions of paper folding (Figures 7.12. & 7.13.), sketching (Figure 7.14.) and CAD, which in turn were applied to find a suitable design frame for the system. The sessions resulted in several interesting forms that were sorted into two major categories - a foldable system and a greenhouse tube.

Greenhouse capsule

The underlying thought with the system of a greenhouse capsule was to depart from a simple form and to push for the inclusion and communication of being identified with a greenhouse environment. The tube shape (Figure 7.15.) was chosen since it incorporates a simple, yet more natural and dynamic form than for example rectangular shapes, but also because it speaks with the verticality by stretching upwards, and allows the inclusion of all functionality that is needed in a hydroponical cultivation system.


Figure 7.12. Paper foldings

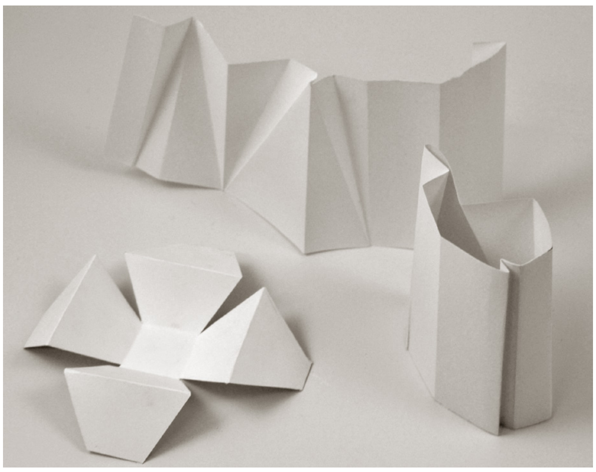


Figure 7.13. Paper foldings

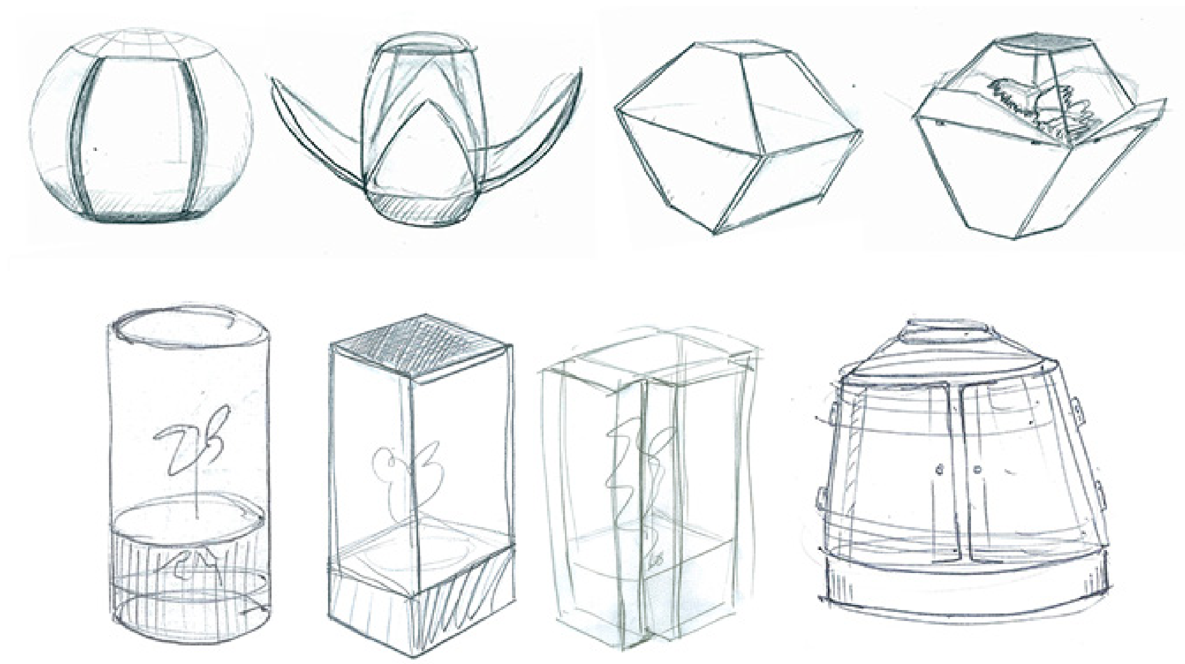


Figure 7.14. Early sketches

Foldable system

The main idea with the foldable system (Figure 7.16.) was to have a supporting and protective structure around the plant, which changes over time by being unfolded and thus speaks with the dynamicity. It becomes a package that carries the plant and is opened up allowing it to grow. Different ways to include the vertical and greenhouse messages were discussed and elaborated around.

Figure 7.15. Greenhouse tube

Figure 7.16. Foldable system

Evaluation

An evaluation of the two categories, against the requirements and the semantic guidelines developed, was performed, and it was concluded that the smaller foldable concept is very attractive in its format. It was, however, difficult to include all the technical functions needed without removing the positive aspects of its communicative message. Another negative aspect about the concept is that it is identified too much with a traditional pot. It was concluded by the project group that the concept should communicate that "this is not traditional farming, this is something different" and therefore, the traditional pot-identification was not wanted, nor aimed for.

The tube concept did, on the other hand, fit all necessary functions without interfering with its communicative characteristics. It was concluded that the form is simple enough to allow the plant to grow and speaks for itself in the center, yet the form incorporates the wanted expressions of dynamicity and simplicity and is highly identified with a vertical greenhouse cultivation. The tube concept was thus chosen to be developed as the final concept of this project.

7.5.3. User aspects

The mini cultivation concept needed to be designed not only to fit the greenhouse in terms of the communicative message but also to target the correct consumer group and the situations where the concept should be used as well as the different user interactions needed to make the concept work as desired.

Target group

The target group of the project as a whole is vegetable consumers in larger Swedish cities, thereby a wide range of people is included. When it comes to the it should withstand a wide range of users in order to achieve the goal to facilitate the implementation of the greenhouse as such.

Usage situations

The mini cultivation system is primarily designed for usage in homes. The focus is not on producing a large amount of vegetables for the household consumption, but rather to offer something extra to the cooking such as fresh herbs or lettuce and be a pedagogical symbol. It is however, possible to see other usage situations such as at offices or even more public spaces, even though these contexts might require some modifications of the concept.

User interactions

Several interactions are involved in the process of cultivating a plant in the mini cultivation system and must be accounted for in order to achieve a positive user experience. The user interactions need to be as easy and understandable as possible and the design of the system should therefore be developed to address also those.

The most prominent interaction - to reach the plant and harvest - can be performed whenever wanted. Other interactions - to assemble the system, to add water and nutrients, to clean the water reservoir and to ventilate - are done more seldom. Some of the interactions will need simple instructions at first, but the biggest challenge regarding the interaction is to make sure the users remember to add nutrient enriched water and to open up the tube when the inside temperature is too high.

7.5.4. Functions and components

In order to serve as a mini system where the user can become familiar with hydroponic cultivation, the concept should incorporate many of the functions and technologies that the vertical greenhouse is built upon. Moreover, it should, in its interaction with the user and need for maintenance, offer a balance of convenience and educational functions.

Closed greenhouse environment

To clearly connect to a greenhouse and offer a relatively better yield, a closed environment allowing the sun to enter, but keeping moist and heat inside for the plants, was elaborated around in the concept development. The concept should be equipped with a transparent protective coating that keep heat and moist inside when necessary, but still allows oxygen to enter. In order to allow for an easy-to-use, as well as a large enough, opening for removing the water container when needed, it was decided to use two doors. It was discussed whether these doors should hold an automatic opening function to be active when the temperature rises over a certain degree. However, in order to include an educational and interesting interaction with the user, it was decided that the users should control the opening of the doors themselves.

The temperature and moist needs varies between plant species and growth phases. In the germination phase, the temperature and moist rate should in general be approx. five degrees higher than for a seedling or a full-grown plant (Evans and Blazich, n.d.). Generally 17 - 25 degrees Celsius is best for most plants (Whiting, 2012). Moisture and temperature is critical but it is still important that the plant is aerated (Evans and Blazich, n.d.; Rindels, 1996).

A thermometer could be added to the system to communicate when the temperature is too high or low. This is needed to succeed with the intended user interactions the user needs support in knowing when the doors should be opened. Since different plants have different needs for temperature, one alternative would be to include temperature strips. These strips exist in many designs and are not very expensive (e.g. Omega, 2013), however it might be too expensive to include individual strips with every new seed and a general strip could therefore be an alternative. That would give a lower overall performance for each plant, but still be better than if no strip or greenhouse chamber were used at all. The strip could thus give indications whether the temperature inside is in the desired interval of 17-25 degrees Celsius.

Hydroponic cultivation

To connect to the industrial greenhouse cultivation, hydroponic cultivation is implemented in the mini system (see Sec. 3.2.2.). Several different hydroponic technologies exist and different types was therefore considered during the concept development. Important criterions when evaluating the technologies were to minimize the amount of water to not make the system too large, to minimize the power demand, and to optimize the aeration and nutrient supply, still allowing a low maintenance degree. A technology built on bottom-up absorption (see Sec. 3.2.2.) was chosen since it requires less lift power than top-down technologies. Another important consideration was that top-down systems expose the water to sunlight whereas the photosynthesis can produce alga, a problem that was noticed in the experiment of a drip system window farm (see Sec. 7.3.1.).

When choosing between different bottom-up systems, the volume, technical complexity, effectiveness, and security were decisive. After reviewing a few systems, the choice was between Deep Water Culture (DWC) and Ebb and Flow (EF) systems.

DWC is a system where a plant is submerged in nutrient solution that is aerated with an air pump. DWC is the easiest system to run since the water remains in the same place all the time and few parts are needed (Hydrogarden, n.d.).

It was concluded that the DWC system is too sensitive to power failures; if the pump for some reason doesn't have enough power to aerate the water, the plant will shortly suffer from lack of oxygen. Another negative aspect regarding the DWC is that not all plants like the constant moist the system requires.

The main principle of EF systems is that a water pump flood-and-drain a plant pot/container with nutrient solution in cycles 2-4 times a day. It works by placing a water pump in a water reservoir with nutrient solution. For a few minutes water is pumped upwards to a container where the plant medium and roots are being soaked. When the pump turns off, the water is drained back down to the reservoir. The process draws oxygen back to the roots when drained, while the medium still holds a great deal of nutrient solution available for the plant throughout the day. (Hydroponics-Simplified, n.d.; Garden Guides, 2010; EasyHydroponics.net, 2011)

The Ebb and Flow system is power efficient and secure. The pump only operates a few times a day and by installing a secure draining system, the risk for failure is not as severe as with the Deep Water Culture. Due to these aspects the EF system was chosen.

To succeed with the EF system a medium, that holds the nutrient solution and provides stability for the plants, is necessary. Since pumice will be used in the vertical greenhouse, it was desirable to also use it in the mini system, mainly to increase the relations between the two greenhouses. In addition to the communicating function, it has a very high water holding capability and is beneficial for EF cultivations.

The medium provided with the cultivation system should for the germination phase thus be rock wool, which can be placed in a pot with pumice in order to allow for the roots to grow and spread over a larger area. Rock wool was used in the window farming experiment (see Sec. 7.3.1.) and it was noticed that it is possible to leave the rock wool within the pot even after the germination phase, since the roots will stretch out from it.

It is necessary, in order to germinate seeds, to use a medium that is fine in its texture and hold a very uniform consistency. In the same time, the seed medium should be aerated and drained, and offer high moisture and sterility. Rockwool is a common germination medium possessing all of these qualities. (Hydrogarden, n.d.; Evans and Blazich, n.d.)

The amount of nutrient solution needed and how often it needs to be exchanged, were investigated by comparing different existing systems on the market and by evaluating the executed experiment. The vaporization is not a big problem since the water is contained in a rather closed container, however some water will evaporate and disappear. The amount of water is highly related to the nutrients; the more water, the more even concentration of nutrients and the less sensitive the water is for fluctuations in PH etc. With this in mind, it was decided that one liter of water is necessary and feasible to give the plants access to enough water for three weeks without making it too sensitive for concentration fluctuations.

In the beginning of the cultivation, when germinating, the seeds should not have access to nutrients but only water. In general, seeds germinate in approximately 5-10 days and when the seed has turned into a seedling, it should get access to nutrient enriched water. (Hydrogarden, n.d.)

To succeed with the germination, it was decided that the user would need to start up the system with only water. When the user notice that the seedling is a few centimeters high, nutrients should be added to the system. After three weeks, the reservoir should be refilled with new nutrient enriched water and then, every three weeks, the reservoir should be refilled again.

Light

An integration of lighting in the mini system was considered, both to increase the yield but also to once again connect to industrial greenhouse productions. Since it is important to minimize the power consumption and heat production, LED was the natural option.

Light Emitting Diodes (LED) are low powered and do not produce as much heat as many other light sources. The lighting technology also provides flexibility for composing the optimal spectrum for plant cultivations. This spectrum depends on the different plant processes, where the main process - photosynthesis resulting in biomass by absorption of light energy - is when mainly chlorophyll absorbs photons. The most important and efficient wavelengths for this process are red, which are also needed for the morphogenesis, another important process for healthy plant development. Finally blue light is required for the phototropic processes in plants that control plant organs and are important for the growth. (Tamulatis, et al., 2004)

When comparing with other hydroponic systems, e.g. Click and Grow, it was detected that approximately six Watt-LEDs are common to use for smaller cultivations of two to five plants. However, in these cases LED is used as the primary light source why the wavelengths and light efficiency is crucial to ensure growth. In the mini-cultivation system, the LED will be a complement to the sunlight that already provides the plant with the necessary wavelengths, hence the LED does not have as high demands on spectrum and efficiency. Accordingly, aspects such as price and power consumption became increasingly important and it was decided to use a set of LEDs with a lower efficiency of one to three Watts. This would result in a higher yield where all extra light is beneficial, and communicate the right message without adding too much extra cost or power demand to the system.

Power supply

The vertical greenhouse of Linköping will use excess energy from a biogas facility in order to power the different processes. The reason for this is that it is in Plantagon's intention to create a closed system when it comes to water and energy. However, the specific construction of the different greenhouses will depend on the specific contexts and one alternative is to power the greenhouse with solar cells placed on the facade. Different energy sources for the pump and the LED-lamp were considered. Since the system shall be placed in a window, solar cells that profit from the sun emerged as a very good alternative. Its main competitor was to plug the system onto the household electricity grid, which could be sustainably produced even though it lies outside the control of the mini cultivation system. It is notable that such a solution would result in a less expensive and complex construction than the use of solar cells. Even so, the possibility to create a system that provides an ultimate growing environment by using only renewable energy sources was more attractive. With solar cells powered with sun entering through the window, the system becomes very descriptive in explaining where the energy comes from. In addition to this, it was tempting to create a system that literally stands on its own without a power cord, since this can strengthen the products inherent identity and symbolic value. Consequently, it was decided that solar cells were worth the extra cost and effort.

Solar energy is a sustainable energy source that is inexhaustible and free. It works since electrical current can be produced from radiant sun energy through a process called the Photovoltaic effect. Solar cells made from different semiconductor materials, make this process possible. The most widely used is crystalline silicon, representing 90 % of global commercial production. (Foster, Ghassemi and Cota, 2009)

Due to several reasons the solar cells in the mini cultivation system have a rather high demand on efficiency. They will loose some degree of efficiency from being placed behind a window, and since the surface available for the sun cells are limited in order to keep the wanted expression of the product and to not make the product inconveniently large for the window.

There exist many different kinds of solar cells with efficiency varying between a few percent and over 40 percent. In a collection of the efficiency for solar cells, the best research cells made from crystalline silicon have an efficiency of 25% (NREL, 2013). Though, the sunrays' diffusion through different mediums decrease the amount of energy the solar cells can transform and it is common to extimate that approximately 8% in efficiency loss occur when diffused through a window.

The major factors in the system that affects the solar cells are their angle towards the sun and the area they cover. These two parameters will be designed in order to ensure the power supply and to reach the wanted expression. It was decided that a tilted surface with solar cells is not only more efficient than a completely horizontal surface but also serves a semantic function in explaining that the system should be placed directed towards the sun.

Within the area of solar cells a lot of development is occurring, e.g. research in foldable solar cell panels and thin film solar cells (Karlberg, 2013), which indicates that thin solar cells with high efficiency will be common in the near future. Existing commercial solar cells with a thickness of 2 cm are common, and smaller applications also containing batteries and a frame have the same thickness of 2 cm (e.g. clas ohlson, 2013; Lego Elektronik, 2011).

The maximum solar energy collection is achieved when the sun's rays are perpendicular to the collecting area. In the northern hemisphere the cells should be on a south-facing tilted surface for the best result (Foster, Ghassemi and Cota, 2009). Stated by Stephan Mangold[2], the optimal fixed angle in Sweden is generally approximately 45 degrees, however this varies with season; in the winter the angle should be higher or even vertical in order to receive as much solar energy as possible. The number of cells can be combined in order to design the system to match the voltage of the other devices and achieve an efficient system (Foster, Ghassemi and Cota, 2009).

2 Stephan Mangold (Project Leader, Chalmers Industriteknik) interviewed by the authors 6 May 2013.

Design of electrical system and devices

Research on the electrical devices needed in the system was performed to finally decide the dimensions and the structural design. Approximate dimensions and values are specified for each device and for the system as a whole.

Pump

In order to maintain the Ebb and Flow system, a pump is needed. There exist many water pumps on the market with dimensions from the size of a golf ball to larger ones like the common type that is used in aquariums. The power demand differs also, but is often low with around 1 - 6 W depending on its lift capacity. In the mini cultivation system the pump should only lift a small amount of water a few centimeters, why a low electrical efficiency as well as small dimensions could be used. The pump should run in 2- 4 intervals for a few minutes per day.

- Operating time:
  15 minutes, 4 times per day = 1h/day
- Estimation of electrical efficiency pump:
  1 W
- Dimensions pump:
  5*5*5 cm = 125 cm_2
- Energy consumption pump per day = 1 Wh

LED

There exist many different LED-applications for cultivations with a wide range of power demand. As mentioned earlier, the LED shall only complement the sun, which is why a 1-3 W lamp can be used. The operating hours of the lamp were discussed regarding whether it should be active when the sun is shining or not. It was concluded that the LED would serve its communicative purpose the most, if it shines during the dark hours. It would be difficult to promote that solar energy should be transformed, with extensive energy losses, to LED when the sun is shining, therefore solar energy from the day should be saved to prolong the growing day during the darker hours. The hours it can shine, will depend on the available power each day; during the winter months when it is needed the most, unfortunately only one or a few hours will be covered while other seasons will allow several hours of lighting.

Solar cells

In order to not make the concept too expensive and to make it possible to implement with technology existing today, the commonly used Crystalline Silicon cells should be used. The efficiency of the solar cells in the cultivation system was assumed to be 20 %. This is a relatively high figure, but still realistic since similar cells already exists on the market (e.g. Solarplaza, 2012).

The power that can be generated from the solar cells varies over the days depending on the solar movement and particles and clouds covering the sun, as well as where the panel is placed and in which part of the country (Foster et al 2009). Data from SMHI (Sveriges Meteorologiska och Hydrologiska institut) provides a long term mean value of accumulated direct and diffuse radiation from the sun, that can be used to calculate how much energy the sun provides to the solar cells an average winter day in Sweden. It is based on eight stations from Kiruna in the north of Sweden to Lund in the south. Mean value for radiation during December, January and February in Sweden on a horisontal surface = 410 Wh/m2/day (SMHI, 2007).

In order to set feasible dimensions of the system, it was decided that the concept should be designed to be able to power the pump during the darkest months of the year and preferably provide some excess power to run the LED-lamp. Since the power output in every case can vary a lot depending on geographical and local orientation, the system will be designed to cope for an in Sweden average winter day, but also to include some extra capacity to cover the extremes.

With an approximate efficiency of 12% (20% - 8%) the solar cells in the concept will generate on average 49,2 Wh/m^2/day in the winter on an average in Sweden.

It should be noted that these figures are not exact since many factors will impact the total output, e.g. a tilted surface more perpendicular towards the sun can generate more power, while the battery and local variances can generate the efficiency negatively.

The absolute minimum power is 1 Wh per day, since that is what the pump needs. This would require 1/49,2 = 2 dm^2. In order to have a margin to cover more extreme cases and to allow a usage of the LED-lamp but still design a product that fits in a windowsill, it was decided that the solar cells should produce approximately 1,5 Wh per day during an average winter day, which is why a minimum area of 2,7 dm2 was set.

Rechargeable batteries

In order to allow the pump to work during the night and to store some energy from days with more radiation to darker ones, it was decided to include rechargeable batteries in the concept. To balance the batteries, a regulator should also be used.

A battery regulator can increase the lifetime and productivity by making sure the battery is not over- nor undercharged (24volt, n.d.).

There are many types of rechargeable batteries, it was found that common and not very expensive rechargeable consumer batteries with good capacity are the Nickel-Metal-Hydride (NiMh) cylindrical ones. The number and the dimensions of the batteries would have to be decided depending on wanted storage capacity, and how much volume is available in the concept's dimensions, which is why estimations for the mini cultivation system were performed.

The most important prioritizations are that the pump should have enough energy to function each day and that the batteries should not be too expensive or volume demanding. It was decided that a reasonable back up energy room should cover the electrical supply to the pump for five days.

Regular rechargeable AA batteries (NiMH) has a storage capacity of 2,7 Ah and a load of 1,2 V. To cover the supply of the pump for five days, 5 Wh is required. Two 2,7 Ah batteries has a total capacity of 6,48 Wh, which would be a brimful back-up to cover the daily energy need for the pump but also eventual efficiency losses in the battery and circuit, or if the solar cells fail in producing energy for a few days.

The LED-lamp is daily dependent on the battery to store energy. Everyday it requires a capacity of at least 1Wh, to shine for one hour. However, it would be desirable to allow for five hours of extra light and by equipping the LED lighting with two 2,7 Ah AA batteries they would allow lighting for more than 6 hours. The battery unit should thus consist of 4 batteries with a total capacity of 10,8 Wh.

Controlling system

The circuit includes a circuit board, where the main parts are a microprocessor and a transistor that controls three different functions in the system:

- Controlling the prioritization of electricity to the pump; before any electricity is provided to the lamp, the pump should have a battery backup storage of a minimum of 6 Wh capacity.
- Controlling the pump running time intervals; the pump should run 4*15 minutes in equal intervals during 24 hours.
- Controlling that the LED starts to shine when there is no sunlight, but when the solar cells' charge is zero the circuit to the lamp is closed.

Product architecture

In order to decide the overall product architecture many considerations and compromises were necessary to fit the wanted functionality, technology and form. The size of a standard windowsill has been setting the upper limit for the width of the cultivation system base. In the same time, it was needed to maximize this dimension in order to fit enough water and solar cells and allow the plant to spread vertically without making the concept too unproportionally high or unbalanced. The solar cells are thus placed on a tilted surface on the top of the cultivation system, and the diameter of the base is set to 16 cm as this is the depth of a standard windowsill and fits all necessary functions and components. Further on, the height of the water and plant container is determined on the basis of water amount, space for roots and medium, pump dimensions, and the functionality of the Ebb and Flow technology.

Materials, manufacturing and recycling

Due to project limitations (see Sec. 1.4.), materials, manufacturing and recycling are three areas that not have been in focus within the development of the Plantera. However, the system is considered against specific materials and possible manufacturing techniques, and designed to simplify manufacturing. The construction of the system is therefore made simple and the technology and electricity have been applied with manufacturability in mind.

The system should, to as large extent as possible, be recyclable and have a low environmental impact, and the materials used should not be harmful to people. Preferably, the plastic components could therefore be made of Polypropylene (PP), being durable with low density and more sustainable than for example the commonly used and durable ABS-plastics (Klason and Kubát, 2002). The greenhouse, made of glass, is fully recyclable but the process unfortunately requires a lot of energy. In addition to this, the manufacturing process of steel can emit a high degree of carbon dioxide. The design of the different system parts has been adapted in order to ease the process of assembly and disassembly. One of the biggest uncertainties and difficulties regarding recycling is the separation of the electrical parts from the plastics. The solar cells, the pump, and the LED-lamp add to the material list and the overall environmental impact, but due to the scope of the project the materials in these devices have not been investigated further.

7.5.5. Challenges

The main challenges with the finalization of the concept was to consider and make room for all different functions that are needed, and in the same time to reach the wanted overall expression. For example, it was desired to maximize the surface of the solar cells in order to be able to use the LED all year around, and when it is most needed for more than only one hour. However, the window placement that actually is making the solar cells possible to use, is also what is limiting the size of the entire product.

Another challenge was to simplify the handling of the concept in the same time as giving enough, however not too much, information to make the system run smoothly. For example, the temperature within the greenhouse need to be in a certain interval and in order to ensure that it is not too hot during the summer, the user needs to open the glass doors. This responsibility was desired in one way, to create an interaction between the system and its user, but is a challenge since the user must not forget to open the doors when necessary. Another issue concerning the direct interaction, is the need for water and nutrient refill every third week, which might be so seldom that there is a risk of not becoming a habit for the user and that they would need to be reminded somehow.

8. Final result

The final result of the project - the mini cultivation system Plantera - is in this chapter presented and described in detail. The initial part of the chapter is describing the concept's physical design and usage, and is followed up by the product semantics and usability.

Figure 8.1. Plantera

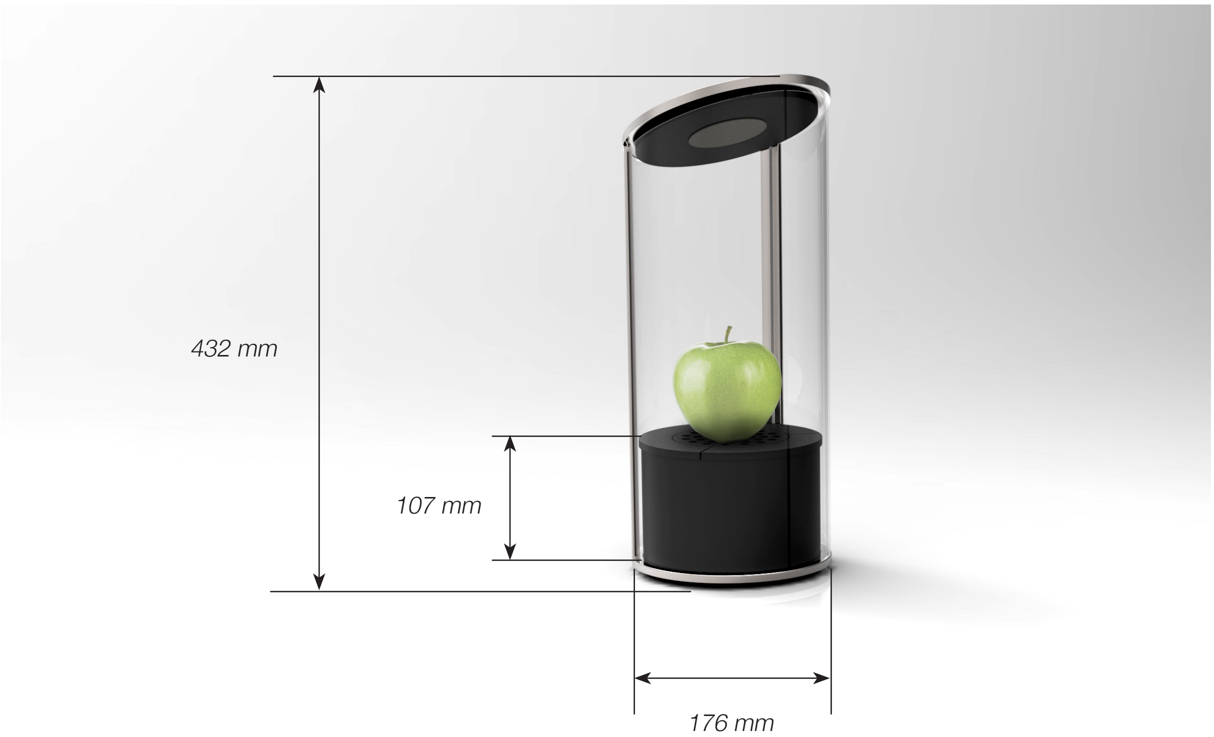


Figure 8.2. Plantera with dimensions

8.1. Plantera

Plantera is designed to increase the understanding and adoption of the vertical industrial greenhouse production of Plantagon. It is an automated system for the cultivation of one plant at a time, opening up for user interaction with pedagogical meaning to, in a simple way, explain the advantages of industrial greenhouse productions (Figures 8.1. & 8.2.). The concept is formed from the characteristics and expressions of *dynamicity* and *simplicity*.

The system should be placed in a sunny window and can nurture different types of plants, e.g. herbs and salads as well as perennial indoor plants. It is designed for cultivation and/or technology interested users, and it is believed that one interest can spur the other. The users may have knowledge about the art of cultivation from before, but Plantera is also created for users that are urging to learn how to grow plants in a innovative and technological mini greenhouse.

The name developed during the work with the system and was chosen due to its clear connection to Plantagon and the era of urban growth we are now entering. The second signification of the name is its meaning in Swedish - to plant.

8.2. Technical specification

This section is describing the system's different components and technical functions.

8.2.1. The water containers

The section of water containers consists of a water reservoir, an upper water container and a plant container (Figure 8.3.). The reservoir is to contain nutrient enriched water and a pump, having two additional and separate lids, one of which is carrying the upper water container. The plant container is a plastic pot dimensioned for pumice and plant roots, and designed to be placed in the upper water container.

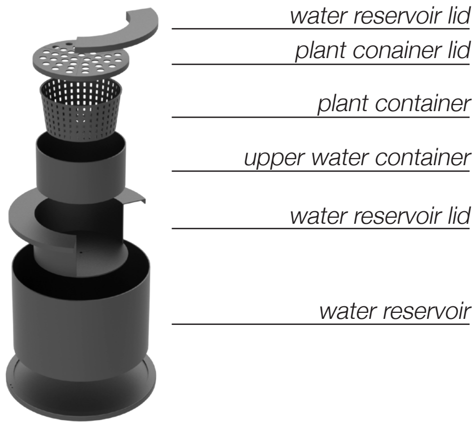
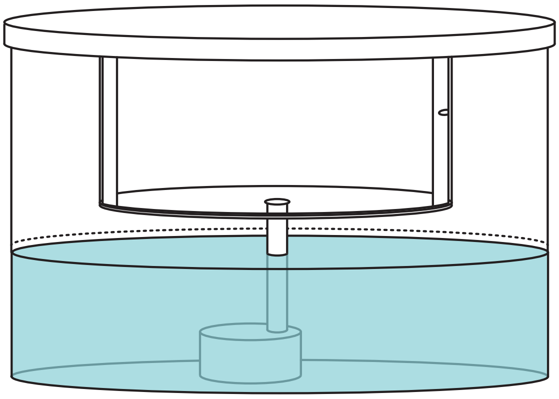


Figure 8.3. The water containers

The water pump is connected to the power supply, through a contact in the bottom plate (Figure 8.5.). A tube for water inlet and outlet is connecting the water reservoir and the upper water container, allowing the key functions of flooding and draining in the Ebb and Flow technology (see Sec. 7.5.4. and Figure 8.4).



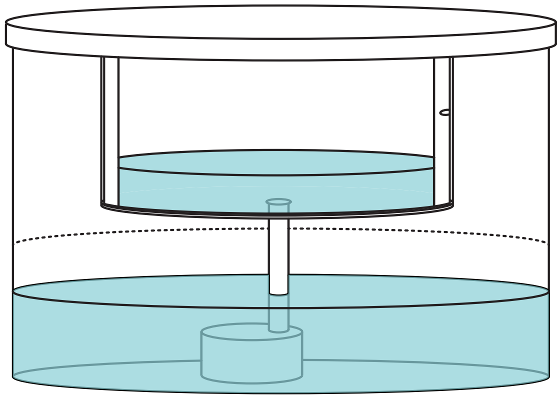


Figure 8.4. Ebb and Flow

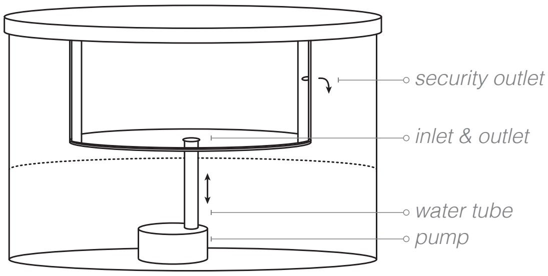


Figure 8.5. Ebb and Flow description

8.2.2. The greenhouse

The middle part of the system is a greenhouse, where the plant has room for growth. The greenhouse is divided into three separate parts; one rigid being a part of the framing and giving stability to the system, and two doors allowing flexibility to open it. The three parts are all covering the water reservoir, but only the rigid one is attached to the inside of the upper part of the frame.

One of the doors has an opening of a half ellipse cut-out, allowing the user to open and close the greenhouse section. The four splines surrounding the edges, except where the greenhouse is to be opened, are linking the doors to the rigid part. A simple construction of a rigid wire is attaching the upper part of the splines onto the frame, allowing the doors to be turned approximately 90 degrees.

8.2.3. The frame

The frame of a lid and a bottom plate is covering the system and giving it structure.

Solar cells, giving power to a LED-lamp in the bottom of the lid (Figure 8.6.) and the pump in the water reservoir, are placed on the top of the frame. Within the frame, batteries and a controlling unit with circuit board and regulator are placed.

On the upper part of the bottom plate, an electronic contact is placed. The contact is designed to match the water reservoir contact and to lead electricity between the two parts.

8.2.4. Technical functions

The two major technical functions, of power supplying and watering system, are designed for allowing allow a clear connection to the vertical greenhouse of Plantagon and are crucial for the mini cultivation system to work.

The group of solar cells placed on top of the frame (Figure 8.7.), is the one and only power supplier of Plantera. Solar cells transform solar energy to electricity ➔ The electricity is led to a rechargeable battery unit controlled by a battery regulator ➔ A circuit board, including a processor and transformer, controls the supply and demand of electricity.

The electricity is lead through the splines on the fixed glass to the bottom plate and is further transported through the plate contacts on the water reservoir to the pump. The electrical connection on the bottom plate is secured from working when in direct contact with humans. A battery pack will be placed in the top or the bottom of the system depending on type of batteries.

Figure 8.6. LED

Figure 8.7. Solar cells

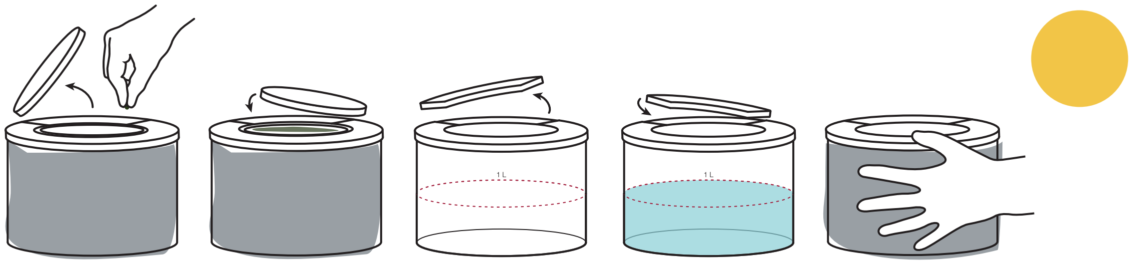


Figure 8.8. Instructions - Day 1

The pump and the LED-lamp is driven by the power from the solar cells at pre-programmed operating times; the pump will run four times a day and the LED-lamp will only shine when there is no sunlight, i.e. when no solar energy is produced from the solar cells. The system is designed to prioritize the pump, making sure that the pump always has enough power to supply the plant with nutrient solution for five days without any new energy input. Consequently, the LED-lamp will be active only when excess power is available. Since Plantera is placed in a window and direct sunlight nurtures the plant through the glass, the additional LED-light is not necessary for the cultivation to work. However, all extra light is beneficial for a plant being cultivated in a country like Sweden.

The watering system is based on the Ebb and Flow hydroponic technique, where the plant roots and medium are submerged in nutrient solution in intervals of 15 minutes on four occasions evenly distributed over the day, in order to provide the roots with necessary oxygen, nutrients and water. At time of watering, water from the reservoir is pumped up to the upper water container through the inlet tube, and the security outlet is directing the water back to the reservoir if too much water is pumped up to the container. When the pump turns off after 15 minutes, the water is drained back through the pump to the reservoir. The draining creates a suction of new air to the medium and roots from above.

8.3. Usage

Plantera is designed to be easy to use and nurse, and invites its owners for regular and needed, but few and seldom, interactions, as well as optional ones whenever feeling a desire of caring or harvesting. It only has a few must-do's to remember; when the initial assembly of the product and the germination process are succeeded, Plantera only requires a few minutes of interaction every three weeks. Simple instructions coming along with the purchase, is describing briefly how to run the system from the start successfully in a 4-step process (Figures 8.8-8.12.).

Step 1 - Day 1

1. Demount the plant container lid, place seeds in the predefined rock wool holes, and put the lid back on.

2. Remove the smaller water container lid and pour tap water into the reservoir until it reaches the inside marking of 1 liter. Put the water reservoir lid back on.

3. Place the water reservoir inside the greenhouse structure, on top of the bottom plate. Make sure it clicks; the indication is the start of the system.

4. Close the doors to the greenhouse.

5. Place the system on a sunny windowsill. For an optimal result, choose a window facing south.

Step 2 - Day 5-10

Add seedling nutrients to the water container when the seedling is approximately 5 cm high.

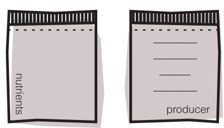


Figure 8.9. Instructions - Day 5-10

Step 3 - Continuous cultivation

Every three weeks, the water needs to be refilled and plant nutrients have to be added: open the smaller water reservoir lid, add water until the water line reaches the 1 liter marking and pour a sachet of nutrients into the water. The system offers a semi-closed greenhouse environment where the user can decide, dependent on plant and external temperature variables, how much ventilation the plant needs. A temperature strip is available for keeping track on the greenhouse temperature and is a reminder for the user of when it is necessary to open the doors for ventilation.

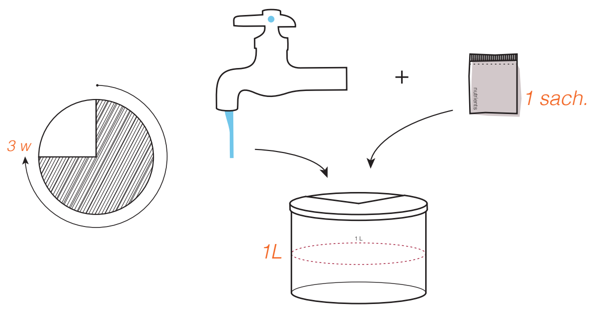


Figure 8.10. Instructions - Continuous cultivation

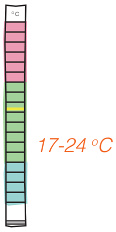


Figure 8.11. Instructions - Temperature strip

Step 4 - Cleaning

The containers that come in contact with water should be cleaned a few times a year, specifically if alga is produced. By removing the plastic pot, holding the pumice and the plant, the two water containers can be lifted out of the greenhouse structure and be cleaned using hot water in a sink. If necessary, the pump and greenhouse section can also be cleaned or wiped off.

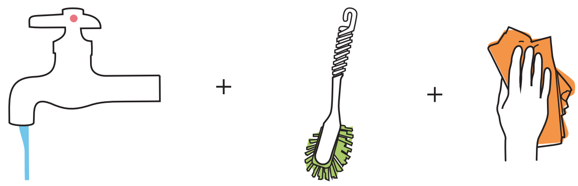


Figure 8.12. Instructions - Cleaning

When starting up a new cultivation, the pumice and plastic pot need to be cleaned and a new seedling can be placed on the medium. Alternatively, new seeds can be placed in new rock wool as from the very beginning.

8.4. Product semantics and usability

Plantera is given a subtle and cylindrical form made of transparent glass both allowing the plant to speak for itself and expressing the simplicity and dynamicity of the product (Figures 8.13. & 8.14.). The overall form expresses stability, having almost the same diameters throughout the system; from the bottom plate to the top of the frame. The slight differences are forming a tension, giving a mild dynamic expression that is increased with the greenhouse's flexibility of opening and closing the doors and the constantly changing plant, all of which are created in order to be identified with Plantagon's design language that is incorporated in the vertical greenhouse (Figure 8.14.).

The design of the cultivation system is adapted to suit and highlight the different functions, enhancing the feeling that it has a specific purpose of technically cultivating and nurturing a plant (Figure 8.13.). However, covering a large part of the technicalities is not only keeping light from water and hiding electronics from users, but is also aimed at communicating the simplicity of running the system.

For turning on Plantera, the water reservoir needs to be placed on the bottom plate, whereas audial feedback is given by a discrete click, and haptic feedback by the two matching surfaces fitting together. Respectively, for turning off the system, the reservoir must be removed from the bottom plate. When the pump is running, it is making a mild sound and is thereby also reassuring the user of its operational state.

Figure 8.13. Plantera with plant

Figure 8.14. Plantera with light

The greenhouse section is surrounding the plant in an embracing manner to spotlight the plant and express a hint of responsibility - an important word Plantagon is aiming to communicate to its consumers (Figures 8.13. & 8.14.) Together with the elevated bottom cylinder containing the nutrient solution, the plant can be seen as on a pedestal; being protected at the same time as showing off its pride. Consequently, the positive aspects of a controlled greenhouse environment can be communicated to the user. Furthermore, having a cylindrical formed greenhouse is both enriching the identification with vertical greenhouse cultivation and inviting the user for interaction. The transparency of the tube is allowing permeation of sunlight and giving the entire system a lighter, more exclusive, and a dynamic impression. Also, it is allowing and encouraging the user to follow the life of the plant at the same time as it is giving the user a sense of control. To open the doors, the user simply uses the cut-out opening in the right-hand sided glass door (Figure 8.15.). The doors can be opened on any angle without much resistance and hence giving the user instant haptic feedback.

The design of the smaller water reservoir lid is indicating to be easier to open and close than the other lids, because of its placement directly behind the greenhouse doors and its size (Figure 8.15.). The outline, following the form of the lid, is also heavier and more distinct than the other split lines and is therefore clarifying the user of which lid to open up for the water check-up. The positions of the reservoir and container lids are secured from being placed in the wrong positions by making them fit with three completely different shapes (Figure 8.15).

The main part of the frame and the splines encircling the lid of the upper section are all made of steel. The material is chosen to generate a strong connection to a greenhouse environment and to make a good partner with the glass parts. Additionally, steel is a rather ordinary material that can relate to industrial applications as well as a more clean and high-end area. Steel, being a wide used material, is giving neutrality to the system and allowing an expression of simplicity that is directing the focus to the plant.

Figure 8.15. Zoom of water reservoir lids & cut-out opening

The solar cells has a dark blue, nearly black, appearance with a streaked embossing, which visually and haptically is separated from the rest of the upper frame, and thus highlights their function. The tilt of the solar cell surface is describing how Plantera should be placed, directed towards the sun in a window, and is, in contrast to the main shape of the system's body, enhancing the overall dynamic expression (Figure 8.16.).

The lower section of water containers and lids, and the lower part of the upper frame, are all made of a dark grey, opaque, and semi-rough plastic. The material is chosen partly out of practical reasons connected to manufacturability, but also because of its dark appearance and soft touch that is meant to add a less sterile and strict look, balancing the natural factors with the high technological ones.

To get an overall aesthetic impression of Plantera, the glass parts are covering the water containers. In this way, the strict cylindrical shape can be transformed and optical formations can be glimpsed through the glass at the same time as the meeting between the two different materials is becoming more interesting (Figure 8.17.). Also, the shape of the water reservoir is showing an interesting appearance without interfering with its interior of functional demands.

Figure 8.16. Plantera, without and with tilted solar cells

Figure 8.17. Plantera in context

9. Evaluation and Discussion

In this chapter the project and its results are evaluated and discussed. The final outcome, the process and the methods used as well as lessons learnt and recommendations for further development are areas brought up for discussion.

9.1. Project outcome

This project has resulted in a comprehensive consumer analysis and a conceptual development of a product that, as predefined in the goals, should drive adoption of the vertical greenhouse. The consumer analysis executed has a solid foundation with user studies and theory about the spread of new ideas and food innovations, as well as research in food security and relevant market trends. Consequently, the analysis and summary of the result provide a broad picture of what the obstacles and opportunities the implementation of a vertical greenhouse might meet among consumers. The concept developed is an example of how the future implementation of a vertical greenhouse could be eased. The mini cultivation system is built upon and inspired by already existing technologies and product solutions, but adapted to fit the Plantagon design framework and the overall problem description defined within the project. A cultivation system, using solar cells and a hydroponic technique, has not in a combination been seen elsewhere and is making the product innovative and straightforward as the vertical greenhouse and the company it is designed for. The Ebb and Flow technique (see Sec. 7.5.4) is well-known and is therefore ensuring that the mini system can give plants effective cultivation conditions and optimal chances of a good yield with minimized time effort.

Plantera has been designed with a focus on making potential usage situations as beneficial for the users as possible. However, due to the project scope, the system has not been formally evaluated against any users or against any evaluative methods, but the consumer point of view has been included by coordinating the development and evaluation against the personas and the set guidelines and requirements instead. Hence, the overall design of Plantera and user interactions fits well with what were aimed for, yet some possible areas of improvement would likely improve the user experience (see Sec. 9.5.).

9.1.1. Plantera's role as an adoption tool

The underlying purpose with Plantera is not to make sure that people will be fed for the day and the system will not have a direct bearing on malnutrition problems. The purpose is rather for it to be an educational tool that can spread knowledge about cultivation and also drive the adoption of the vertical greenhouse, which in turn could push for more sustainable food consumption. The question is though if the mini cultivation system will be adopted in itself. It is assumed that, for many users, the system is an encounter with a new way to cultivate, something which could impede the adoption. On the other hand, the concept clearly describes its own functions and is easy to review, both due to its physical size and its simplicity in construction and design. In addition to this, the system puts the user in control of the growing process and the user could thus easy evaluate and have control of how it affects her/him personally. Consequently, Plantera ought to have the right prerequisites to encounter a fast and vast adoption.

There is a risk that the realistic target group would be more narrow than what was aimed for. Plantera has been designed for the four personas described in section 6.3., and is thereby in its design aimed at the broad target group of Swedish urban crop consumers. However, since the concept had to be educational, but also house all the necessary functions, technology, and expressive characteristics, Plantera would be a product with a relatively high cost. It is advisable to further evaluate the concept in regards to its cost, target group and how it should be distributed and promoted. It would for example be possible to adjust the design so that Plantera could be connected to the electrical grid and in that manner reduce the cost by removing the solar cells. Even if this could have a negative impact on its pedagogical purpose, the fact that it offers a less expensive and more secure option, in regards to power supply, makes it a feasible and perhaps favorable alternative. Still it is also possible to evaluate if the distribution and promotion of Plantera could be adapted to fit its current design and thereby secure a spread of the concept regardless its high cost. For example it could be used as a promotion tool to be given away as free samples or as prizes in competitions. This could consequently create an interest for the vertical greenhouse and the system as such, and increase the overall spread through the specific social system where the new crop production is to be implemented.

With a project focus on simplifying the adoption of the Plantagon vertical greenhouse, an obvious query is if the connection between Plantagon and Plantera is clear enough. The concept is designed to create identification with rather subtle design cues that might not entirely speak for themselves. For this reason, the connection depends to a large extent on how the concept is promoted and distributed; for example, by using Plantagon channels of communication the connection would be reinforced.

9.1.2. Guidelines and requirements

The concept development departed from a set of guidelines describing what a design intervention would have to fulfill in order to simplify the implementation of the vertical greenhouse (see Sec. 7.4.1.). When placing Plantera in relation to these guidelines, it is clear that it delivers on all of them. However, since the guidelines are not measurable, it was difficult to determine to what extent the concept is fulfilling them. Moreover, the final result will to some extent, depending on several factors outside the product as such, e.g. through which channels the product would reach the consumers.

When evaluating the mini cultivation system against the product specific requirements, presented in Appendix VIII, the mini cultivation system proved to fulfill most of them to a high extent, but since the concept is still in an early phase of development, some parts of the evaluation against the requirements remain rather speculative. Nonetheless the requirement concerning the air and water temperature in the system is one example of what is not fully controlled by Plantera and depends, in this case, to a high extent on the user, his/her attention to the cultivation, and prior knowledge. These variances will however not result in a cultivation failure but only a not fully optimized growth.

Final cost

The scope of the project did not allow for a consistent investigation or estimation of the cost, neither of different parts nor the final price of the product as a whole. However the electronics, materials, and devices in the concept are neither uncommon nor exclusive, which is why an estimation of the final price to consumer would not surpass the requirement set to 1500 SEK. It should nevertheless be noted that the final cost depends on a lot of factors that lies outside the control of this project, such as production, distribution channel, and margins.

Electrical components

Another requirement that was difficult to evaluate was the safety and the power supply. Failures in the electronic system should be the highest risk area, but since the technology is not very advanced, and since Swedish standard safety measures would act as guidelines for the final design, it is estimated that the cultivation system would be safe. Regarding the power supply, it was calculated as sufficient, though these calculations are based on the system being placed in a south facing window and on numbers regarding sun radiation on an average for Sweden. In the most northern parts of the country, where the winter months only allow one or less hours of sun per day, as well as for the sunniest parts, these calculations might be inaccurate. However, the batteries have a capacity for a few days of darkness and in addition to this, the plant will survive and be well off with only a few minutes of flooding per day, which could half the power demand for the pump. Nonetheless, in a dark window far up north in Sweden the system could encounter some problems.

Sustainability

Many factors, more or less investigated, have an impact on Plantera's overall social, economical and environmental sustainable impact. Since the main aim with Plantera is to aid the implementation of the greenhouse, which in turn is designed for increasing food security, it is thus touching all the areas of sustainability. However, the issue is complex and it is difficult to draw conclusions about Plantera's role, especially since the greenhouse has not yet been built and served its function. When it comes to the actual usage of Plantera, the ambition is to offer the user a possibility to learn more about cultivation and hence increase social sustainability. Environmental sustainability is affected by the water and nutrients that are consumed on a regular basis. Though, the volumes being diminutive should be further considered; nutrients can be prepared in many ways and it is important to ensure that the amount of nutrients is optimized in order to minimize the volume rinsed out in the public water system. Moreover, it is not investigated what environmental effect the manufacturing processes, and the use of different materials and devices could give rise to. Also, the mini cultivation system holds a considerable amount of material for merely one plant, which neither is very resource effective. On the other hand, the consistent usage of durable and abrasion resistant materials and devices, adapted to their specific function, would increase the possible theoretical lifetime of the cultivation system. The practical lifetime though, depends on the user, and the experience that is elicited from the interaction with Plantera.

9.2. Project process

When working on this Master Thesis, Plantagon had not yet finally set an end product or aspects concerning the potential consumers, which is why the project started off with a rather broad scope. The project process and its outcome were formed gradually as decided from the beginning. Consequently, the final concept and result of the project could therefore not have been predicted, not even directly after the research phase. Hence it is important to have in mind that the concept is only one example of what could be done to ease the implementation of vertical greenhouses and educate users of modern cultivation technologies.

If time had not been a limit, it would have been interesting to analyze the idea of a mini cultivation system against users before conceptualizing it as well as to evaluate the final product with a functional model against possible users. This would have allowed an investigation of the user needs for the mini cultivation system as such, and could have been combined with the vegetable consumption insights to create an even stronger foundation for the concept.

9.3. Methods used

The generalizability of the user study result can be discussed departing from the in-depth interviews. The focus on qualitative research gave a nuanced result that in turn gave deep and rich insights. Also, using this qualitative method increased the validity since the research was aimed at investigating behaviors, attitudes and values, as well as future trends, which all are factors difficult to give a precise value to. Per definition in-depth interviews are different depending on the individual respondents, which is a fact that might affect the reliability. However, the same template and more importantly the same purpose were clearly pre-defined and used consistently. Trying to be vigilant to notice and avoid any kind of subjectivity and/or bias in the interviews and the following analysis of the data has been a goal throughout the project. Although, it is recognized that every analysis will hold some sort of subjectivity, but the use of well-defined and structured methods for the process increased the reliability of its result.

Several aspects regarding the sample of respondents participating in the interview and survey study might have had an impact on the result. The survey was sent out through a social media channel, which is why the majority of the respondents were friends or friends of friends. It is however not likely that this have affected the responses to a very high extent since the questions were rather straightforward and did not address a sensitive subject. The answer frequency was one on five and therefore it is necessary to consider if specific characteristics separate this answering group from the rest; likely they have a higher interest for the topic and perhaps also more extreme opinions. It is hence probable that the result from the survey mirror more early adopters interested in new ideas for food production. In all, the user study is aimed at being representative for the target group for the project, being crop consumers in larger cities in Sweden. This could be seen as a rather large and relatively heterogeneous group, which would imply that a larger sample would be necessary to be representative. Since resource constraints exist in reality and in this project, a limit was however necessary. The issue is to some extent covered, since the interview study and survey complement each other, and since expert interviews and theory including consumer research in Sweden have been used to validate the result. Still, the consumer needs investigated in this project have likely not been identified abundantly.

The interview situation as such might have affected the result, since being interviewed and asked about consumer habits might have been difficult and a bit stressful for some of the respondents. It is believed that some felt guilty about not being as aware of their own consumer habits as they perhaps had thought. Additionally, it was sometimes obvious that the respondents wanted to mention something about sustainability, likely because it is believed as something one “should” take into consideration when making both smaller and larger life choices.

Another important aspect, that might have had a negative impact on both the reliability and validity of the research, is that the interviews were not recorded nor transcribed. Due to time limitations notes were taken during the interviews instead. Analyzing the notes, taken in pressure of time, instead of a recording opened up for possibilities of wrong interpretations since a translation and minor analysis of the data were already performed during the interview sessions. Being aware of the issue and vigilant when taking notes, were precautions that might have decreased eventual bias or other errors in the result.

Overall, it would likely have been beneficial to conduct a more encompassing literature study, where different references could have been compared more extensively, in order to get a more nuanced picture of the different topics. This did however, not fit in the scope of the project. The adoption theory is mainly based on one reference, and that could be seen as a weakness since this theory act as a foundation for the concept development. The reference used is though well established in the topic and a collection of different research results in a comprehending review of the subject. Furthermore, since different references were used as a complement for the theory about food innovations, the credibility of the material was increased.

The methods used in the phase of the concept development have all been a great part of creating the final outcome of the project. The benchmarking, initiating the work with mini cultivation systems, was crucial for the development of the ideas; the session mapped the route towards the final concept with inspiration and knowledge concerning advantages and disadvantages to either include or exclude in the concept. In addition to this, the use of brainstorming, sketching and CAD have all been beneficial for the project, both for the visualization of ideas and concepts, and for the process of evaluation.

9.4. Lessons learnt

Starting from a clean paper without clear directions or delimitations was difficult in terms of defining and planning the work, as well as for putting up strategies and goals. Inevitably, the preparation for the project was executed with high expectations, visualizing the project to fulfill most eventualities and findings from the user study. The process of taking the work to its final point was therefore somewhat of a struggle.

Aiming high was definitely not negative in the context of the project, but rather beneficial in terms of creating incentives to push the work forward continuously. However, the high ambitions were sometimes directing the project in wrong ways, which could be connected to a desire to develop something Plantagon would appreciate and benefit from. Accordingly, this resulted in a high degree of openness, and urging for feedback and responses on the project. Gradually, the importance of finding own goals and engagements was realized and the strengths of believing in the own competences and intuitions pushed the work back on track.

Even though this Master Thesis covered 20 full weeks of work, it has been crucial to make substantial decisions early in order to move on with the coming phases. Moreover, it has been important to remember and realize that a thesis work at Industrial Design Engineering not only imply the completion of a concept development project, but also an academic report in which the entire project is declared.

To sum up, the lessons learnt are mainly the importance of not being too ambitious in the definition of the Master Thesis' aims and goals, but instead use a great portion of realism. The goals should be well balanced for both the process of a concept development and the overall thesis demands.

9.5. Further development

To ensure that the purpose, functionality and usage of Plantera are successful, the following points need to be further investigated and developed.

- The most important part of a further development is to involve users in an evaluation; the different design features, developed to ease the usage and push for the connection between the cultivation system and the vertical greenhouse, should be evaluated and ensured.
- The smaller water reservoir lid needs to be positioned directly behind the glass doors, and in order to improve the semantics and feedback a better positioning marking could be investigated. In addition to this, the water level marking should be improved; unobservant users might miss it and pour too much water into the reservoir.
- When the temperature is too high in the greenhouse section, the user must open the doors for ventilation. This manual version is chosen for the purpose of interaction, but might not be optimal for the system since it is requiring attention from the user. An evaluation regarding this user interaction needs to be performed; perhaps an automated function combined with the manual one would be better for the mini cultivation system.
- It would be beneficial to run a prototype, offering a thorough troubleshooting session. There might be additional errors, which have not been foreseen, that should be removed.
- Since no proper materials selection, nor manufacturing investigation, have been performed within the project, this must be further investigated to make sure the optimal combination of recyclable and cost-efficient materials, as well as suitable manufacturing techniques is chosen.
- Making sure the solar energy is enough to run the pump and the LED-light at all times could increase the overall performance of the cultiva-

tion system. The calculations connected to the solar energy performed in section 7.5.4. need to be investigated further in order to, in the instructions, be able to more accurate specify performance level of the included LED-light.

- The technical functions of all devices should be further investigated, making sure the system have enough power even in the darkest periods of the year and further specifying cost, dimensions and functionality. This includes the solar cells, pump, circuit board unit, and LED-light.

9.6. Recommendations

Below follows a list of recommendations that have been identified as important for improving the mini cultivation system even further.

- To increase the user experience, hands on tips about growing should be developed and included in the instructions.
- Packages of nutrients, that are to be added into the water reservoir regularly, should be developed and adapted for the system specifically.
- To spread information about Plantera and the vertical greenhouse, sharing experiences with others should be encouraged. Possibly, the users can compare growing results through a mobile application or a web page.
- To optimize the power for darker periods of the year or darker parts of Sweden, a back-up system where batteries could be charged by another source than solar cells could be developed.
- The concept could be distributed as a promotion tool minimizing the cost for the consumer and making sure it reaches important decision makers in a social system.

Conclusion

With an extensive consumer research along with a creative design process the project outcome is a comprehending review of oppurtunities and challenges for the adoption process of the vertical greenhouse, and an adoption tool meant to facilitate the implementation of vertical greenhouse productions in large cities in Sweden. The research questions, setting the overall direction of the project, are answered in this chapter.

>> What prerequisites are there for the specified target group's adoption of an industrial and high technological urban food production in vertical greenhouses?

Food has a direct impact on people's personal health and new food innovations such as the vertical greenhouse can thus require more time than other innovations to adopt. The research result indicates that the target group holds skepticism towards greenhouses and industrially produced food, something that could impede an adoption. On the other hand, it was detected that there is a desire for knowing the producer and for consuming locally produced vegetables, even if price and convenience are strong driving forces and often are prioritized. In the same time, the organic demand is increasing in Sweden, several food scandals are revealed, and public discussions about a trend from a decreased price focus to an increased focus on knowing and trusting the sender. These are factors that could be beneficial to acknowledge for vertical vegetable producers offering a sustainable production close to the consumer, such as Plantagon. A successful adoption implies though, that the producers remain transparent, explain the benefits of the production, deliver what they promise, and try to push for a personal connection to the consumer. However, the price and convenience factors cannot be neglected. Lastly, because of consumers' relatively high skepticism to and fear of chemicals, it will be important for Plantagon to be transparent about the nutrients added to the crops within the vertical greenhouse, how they are produced, and in what way the residues are being taken care of.

>> How could the awareness of the relation between sustainability and the vertical greenhouse be increased and how would this affect the consumer experience?

An increasing organic demand along with an increased awareness and interest for sustainability among the target group indicate that a sustainable framing of the vertical greenhouse should be beneficial for the adoption. It should be recognized however that the matter is complex, something acknowledged by the consumers, and a reason of why reliance in markings ensuring the quality e.g. KRAV and eco becomes a resort. Accordingly, the vertical greenhouse could profit from promoting itself as a sustainable option, but having in mind that the information should be easy to interpret and compare to other sources, and not require too much effort or prior knowledge, which is why a reliable sender standing as a guarantor could simplify the matter.

>> How can we with design control the consumer experience and facilitate the implementation of the concept?

By increasing and adapting the communication, information and experiences that are offered to the consumer, according to the theory about adoption of food innovations and the user study performed, the implementation of the vertical greenhouse can be facilitated. Plantera is one way to do this by offering the consumers to have control of the growing process. When cultivating in Plantera themselves, the consistency between the technology and the users' values and experiences increases. The user will by using Plantera learn about the cultivation processes in the vertical greenhouse, how it works, and the result of it. Plantera communicates that the merge of technology and food can be something positive, which in turn will decrease the consumer's worries about dangerous chemicals in the processing of crops, and explain that the crops are actually natural.

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Figures

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Figure 2.2. - Plantagon, n.d. *Feeding The City*. [illustration] Available at: < http://www.plantagon.com/> [Accessed 21 April 2013].

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Figure 2.4. - Plantagon International AB, 2012. *The Plantagon Greenhouse*. [illustration] Available at: <http://www.mynewsdesk.com/uk/pressroom/plantagon-international/image/view/the-plantagon-greenhouse-in-linkoeping-sweden-154057> [Accessed 21 April 2013].

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Figure 6.4. - Kindler, A., n.d. *Portrait of a smiling middle-aged woman*. [photograph] Available at: <http://www.gettyimages.se/detail/foto/portrait-of-a-smiling-middle-aged-woman-royaltyfri-bild/75455664http://www.gettyimages.se/detail/foto/portrait-of-woman-royaltyfri-bild/142762634> [Accessed 19 March 2013].

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Figure 7.5. - Click & Grow, 2013. *Click and Grow is a Smart Garden*. [online] Available at: < http://www.clickandgrow.com/> [Accessed 25 March 2013].

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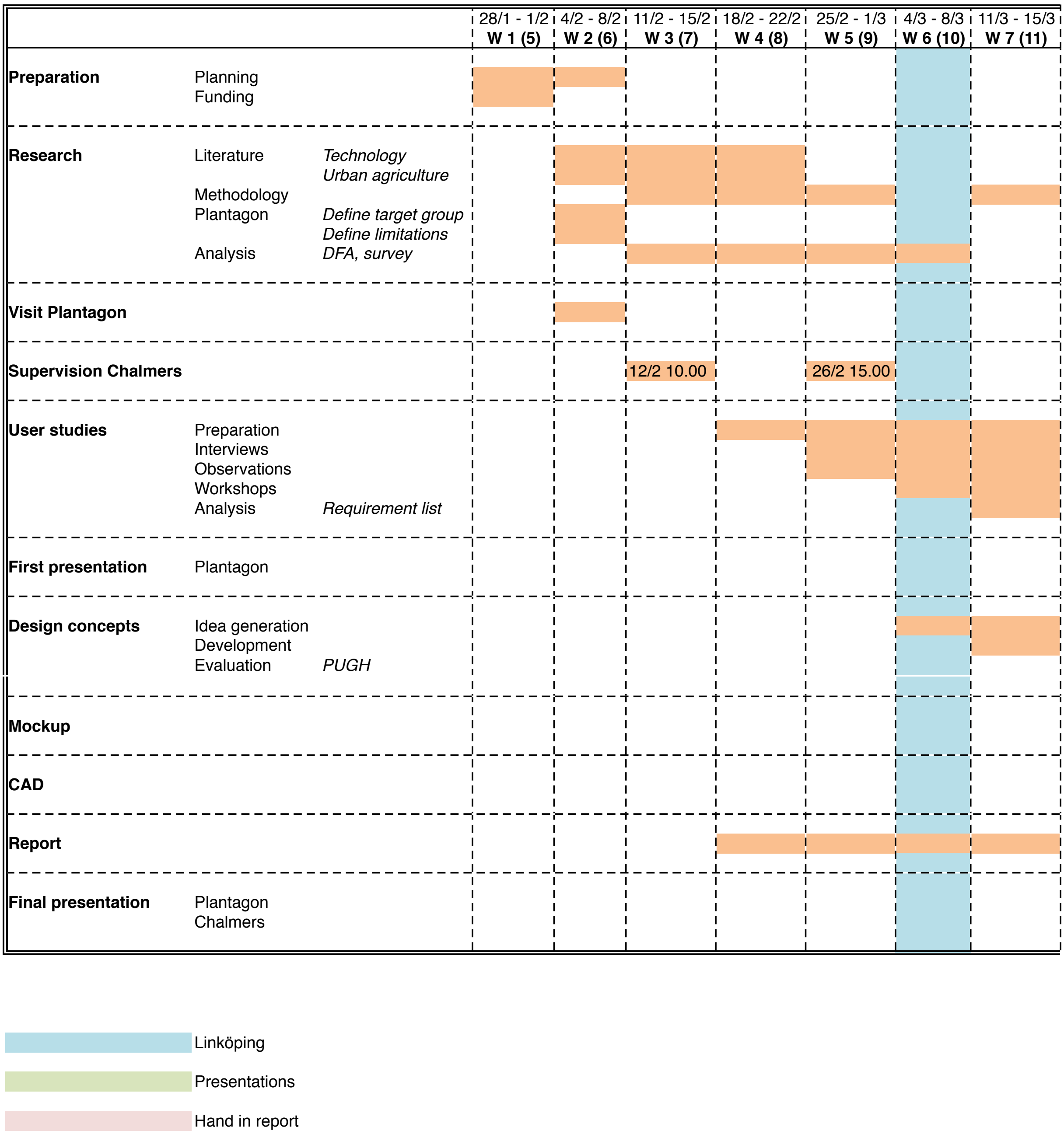
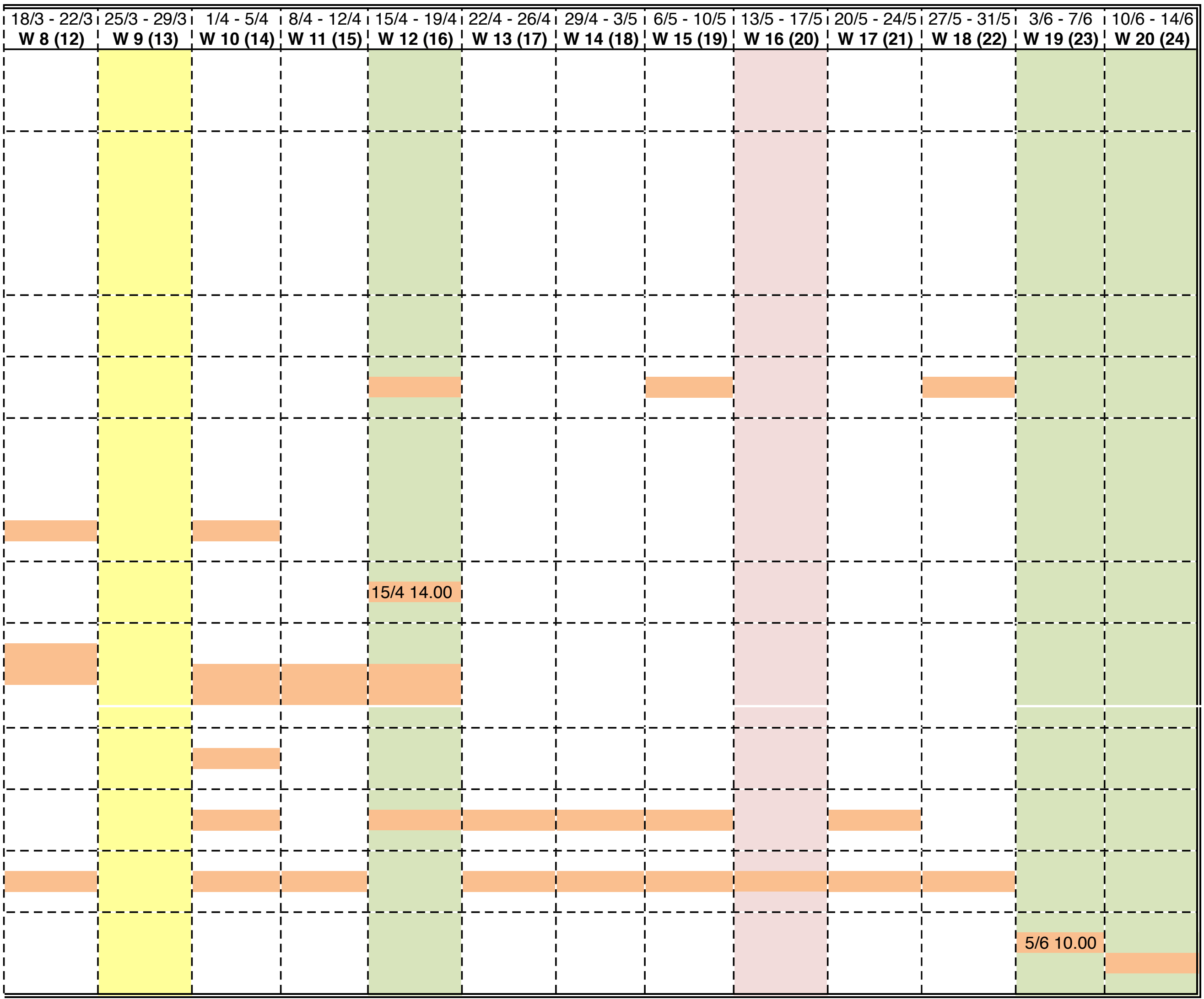
Appendices

I. GANTT chart
II. Flow chart
III. Organizational structure Plantagon
IV. Feeding the city, a system overview
V. Interview questions
VI. List of interview test subjects
VII. Mood board
VIII. Requirement list

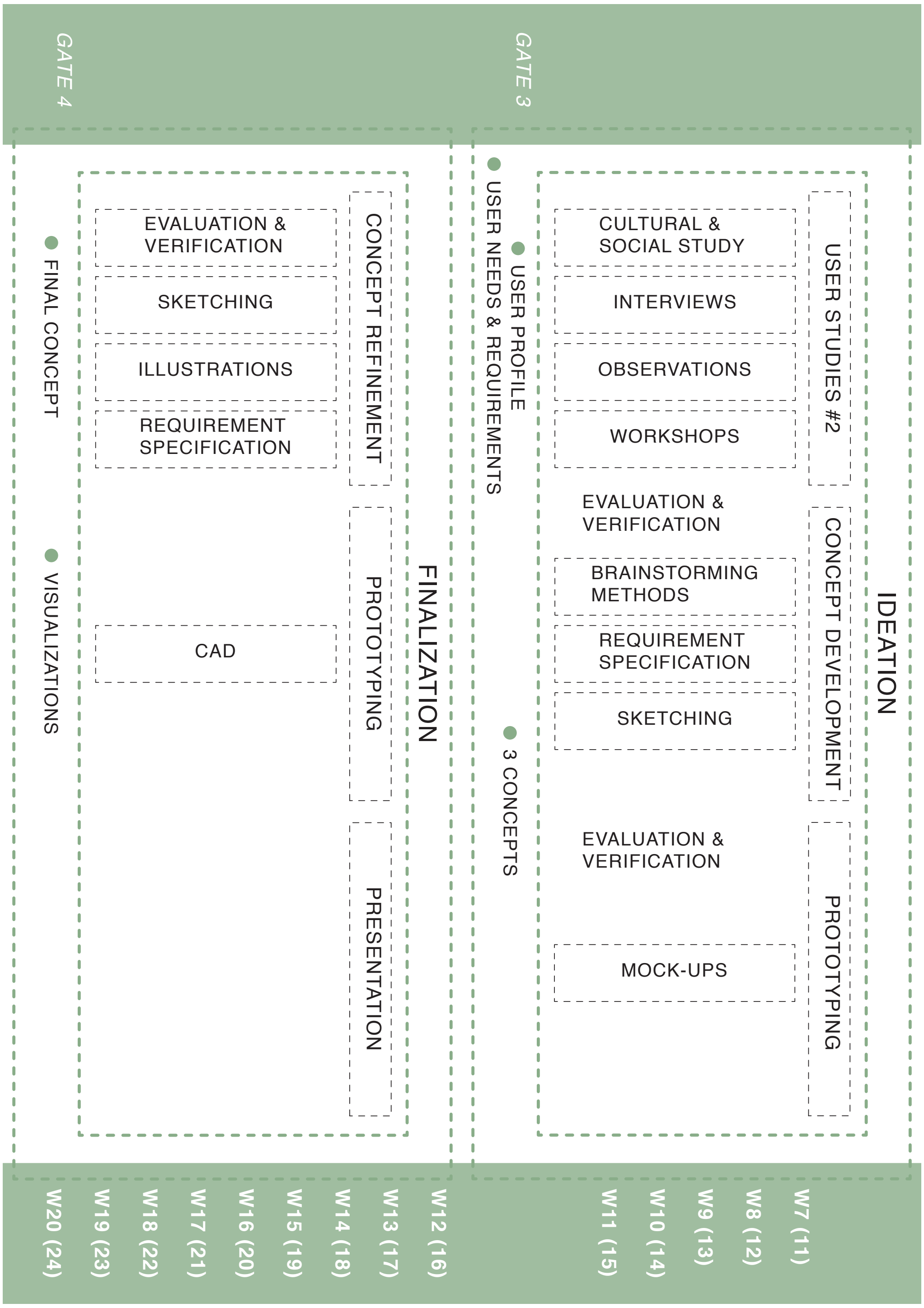
Appendix I - Gantt chart

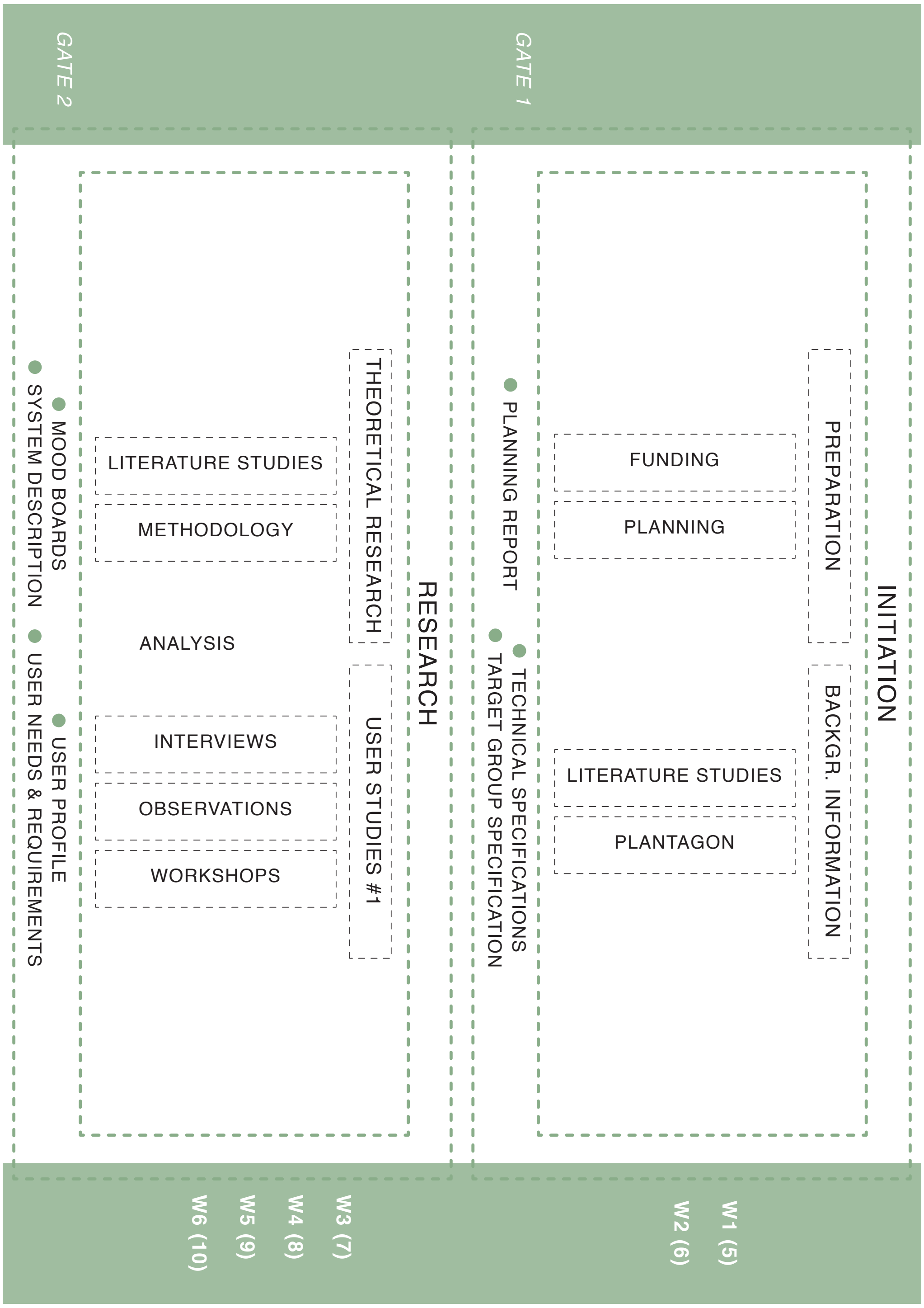
GANTT




18/3 - 22/3
W 8 (12)
25/3 - 29/3
W 9 (13)
1/4 - 5/4
W 10 (14)
8/4 - 12/4
W 11 (15)
15/4 - 19/4
W 12 (16)
22/4 - 26/4
W 13 (17)
29/4 - 3/5
W 14 (18)
6/5 - 10/5
W 15 (19)
13/5 - 17/5
W 16 (20)
20/5 - 24/5
W 17 (21)
27/5 - 31/5
W 18 (22)
3/6 - 7/6
W 19 (23)
10/6 - 14/6
W 20 (24)
15/4 14.00
5/6 10.00

Appendix II - Flow chart



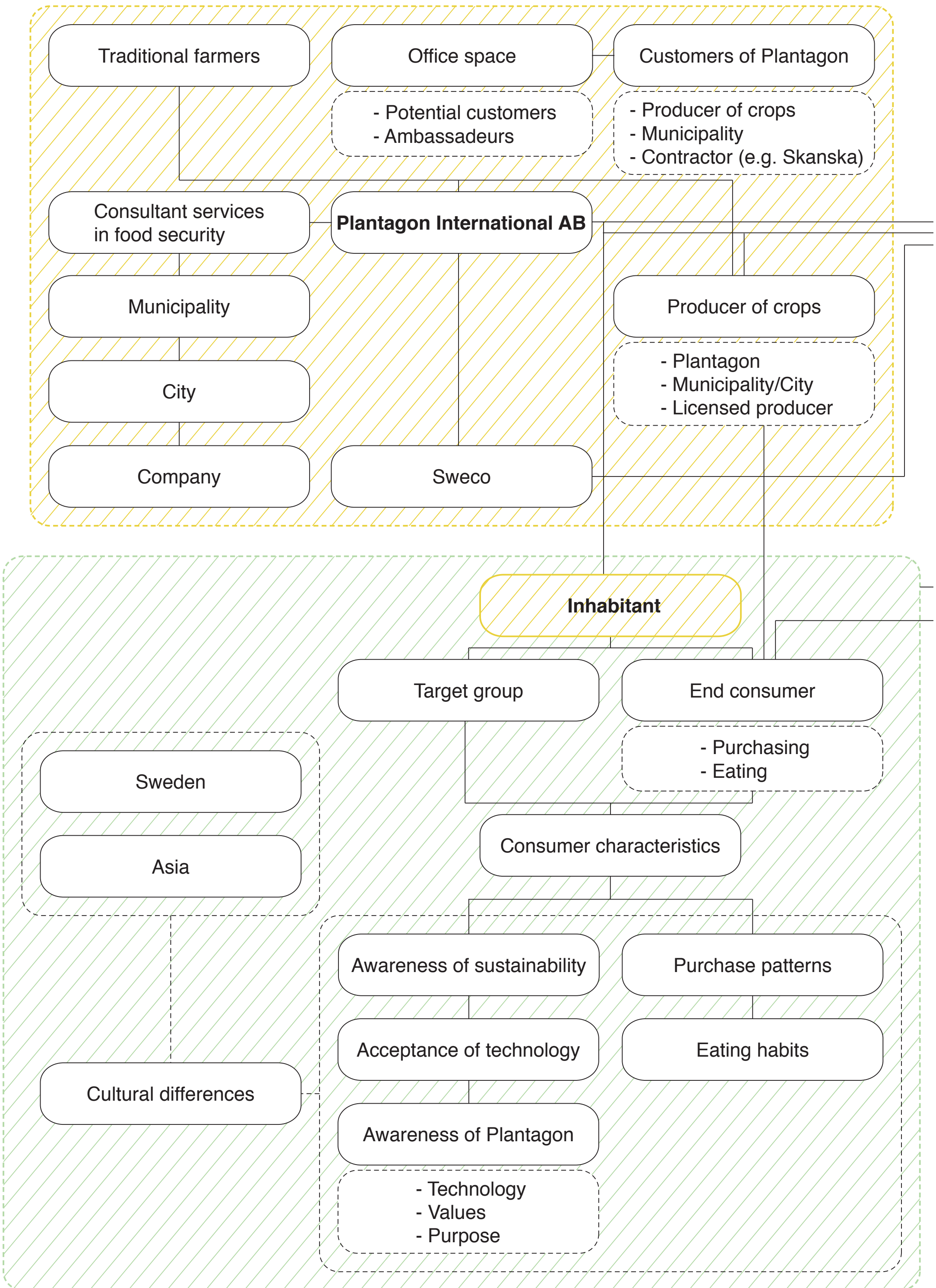

GATE 1
GATE 2
INITIATION
PREPARATION
FUNDING
PLANNING
BACKGR. INFORMATION
LITERATURE STUDIES
PLANTAGON
PLANNING REPORT
TECHNICAL SPECIFICATIONS
TARGET GROUP SPECIFICATION
RESEARCH
THEORETICAL RESEARCH
LITERATURE STUDIES
METHODOLOGY
ANALYSIS
USER STUDIES #1
INTERVIEWS
OBSERVATIONS
WORKSHOPS
MOOD BOARDS
SYSTEM DESCRIPTION
USER PROFILE
USER NEEDS & REQUIREMENTS
W1 (5)
W2 (6)
W3 (7)
W4 (8)
W5 (9)
W6 (10)

Appendix III - Organizational structure Plantagon

10 % of the Plantagon International AB is shared to the non-profit organization, within which anyone in the general public can become a member. The non-profit association appoints 50 % of Plantagon International AB's board members. The association issues "closure right documents" that allows the initial owner's seventh generation inheritor, the right to acquire a part of the income if the limited company - Plantagon International AB - is sold. The closure right document is given to individuals that have been members of the association for ten years or have paid the annual fee for ten years in advance. To use the closure right and receive a compensation, the individual holding of the document must have received it according to the statutes and be in the seventh generation after the first receiver of the document. The number of closure rights equals the number of stocks in the limited company, and the member fee shall relate to the value of the company as well as the ratio between the market value of the company and the number of stocks in the company. (Hassle, 2012; Plantagon, 2013)

The background of the closure right document is that economical advantage will be given to the descendants and that the Plantagon Non Profit Organization will become an "owner with a seventh generation perspective". There is a clear connection with this framework and the main owner of Plantagon International AB (85%), being a North American original constituent nation The Onondaga Nation of the Haudenosaunee. These indigenous Americans make their decisions on a basis that they should be sustainable for seven generations to come, a long-term perspective that consequently is incorporated in Plantagon. (Plantagon, 2013)

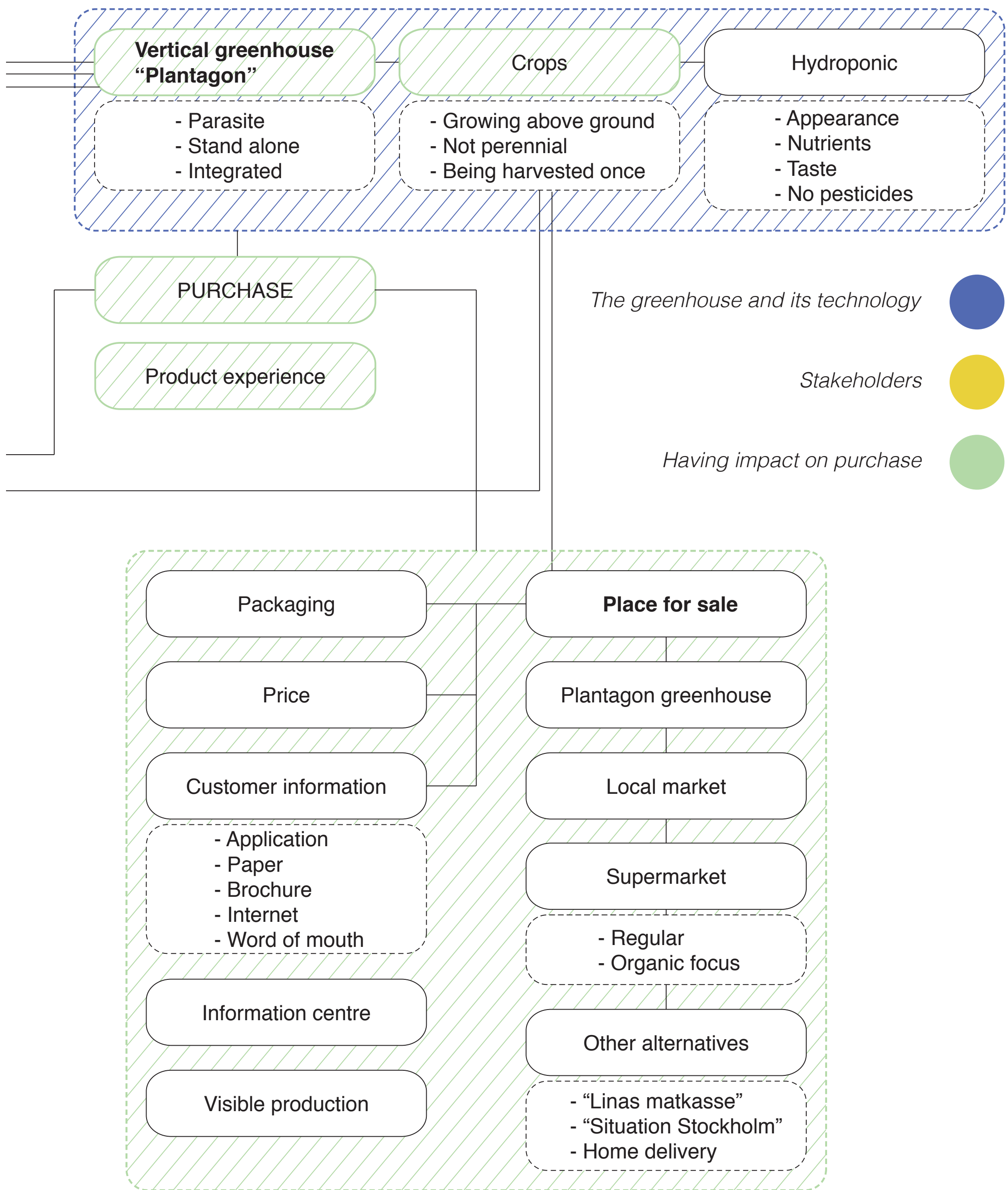
Appendix IV - Feeding the city, a system overview



FEEDING THE CITY

- a system overview

Ebba Hedenblad & Marika Olsson



Appendix V - Interview questions

Intervju

- Intervjuns tid cirka 30 min
- Konsumtionsvanor grönsaker

- Förklara projektet

  Vi undersöker hur man med design kan förenkla implementeringen av en industriell och högteknologisk produktion av livsmedel i växthus. I anknytning till Plantagons växthusbygge i Lkp.

- Anonymitet

- Ålder, kvinna/man, bakgrund, bor, hur många i hushållet?

Intervjufrågor

- Hur handlar du dina grönsaker idag?

- Tycker du att det är bekvämt att handla så? Skulle du vilja få dina grönsaker hem redo att lagas till på något annat sätt?

- *Scenario:* Du är och handlar, du är stressad och ska hinna köpa middagsmat. När du står vid grönsaksdisken och ska plocka på dig en gröda som du behöver (t.ex. tomater eller äpplen) som det finns olika sorter av. Vad kollar du först på?

- Så om du ska rangordna kriterier för att välja grönsaker så är det? (URSPRUNG, PRIS, UTSEENDE)

- Ranka SMAK, NÄRINGSINNEHÅLL och MILJÖPÅVERKAN, vad är viktigast för dig? (Om du skulle välja mellan två exakt likadana grönsaker – vad skulle du basera ditt val på?)

- Hur skulle du beskriva en högkvalitativ gröda?

- Har du någonsin tänkt att vissa grönsaker kan vara dåliga (kanske inte är bra) för dig eller din familj? Varför?

- Vad betyder en naturlig grönsak för dig?

- Vad betyder det att något är lokalt producerat för dig? För att något ska kunna kallas lokalproducerat, hur nära behöver det vara?

- Köper du ofta grönsaker som är lokalt producerade?

- Vet du hur grönsakerna som du köper odlas? Tycker du att det är viktigt att veta mer om det?

- Brukar du fundera kring om grönsakerna du köper har odlats i växthus? Vad tänker du då?

- Söker du aktivt information om grönsakerna? Vad för slags information? Varför?

- Får du information om vad och hur man borde välja grönsaker? Varifrån? Vad tycker du om den informationen? Vad skulle du mer vilja veta? Varför?

- Om det fanns mer information om grönsakerna på plats i din mataffär, skulle du ta dig tid/ ha ork att läsa den? Skulle du förlita dig på den här informationen, och välja dina grödor därefter?

- Varierar ditt förtroende för olika matbutiker? Varför?

- Har du en smartphone? Använder du dig av mycket appar för matlagning eller för att förenkla inhandlingen? Varför/Varför inte? Skulle du uppskatta att få information om grönsaker via din telefon?

- Är det något som du känner att du vill ändra i hur du handlar och konsumerar grönsaker. Är det något du stör du på?

Bilder industriellt och högteknologiskt

- Vilka skulle du välja? Varför? Vad skulle krävas för att du hellre skulle välja dem?






Plantagonspecifika frågor.

- Känner du till det planerade växthuset som ska byggas i Linköping?

- Vad är dina tankar/känslor inför det? (Högteknologisk hydroponisk odling) Varför?

- Kommer du handla grönsaker därifrån? Varför/Varför inte?

Appendix VI - List of interviewees

TS = Test Subject

TS1	Male	Gothenburg (originate from Linköping)	25 yrs
TS2	Male	Gothenburg (originate from Linköping)	24 yrs
TS3	Female	Linköping	25 yrs
TS4	Male	Gothenburg	20 yrs
TS5	Female	Gothenburg	29 yrs
TS6	Female	Linköping	35 yrs
TS7	Female	Malmö	60 yrs
TS8	Male	Stockholm	65 yrs
TS9	Female	Stockholm	50 yrs
TS10	Male	Malmö	31 yrs
TS11	Male	Linköping	39 yrs

Appendix VII - Mood board

responsibility

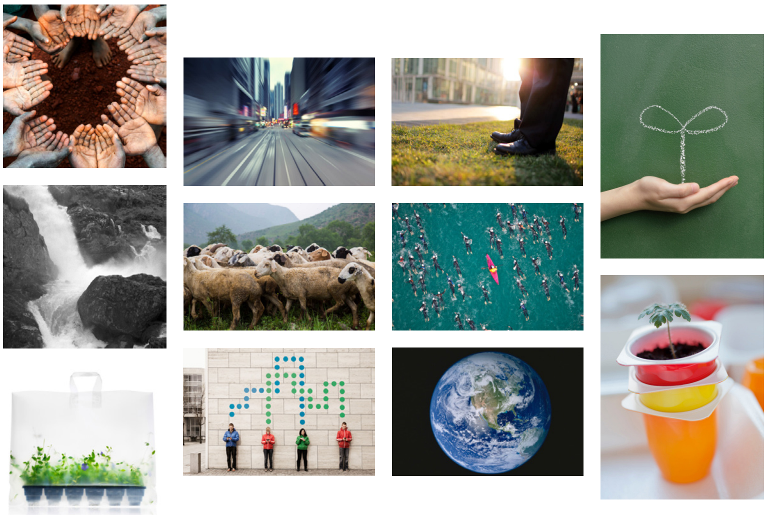
action (we do things)

long-term

locally produced

sustainable

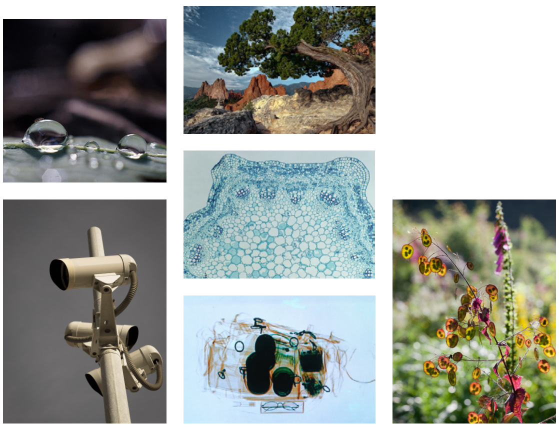
sharing



natural

trustworthy

high-technological



Appendix VIII - Requirement list

1: not fulfilled at all
5: completely fulfilled

Demand	Description	Value	Fulfillment
Dimensions			
Weight without pot & plant	Minimize weight for user, but secure stability and expression.	< 8 kg	5
Overall size	Minimize for user, match with standard windowsill, but allow plant to grow.	45 x 16 x 110 cm	5
Size of water reservoir	Minimize amount of water; adapted to how often the water should be changed and its nutrient concentration.	1 L	5
Environmental impact			
Overall environmental impact	Minimize carbon emission, dangerous chemicals etc. in manufacturing, materials and usage.	For further development	
Power consumption	Minimize power consumpotion in usage.	For further development	
Provide knowledge about Plantagon			
Match technology with the vertical greenhouse	Allow for usage of the same technology to as high extent as possible. Hydroponics, automatized, LED, greenhouse environment.		5
Durability	Allow for durability comparable to existing products.	> 5 years	5
Safety			
In power failures	Allow safe usage. Apply security measures that contain water within the system.		5
Usage of the electrical parts	Support safe usage; it should not be harmful or dangerous for the user to handle the system following the accompanying instructions.		5
Optimize cultivation conditions			
Sunlight to reach plant leaves	Minimize elements that can impede the sun from reaching leaves.		5
Plant height in window	Minimize distance of windowsill to plant leaves to allow sunlight to reach the plant	10 cm	5
Water supply	Allow for sufficient amount of water: adapted to hydroponic technology.		5
Air and water temperature within the system	Allow for optimized temperature; adapted to optimized growing conditions.	17 - 25 C	3
Air humidity in germination phase	Allow for increased air humidity; adapted to optimized growing conditions.	Depending on plant	4

Roots access to oxygen	Allow for suffiecient oxygen; adapted with ventilated greenhouse environment and Ebb-and-Flow technology.		5
Formation of alga and chalk layers	Minimize exterior visible algas and chalk layers		5
Light inflow to roots	Minimize to as high extent as possible.		4
Maintenance			
Cleaning of water tank and frame	Minimize number of occasions.	< 1 time / month	5
Changing of water and adding of nutrients	Minimize number of occasions.	< 1 time / 3 weeks	5
Changing of water and adding of nutrients	Minimize time needed.	< 5 minutes	5
Running without maintenance	Allow for minimum maintenance without plant dying.	> 3 weeks	5
Usage			
Information and feedback about usage	Support the user with information and feedback.		4
Initial assembly of the system	Allow for a quick and easy assembly.	< 30 minutes	5
Change of plants	Allow for a quick and easy change of plants.	< 10 minutes	5
Cost			
Price for end-consumer	Allow for price comparable to existing products.	< 1500 SEK	4

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