Priva Microfarm

Design of a small indoor farm for specific context use

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As of June 2019, Priva's indoor growing department operates under the joint venture Infinite Acres. For consistency Priva is used in the report.
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ACKNOWLEDGEMENTS

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To Ailid and my family for always supporting me and putting their trust in me.

EXECUTIVE SUMMARY

This master's thesis documents the design process behind Microfarm, a small-scale indoor farm designed specifically for restaurants. Facilitator of this project is Priva, which is a company specialized in horticulture and venturing into indoor farming. Indoor farming involves growing edible plants in closed structures using artificial lighting

The first phase of the project aims at understanding Priva and the technical principle behind indoor farming as well as determining which competing products exist and which users are interesting to design for. It is concluded by choosing a specific market segment, which are high-end restaurants. Based on this result, an ideal scenario is created and seven restaurants are interviewed and analyzed using techniques from contextmapping. It is concluded with a design vision that serves as input for ideation.

Next, multiple aspects of the ideal scenario are ideated upon, such as the Priva Portal which supplies restaurants with their growing supplies, and working out specific details regarding the physical design and technical aspects. Following ideation, three concepts are proposed, with one being chosen through objective criteria. In the first iteration, the concept now known as Microfarm is further worked out and a business model and prototype are developed and validated. In the second iteration, a customer journey is set up for generating new ideas in enhancing the guest's indoor farming experience, resulting in Nanofarm, and Microfarm's design is changed to be smaller and compacter as a result of the first iteration.

The last phase of the report describes the final designs of Microfarm and Nanofarm as well as Priva Portal and the business model. Recommendations are given and the project is evaluated. The project is concluded by stating that a small indoor farm is feasible and that high end restaurants are a fitting context for such a product, but there is a considerable chance that such a product will ultimately not work regarding the small impact such a product will have compared to the amount of resources a restaurant will have to invest.

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INTRODUCTION

With a growing population, and specifically urban population, more nature and arable land is required to provide a comfortable living environment and enough fresh produce. In urban environments agriculture is, however, non-existent and requires fresh produce to be imported, sometimes from far away. Over time this puts an increasing strain on the available arable land through over use and potentially negative effects of climate change. On an individual level this will lead to a decreased awareness of how food is being produced, even though such awareness could likely influence people's view towards their nutrition and overall consumption.

Currently, much of the food consumed in the Netherlands is either imported, comes out of the ground, or is grown in a greenhouse. A greenhouse provides a regulated environment to optimize the yield of whatever crop is grown and is built for quick harvesting and distribution of the grown produce. A relatively new phenomenon known as an indoor farm takes the irrigation and lighting technology from greenhouses and adapts them to indoor spaces and structures. Because space in urban environments is expensive, these farms typically have multiple levels to them to maximize the use of space, which are more specifically known as vertical farms. Indoor farms can be built anywhere and pose an interesting and potential solution to supplying an urban environment with fresh produce.

Indoor farms are still in their infancy and most of these farms are rather large, warehouse sized. Some smaller solutions exist, such as Priva's growing container, but not many consumer sized products contain the level of technology used in indoor farming! With this small scale indoor farm concept, Priva was contacted and brought in as facilitator, of which the result is shown in this report.

METHODOLOGY

The design of a small scale indoor farm, as defined by the personal project brief in appendix A, requires an approach that is based on design methodology. To find a fitting solution to the design brief and problem definition, the methodology creates an approach and aims at structuring the overall design process.

Problem definition

From the personal project brief, two research questions are generated that are most relevant for solving the. They are defined as following:

How can the technological principle behind the Priva growing container be scaled down to a design suitable for both the user and Priva?

Who will be the user of such product and what product characteristics are required to be fit for that context of use?

The unknowns in this project are a technical solution and clear context of use, which will have to be answered by the chosen approach.

Process

The chosen design process, shown in image 1 on the page to the right, is an adaptation of Roozenburg and Eekels' [1] design process to the double diamond process [2]. Popularized by the British Design Council, the double diamond describes how a creative process goes from problem definition to solution. It isn't developed for industrial design specifically; it aims to visually simplify the design process, illustrating the similarities in creative processes. Diverging can be seen as an explorative activity as it involves discovering and developing. Converging can be seen as logical structuring and decision-making as a result of this exploration, because it involves defining and delivering. Like the basic design cycle of Roozenburg and Eekels, every step yields a result that serves as the basis for the next one. For the process of this graduation report, instead of two, three diamonds will be in place to define the design activities.

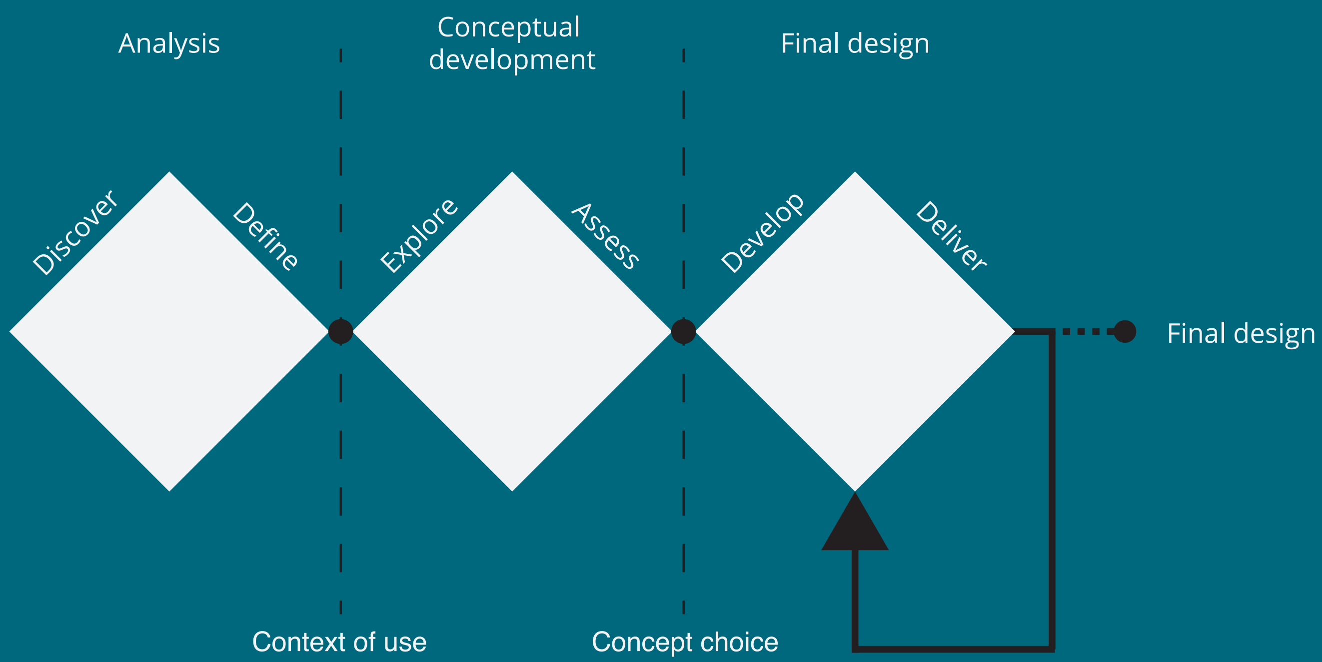
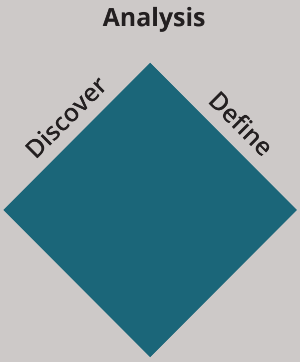


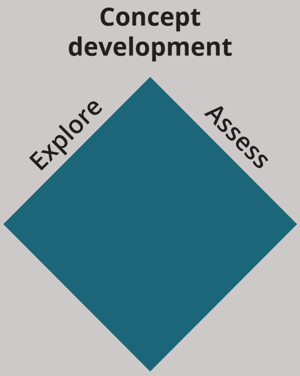
Image 1. Design process for this project

Below, each phase of the design project is explained more in-depth. On page 15 to the right, the methodology used in these phases is briefly explained.



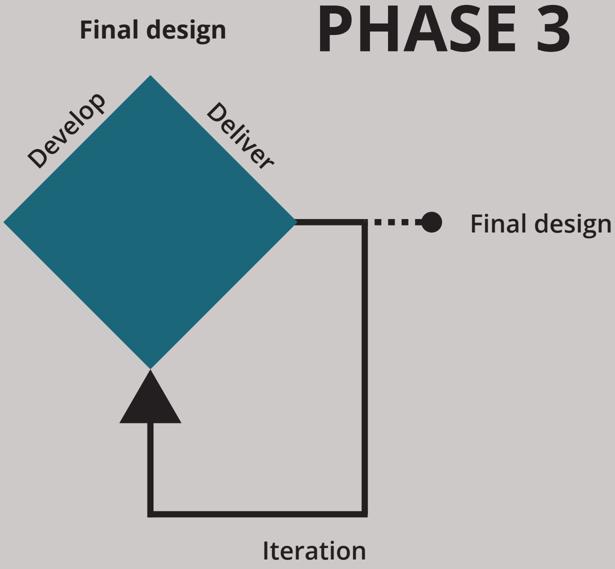
PHASE 1

Through research, relevant information needed for developing concepts will be found and a clear context will be defined for which the design will be developed. The result at the end of this phase is a design vision.



PHASE 2

Using the information from phase 1, relevant aspects of the design will be developed through ideation. Resulting from this are concepts and a concept choice at the end of the phase.



PHASE 3

Once a concept has been determined, the relevant aspects will be worked out and iterated upon according to the result of validation and prototype testing.

DISCOVERING:
Plant growth and cultivation - Field and literature research
Priva and the growing container - Field and literature research
Trends, products, and user groups - Literature research
DEFINING:
Target market - Market segmentation (Kotler, P., Armstrong, G. (2018)[3])
Context - Context-mapping (Sanders, E.B.N., Stappers, P.J., (2012)[4])
User needs - Ideal scenario

EXPLORING:
Ideation and conceptualization
Restaurant styling study
Technical system development
ASSESSING:
Deciding between concepts - Weighted criteria method (Roozenburg, N.F.M., Eekels, J. (1995)[1])
Validating concepts with user group
Prototyping

DEVELOPING:
Customer journey
Iterating design
Technical solution on paper
DELIVERING:
Report
Final design and recommendations

1 Analysis

This chapter contains all relevant background information and knowledge about Priva and indoor farming. To answer the first research question, a step towards a technical solution will be taken in form of a functional analysis. A product and trend analysis will shed light on interesting market segments, and the chapter will be concluded by choosing a specific market to focus on in the user research.

1.1 PRIVA

Priva, established in 1959 under the name Valk en Prins in De Lier, began their business as importers of hot air heaters for greenhouse horticulture. De Lier, which is part of the Westland, is known for its many horticulture greenhouses and agricultural businesses. Priva's vision is "creating a climate for growth" where reduction of natural resources and increasing yields per square meter are an essential contribution to the future of the planet. This section will look at Priva and how they operate, and includes field studies conducted at their facilities.

Priva delivers products for horticulture and building management. Their first product from 1977 was a climate computer for the horticulture industry, followed by a building management system for RAI in 1983, which was developed using their knowledge in horticulture. They define their mission as "creating an optimal environment in which people and plants experience the best way to grow, using leading-edge technology, products, and knowledge".

Building automation

From managing the climate in an entire building to adaptive lighting that switches off when no one is present, Priva has solutions in form of hardware and software to make the workplace more sustainable from a resource and human viewpoint. Both the length of the workday and the size of the building can make this process very energy intensive and Priva's building automation products aim to reduce this impact while giving employees an indoor climate that is comfortable to work in.

Horticulture

Solutions can range from an entire greenhouse set up to software for management of water or labor. Included in this segment is the indoor growing department, which is part of Business Solutions and facilitates this graduation project. While the goal of Priva's horticulture products are supporting activities that take place in horticulture, their mission is to become the leader

Image 2. Priva’s headquarters in De Lier, Netherlands

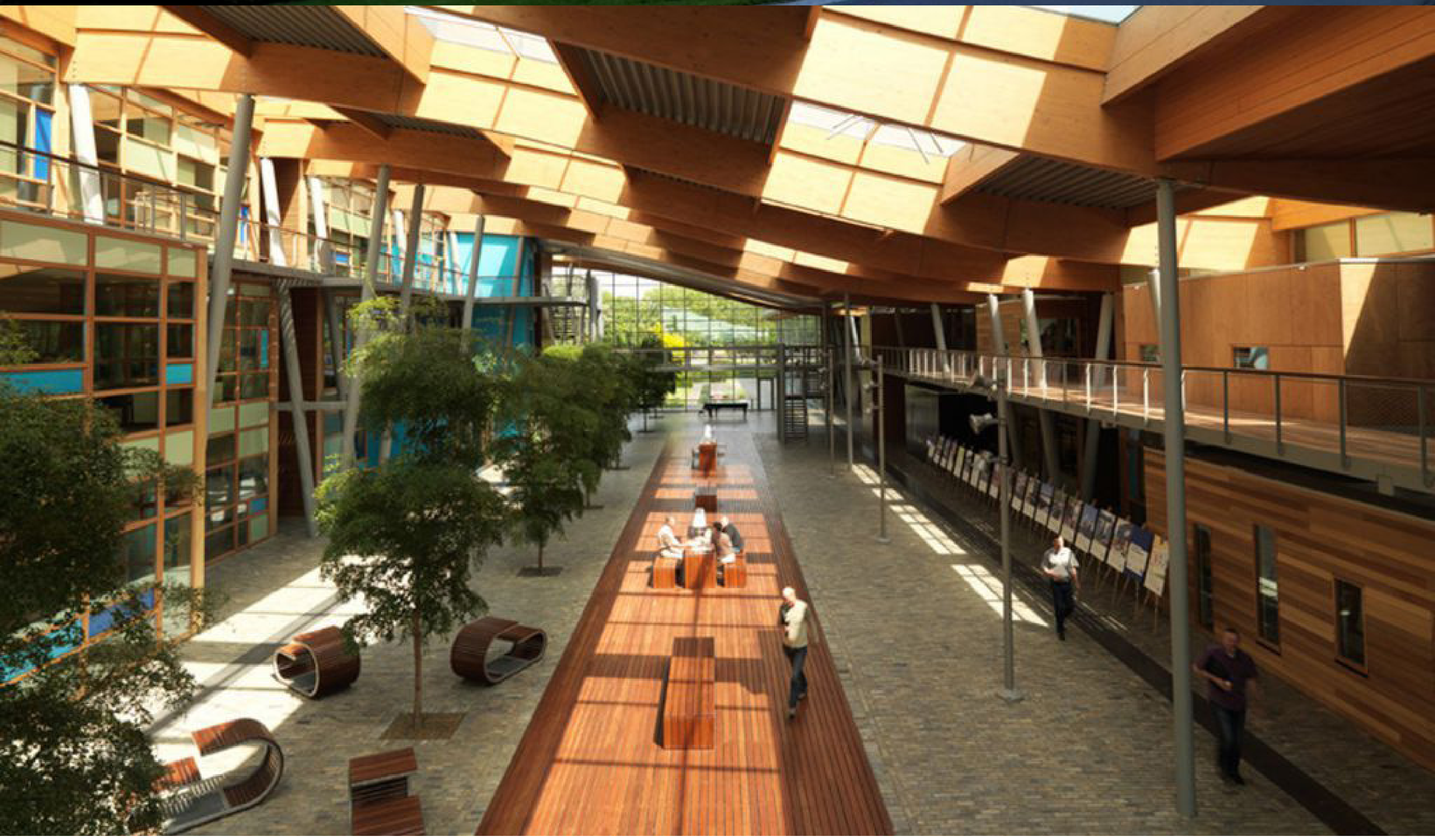


Image 3. Inside Priva’s headquarters in De Lier, Netherlands

Market

Priva operates in a business-to-business market (B2B) market (see image 4), which implies that Priva works with a large dealer network to sell their products. These dealers provide services and maintenance to their customers and end users, but it is also possible to make direct contact with Priva when standard solutions don't suffice or advise is needed on which dealers are best suited to the customer's needs.

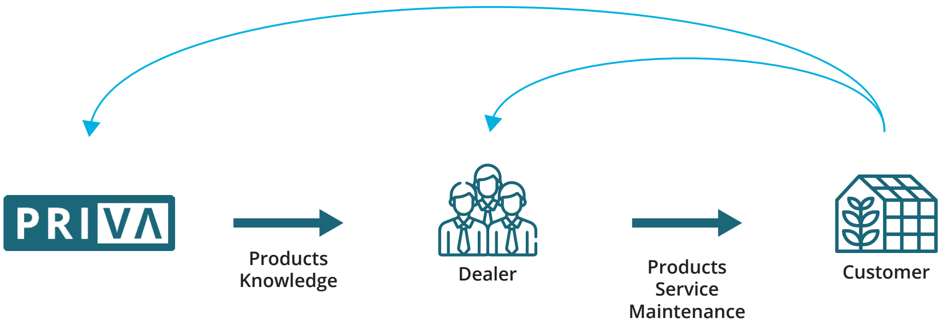


Image 4. Priva's B2B structure

Competition

Priva operates in a B2B market, and is currently divided between their horticulture and building automation departments. The playing field is quite large because there are many players in the field of horticulture and building automation that all use slightly different products and services to tap into their specific market. Below in image 5 is a small collection of competitors.

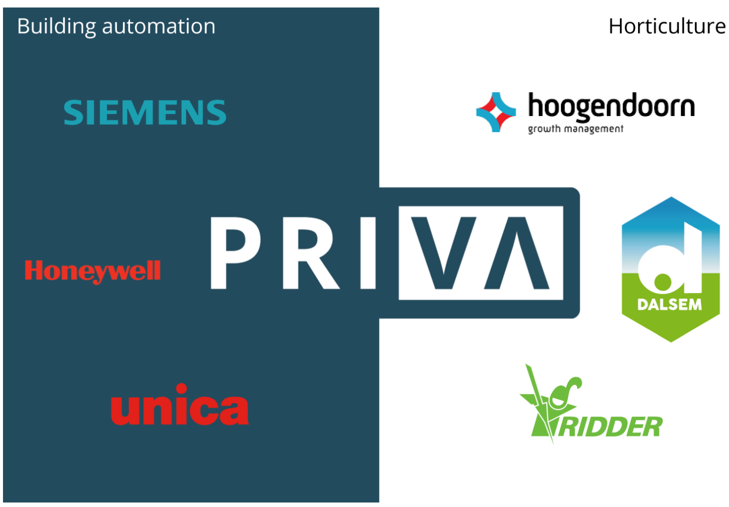


Image 5. Priva's competition in their two fields

Facilities and resources

Priva's headquarters based in De Lier houses both the offices and assembly related to the products sold by Priva. They mainly work with pre made assemblies and sub-assemblies and produce their own parts when a solution is not readily available. In image 6 below this text, Priva's departments are shown.

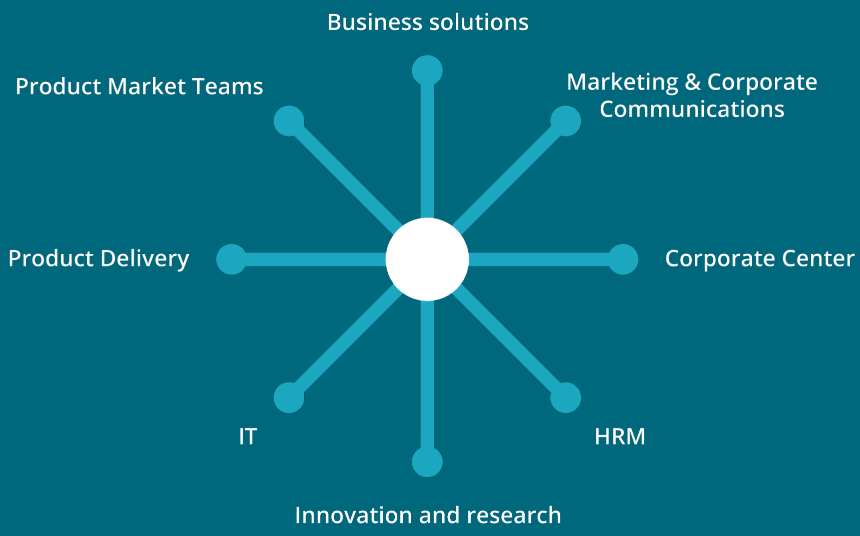


Image 6. Priva's departments

Infinite Acres

Priva has worked with client 80 Acres to set up indoor farms in the US. 80 Acres has expertise in how to grow indoors, however, they lack the technical know how, which is where Priva comes in. Together with 80 Acres, Priva has set up a new venture called Infinite Acres. This former-client-now-partner venture was the result of lessons learned from the previous relationship, which sought to supply a turnkey indoor growing solution.

As of June 2019, Priva's indoor growing department is part of Infinite Acres. To remain consistent, the report will keep referring to Priva as facilitator.

Current products

The products Priva sells can be split up into five categories, as seen in image 7 below.

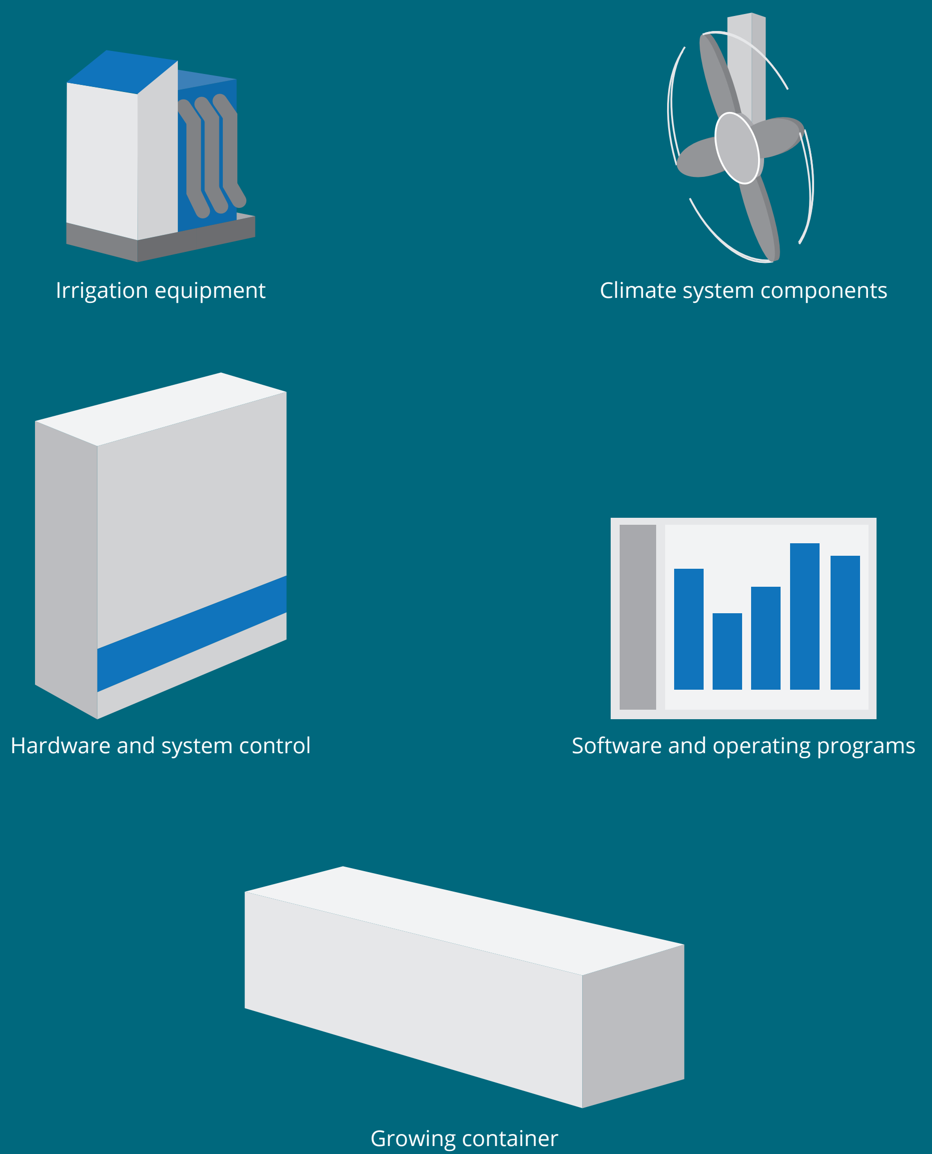


Image 7. Priva's horticultural products summarized

Growing container

One of Priva's most recent products is the growing container, which is a solution that aims to supply a complete indoor farm. In short, it is a shipping container that contains all essential systems and technology for hydroponic indoor growing. It's laid out in such a way that the technology and growing are seperated from each other in this container, which aims to make it easier to use and maintain. The growing container was one of the inspirations for this graduation project, because it is a large-scale version of the to be designed product.

The general layout is displayed in a so-called principal drawing in image 8 below, the proportions are slightly changed to give a more informative view of the whole system. Please refer to appendix B for a short description of each component of the system.

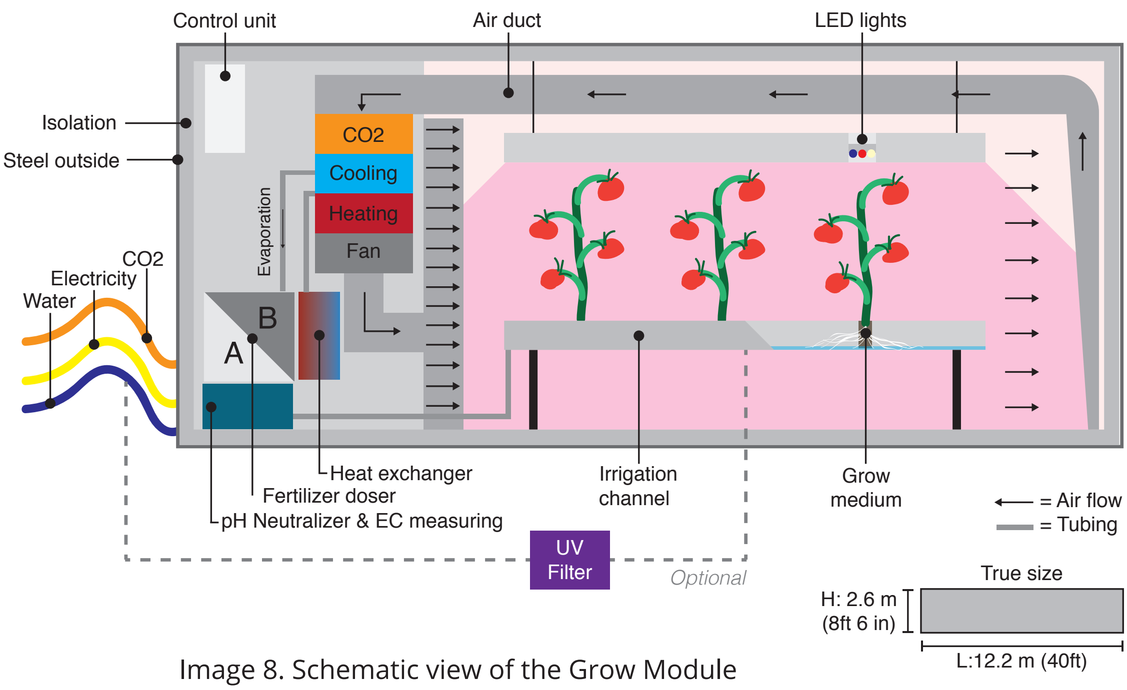


Image 8. Schematic view of the Grow Module

Image 9. Priva growing container on the right (structure on the left not part of the container)

Image 10. Priva growing container on the inside

1.2 FIELD RESEARCH

To understand the use of Priva's growing container and the activities that take place during the growing process, two mornings were spent gaining experience in two of Priva's on-site growing facilities. One session was spent maintining cucumbers in a structure slightly larger than the growing container, while the other was spent seeding basil and lettuce in the container itself. Both indoor farms are set up by Priva to test equipment and setups by growing small batches of different crops. Though slightly different in size, their functionality is almost identical.

Cucumber day

In charge at this facility is Ed, who monitors various aspects of the process, like plant growth and physiology, water supply and drain, water content of the rockwool mats, and the pH and EC content of the solution. To measure the water content of a plant, a large scale is used to weigh the plants before and after irrigation, which is situated under the rockwool mats.

The task given was to clip the upper part of the plant to a wire. Plastic clips are required to attach the plant to a wire, which runs from top to bottom of the structure to allow the cucumber plant to grow up. Observations can be found on page 27,

Pictures

Although the future user will not be doing this specific task, this session gives insight into the working conditions and the functioning of the system. On page 27 to the right, image 11a to image 11h were taken during observation. None of these pictures depict the lighting properly due to the strong lighting in combination with the shutter time of the phone's camera, which can be seen in image 11g. The rest of the images are either processed, which contain more pink, or taken with a different filter, which contain more blue.

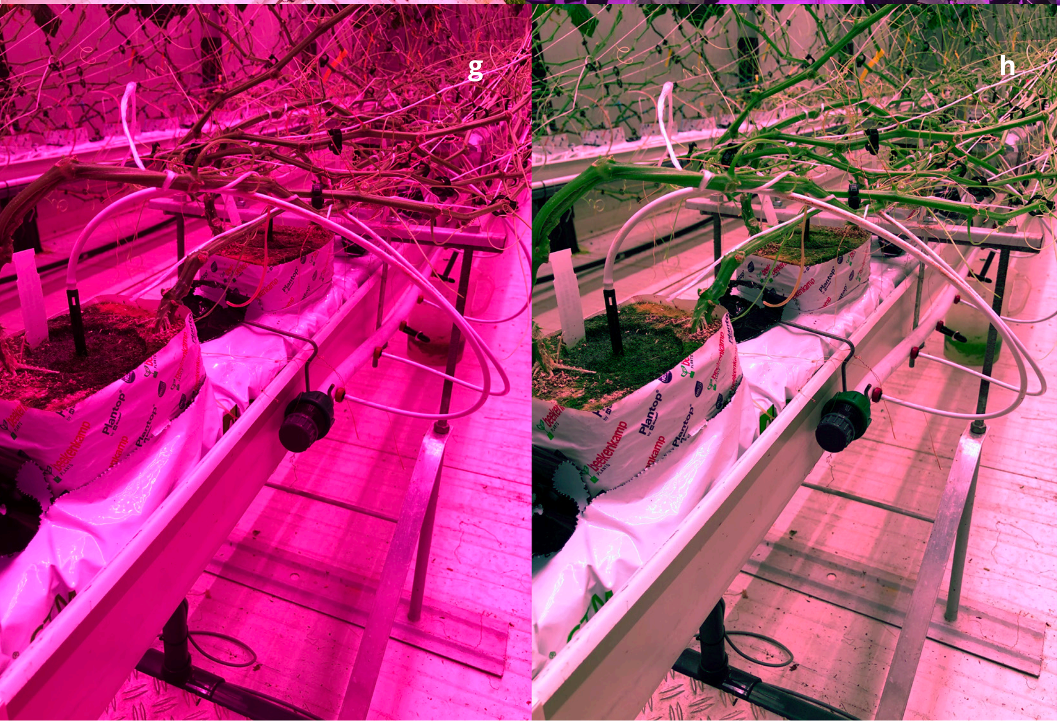


Image 11.

a	Clips holding vine to wire
b	Observation window
c	Rockwool with dripper and stem
d	Ventilation cover
e	Top view
f	Cucumber close-up
g	Non Photoshop
h	Post processed

Conclusion

Glasses are needed for protection from the blue light, which is ironic given that the light color is dominantly red inside of the facility.

It's warm and humid in the room, even in a t-shirt.

The scissor lift is useful for heights, but is wobbly while standing on it and a bulky obstacle when not using it.

Plant smells like cucumber, nice way to experience a plant without having to eat it.

The ventilation is constantly on, which is audible but not loud.

Depending on the plant, leaves have to be removed towards the bottom. With cucumbers, their tendrils sometimes have to be removed as they have the tendency to latch onto other plants, tendrils, leaves, and cucumbers.

Because space is optimized, some plants require a farther reach. Caution has to be taken when grabbing the plants, since it is possible to break the stem or fruit due to its fragility.

The dripper used in the top irrigation can get clogged because roots will grow into it.

Seeding day

A morning was spent planting seeds in the growing container, which is part of a test conducted by an intern at Priva. Several types of basil and lettuce were put in so-called quick plugs for germination and propagation. The activity was useful for understanding the user steps and equipment of setting up a growing cycle, this section will highlight the details of these user steps and how they can be translated into design aspects for the future design. On the next page, in image 12, various pictures are shown taken during observation, very much like the previous section.

Procedure

1. Setting the Quick Plug tray on the capillary mats: Human powered process

2. Pre watering of the plugs: Feeding nutrient solution to the capillary mat (see image FIXME - 7), plug soaks up from the bottom after user turns on the germination program in the control unit.

3. Poking a hole in the plug: Piercing a hole with a semi sharp object, which allows the seeds to be deposited in the plug. It is not necessary as seeds will also germinate and propagate if deposited on top, but does ensure that seeds don't fall off during movement of the tray.

4. Put plastic marker in tray with name and date: Requires a pen and plastic marker, useful for distinguishing multiple varieties of the same plant at propagation.

5. Put seed in/on the plug: Human powered process

6. Put plastic cover over tray: Human powered process, requires covering medium and helps with creating a damp and protective environment for germination.

The following observations were made:

Poking holes and planting seeds is a repetitive and tedious process. Seeding especially, because multiple are put in one hole with certain crops. The plastic marker helped with scooping seeds.

The height of the watering trays induced back pain at some point due to the awkward angle and time duration of the activity.

Conclusion

There is a lot of time to be made on poking holes and depositing seeds. In larger growing operations this automated, but in the final design this is impractical and will have to be done manually.

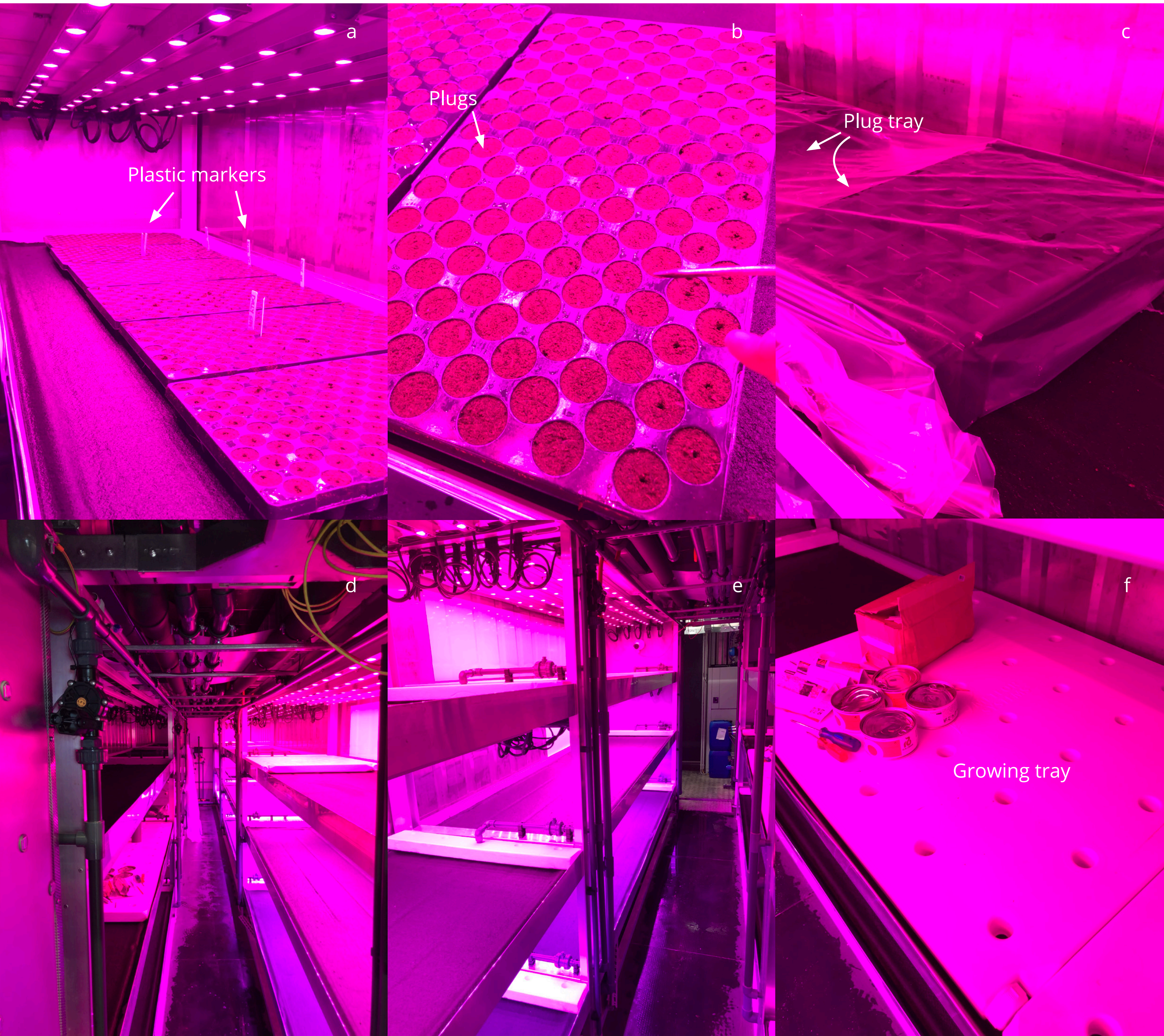
The plastic marker used for indicating the name and planting date also worked well for scooping smaller seeds, which saved time.

Quick Plugs are already in a tray when they are delivered, which makes it easy to use, keeps hands clean, and allows seeds to be propagated and germinated in situ. It seems like an ideal candidate for easy seeding by the user.

Actions performed should be done at an angle that is comfortable for the user. Poking and seeding could be done outside of the product, but the saturated plugs might make this difficult.

The plastic covers used at the end of the process are from a large roll, which is unlikely to be the optimal solution for the end user. It is wasteful and requires the user to acquire the plastic and cut it to size, this step could likely be taken out by designing a single plastic cover that can be reused and cleaned.

While not used during this session, the container has trays (see image 12f) where the Quick Plugs transferred to after propagation, without having to do any additional steps. These work on the principle of ebb and flood and are well suited for leafy vegetables and herbs, which is what realistically will be grown in the final product. Combining the Quick Plugs and floats in the final design could likely make for an easy to use solution, where little effort has to be put in the growing medium and easy transferring of the round Quick Plugs to the floats.



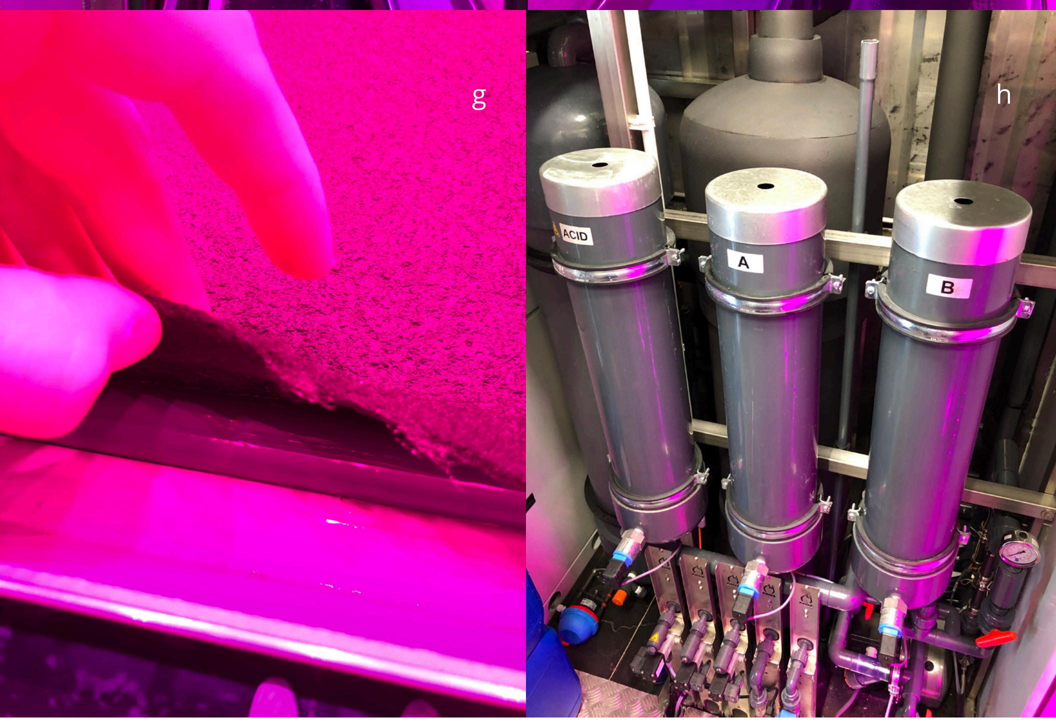


Image 12.

a	Trays standing on capillary mat
b	Quick Plug tray with poking tool
c	Makeshift setup for germination with plastic foil as a cover
d	Entrance of the container looking towards the back
e	Looking towards the entrance of the container
f	Growing tray with seed containers
g	Wet capillary mat
h	Nutrient and acid pump

1.3 HOW DO PLANTS GROW?

Designing a product for indoor growing requires a basic knowledge of how plants grow and which factors are beneficial to growth. In this section, the phases of plant growth, it's physiology, and relevant conditions are discussed.

What sets plants apart from all other life is the inability to move, this makes them highly dependent on the environment they find themselves in. Plants have the ability to extract all essential nutrients and minerals from their surroundings and do so very opportunistically given the chance. [5]

Photosynthesis

The main mechanism behind plant growth is photosynthesis. The process of photosynthesis uses sunlight to create glucose and oxygen from water and carbon dioxide (CO2). This glucose is converted into energy, which the plant uses to grow [6]. Chlorophyll is the photoreceptor responsible for capturing the sunlight and converting it to energy, and is responsible for a plant's green color. [7]

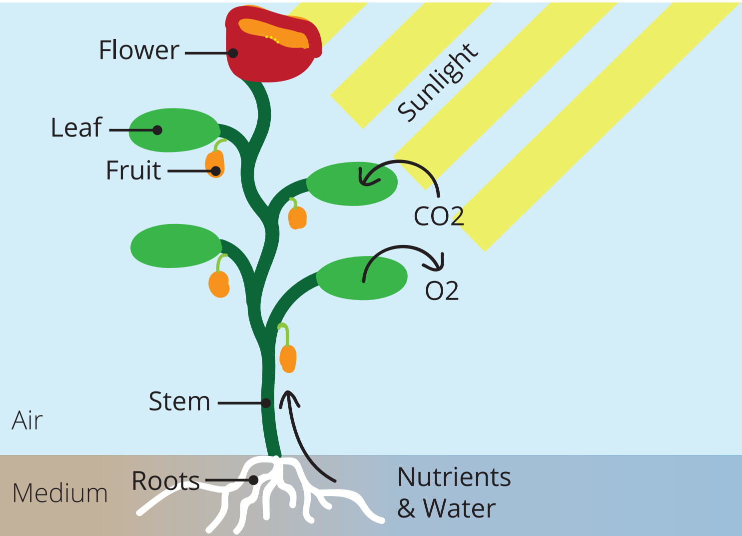


Image 13. Basic plant description

Liebig's Law

The limiting factors of a plant's yield are described by Liebig's law. This law states that not the most abundant, but the least abundant resource will have direct effect on the growth and yield of a plant. It is comparable to the strength of a chain being dependent on the weakest link. If a plant were to have a calcium deficiency, but every other nutrient were to be added in tenfold, it will not make a difference on the yield and growth of the plant because it is limited by this calcium deficiency [8]. This example specifically refers to nutrients, but it also applies to temperature and CO2.

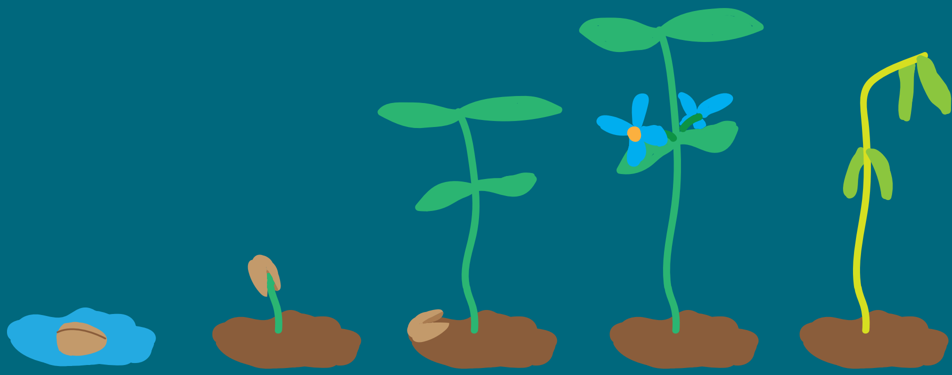


Image 14. Plant life cycle

Growth cycle of a plant

The growth cycle of a plant is defined as following in image 14 above. Below, a description is found for each step and a conclusion is made regarding the information found in this section [9].

<u>Seed</u>

A seed is a tiny embryonic plant in a protective shell that is produced by a mature plant, and allows for the growth of new plants. Seeds can be stored for a limited time until germination has to be initiated.

<u>Germination and propagation</u>

When water is introduced to a seed, the process of germination is started. This results in the emergence of a so-called seedling.

<u>Vegetative growth</u>

Once the seedling sprouts and starts growing its own leaves, the plant starts growing independently. In this phase a plant will grow most of its structure and reproductive organs, and ends when the plant starts flowering.

<u>Flowering</u>

At this point, the plant is mature and has flowers ready to be pollinated for reproduction. As a result of this, the plant will start producing seeds. How these seeds manifest themselves is dependent on the type of plant being grown, with the seed either being inside of a fruit, or being attached to the flower. Annual plants will go through this cycle only once before dying, biennial plants take 2 years to flower, and perennial plants tend to live for multiple years, flowering annually for most plants.

<u>Harvest/Senescence</u>

What happens in this phase is dependent on the type of plant and how it is handled. Fruits and vegetables that are harvested will make the plant cease to exist in the case of annual and biennial plants, but perennial plants have the ability to repeat the flowering process annually. If not harvested, annual and biennial plants will still perish once the seeds reach maturity after one growing cycle.

1.4 PRINCIPLES OF INDOOR FARMING

Indoor farming is defined by Wickers (1978)[10] as being "concerned with the intensive production of horticultural crops". This section looks at all the factors that are important regarding indoor farming, starting with the different types of hydroponic growing techniques, and then looking at what supplements and environmental factors are at play. This knowledge will be used in constructing the functional analysis and provides a basic understanding

Why do people want to grow in controlled environments? First and foremost, this type of growing allows for total control of the growth process of a plant. Plants can be grown at any time, any location, and regardless of the climate in that certain location, given that the right technology is in place to do so. Another crucial factor is the efficient use of resources when such an operation is set up well, far less water and nutrients are required compared to soil and sun grown plants [11][12]. Image 15 shows a setup that is not uncommon for vertical farms.

Taking into consideration the current trend of global warming and population growth, this type of growing is beneficial to not only reducing the impact of plant growth on the environment (like soil erosion), but also increasing the yield per m2 in places that would otherwise be wasted. [13] Logically so, indoor farms are starting to become more popular in urban environments. Their presence can help in raising awareness of food production or act as a substitute for the lack of nature within such environments. [14] There is also the distance that fresh foods have to travel. In the United States this is an average of 2500 km before it is bought and consumed [15]. Cities located in environments unsuited for growing fresh foods have to import these foods, which deprecates the quality of these fresh foods. Research by Menezes et al. (2017)[16] in Latin America has found that limited access to fruits and vegetables may possibly lead to lower fresh food consumption whereas higher incomes and better quality stores lead to higher consumption of fruits and vegetables. [17] Consultancy firm McKinsey reveals that although low pricing and frequent promotions matters, Europeans regard the quality of fresh foods to be more important than either two. [18]

Image 15. Picture of an indoor farm set up by FarmedHere
Source: https://www.businessinsider.com.au/indoor-vertical-farm-is-the-future-of-agriculture-2015-10

The case for indoor farming has been made, however, what are the technicalities behind indoor farming? This is necessary knowledge for both the technical aspects and the user interaction of the product that ensures that the product remains in optimal condition.

Seeds

To start the growing process, seeds have to be placed in a medium to germinate. This medium allows the roots to manifest themselves, but this medium can also be placed in the growing setup.

Different types of hydroponic set ups

Hydroponics is a method of soilless growing where plants are fed a mineral solution during irrigation. There are many types of setups, which can be divided in solution and medium culture[9], and the way it operates can be divided between open and closed irrigation systems. Please refer to appendix C for all of the common hydroponic set ups.

Open and closed systems define what happens to the nutrient solution once it has been supplied to the plant; in open systems the nutrient solution is not reclaimed and will remain in the system or discarded and in closed systems the solution is sent back to the nutrient tank for monitoring and reuse. A closed system has the advantage of control, it allows for the optimization of nutrient supply to plants more sensitive to fluctuation of certain nutrients, however it is much more expensive and difficult to scale up in existing operations.[19]

Solution culture

Solution culture lacks a medium in which the growing roots are situated; this means that the roots will be exposed directly to the nutrient solution, as opposed to growing into the medium. It has to be noted that regardless of the hydroponic culture used, germination and propagation require a medium for the roots to manifest themselves, after which it can be transferred. The advantages of solution culture are that it requires less irrigation, there is little to no disposal needed of the medium, the roots can be monitored more properly, and it can be created relatively easy with little resources [20]. Image 16, at the top of the page to the right, shows the ebb and flood irrigation beds of the growing container, which works by filling and draining the bed multiple times per day with nutrient rich water. Shown in the back is a white tray that holds the medium in which the seeds are germinated and propagated.

Medium culture

In medium culture, the roots are supported by a medium such as rockwool, peat, and coconut, and provide the nutrients to the roots because of the saturation of the medium. The method can be divided into top and sub irrigation, but variations on the method are possible [21]. The advantage of medium culture is that it holds the nutrient solution, which makes plants better protected against deficiencies caused by a lack of mineral solution flowing to the roots. This is important in the whole growing process, but can also protect plants after harvesting if the medium remains attached. Image 18, at the bottom of the next page, shows the rockwool medium used to grow in a structure similar, but larger than the Priva growing container.

Image 16. Ebb and flood irrigation beds

Image 17. Rockwool mat with cucumber

Lighting

Light is needed as a substitute for the sun and provides energy and information to plants. Lighting can be divided into three categories based on the way it emits light: incandescence, discharge light emission, and electroluminescence. Incandescence uses incandescent lighting, which is most well known from the pear-shaped light fitting using filament and relies on radiation (heating of the filament) for light. Discharge light is created after an atom's electron is excited by electric discharge, and can be seen in fluorescent lighting and high-pressure sodium lamps. Electroluminescence is created by application of an electric field to certain materials and LEDs are the best example of this. LEDs have multiple advantages over the other types of lights; they have a long life, are compact, don't weigh a lot, and consume less electricity. Due to the nature of electroluminescence, it is possible to instantly turn LEDs on and off, and their light spectrum can be influenced. [23] Influencing light spectrum is interesting, because plants don't use all of the spectrum for growth and mainly use the blue and red wavelengths for photosynthesis [NEW1]. This is the reason why some grow lights emit a pink light, as can be seen to the right in image 18.

Nutrients

Essential to hydroponic growing, the nutrients have to be mixed with water when fed to plants. There are 17 nutrients that have an effect on plant growth, and these can either be supplied ready mixed as liquid fertilizer, or in parts as dry fertilizer. The latter is commercially more interesting for large scale farms as it costs less to ship and allows for greater freedom in mixing specific recipes, for the small scale solution imagined by this graduation project, liquid mixes will likely be sufficient. Priva's growing container uses two nutrient containers, known as the A and B, because calcium is less soluble than the other nutrients and has the potential to create precipitation when combined with certain elements, which is a solidification of the solution [25]. However, single mixes are also available. Image 19 on the page to the right shows Priva's Nutrifit, which mixes the nutrients with the irrigation water.

pH and EC

The pH and EC (electric conductivity) of the nutrient solution have to be checked often to ensure that their levels are favorable for a plant's nutrient uptake. EC says something about the level of nutrients, while pH has effect on the solubility of the specific elements in the nutrient mix. [26] In medium culture, the pH of the medium will also have effect on the pH of the solution, where depending on the material it will either increase (inorganic materials like rockwool) or decrease (organic materials like peat and coconut) [27]. To adjust EC, either extra water or nutrients are added, and adjusting the pH is done by either adding water or acidity to the nutrient mix to balance it out. The previously mentioned Nutrifit by Priva, as shown in image 19, regulates the pH and EC.

Image 18. Growing lights

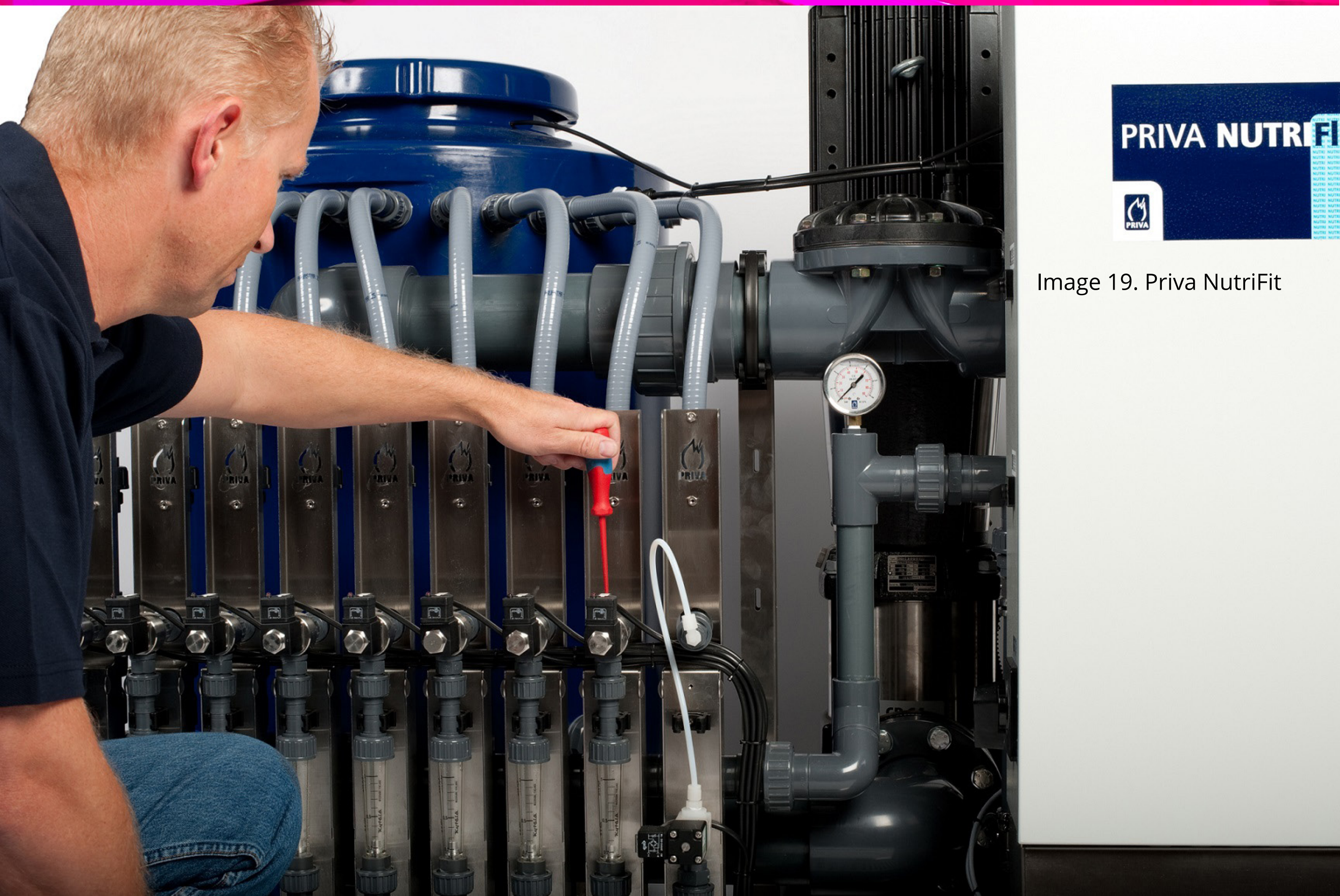


Image 19. Priva NutriFit

Environmental factors

To allow the plant to grow optimally, temperature and humidity control are used. Temperature is kept as consistent as possible to benefit its physiology while humidity has effect on the transpiration of the plant. When the humidity is too high, condensation will form on the leaves and inside of the farm, and the plant will start extracting more water from its roots and ultimately stop transpiration if the humidity gets too low. Humidity can be extracted from air in form of condensation, which provides an extra source of water. Priva's growing container does this using a cooling coil in the ventilation and the principle is considered to be good practice in indoor farms. Temperature and humidity are related to each other; when the temperature is high it can contain more humidity than when it is low. Two other important environmental factors are the CO2 concentration and airflow of the air inside of the indoor farm. Plants use CO2 during photosynthesis and growth, and proper airflow ensures that plants can exchange this gas, along with oxygen, with its environment.

CO2 (Carbon Dioxide)

CO2 is generally known as a greenhouse gas and bad for humans in high concentrations, but plants can't live without the gas because it is a crucial ingredient for initiating photosynthesis. Current atmospheric concetration is about 400 ppm (parts per million) [28], but it is not uncommon for concentrations to be doubled or trippled in horticulture to boost plant growth. It allows for more photosynthesis to take place, and is generally added by using CO2 tanks that pump the gas directly into the ventilation of the growing room. If CO2 wasn't added, the heat and water added to the system will be less optimally be used, as described by Liebig's law in the previous section.

Example of a growing process

To get a rough feeling for the process of an indoor growing cycle, image 20 below was created to illustrate the user steps that have to be taken during the growth of lettuce in Priva's growing container. It excludes the technicalities and takes a closer look at what steps have to be taken once the device is fully operational.

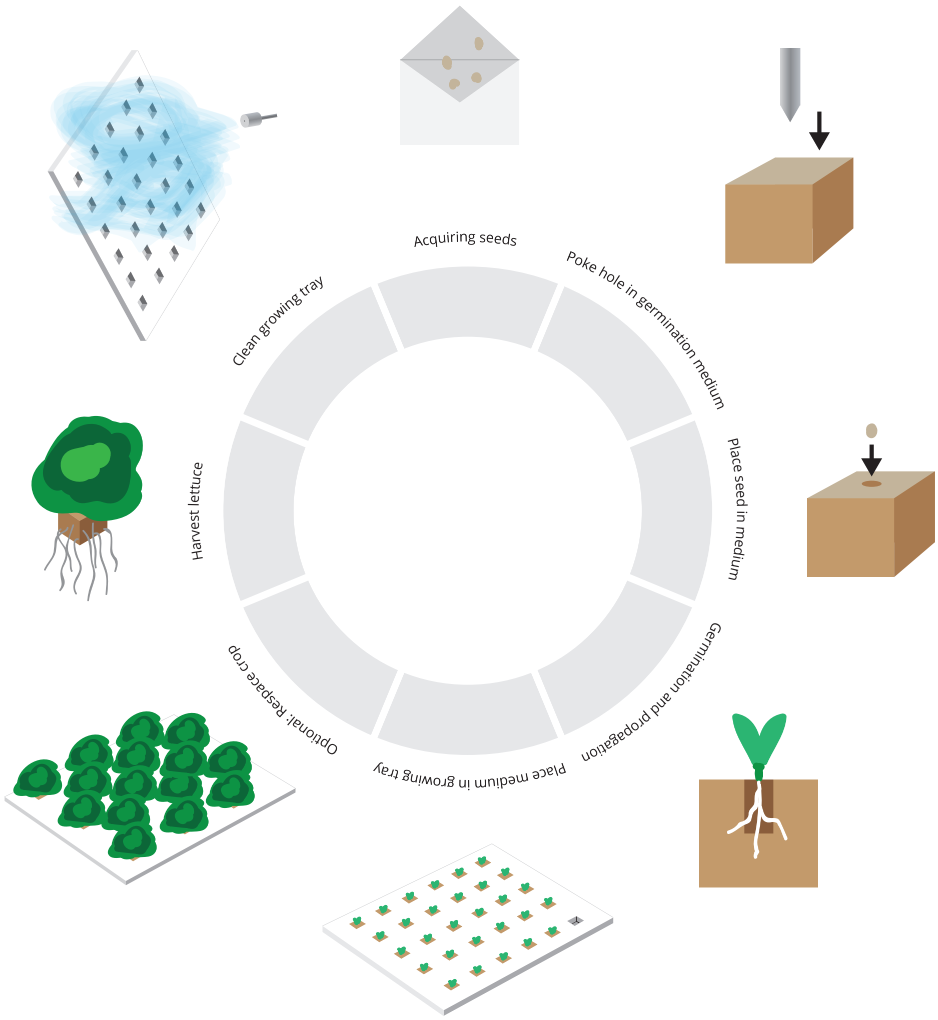


Image 20. Growing cycle of lettuce

1.5 FUNCTIONAL ANALYSIS

A functional analysis was created to get grip on all the resources needed by the system and to get an idea of where user input is required. Where user input is required, user needs need to be determined and an appropriate solution has to be chosen.

A functional analysis, as describes by Roozenburg & Eeckels (1995)[1], was conducted in parallel with the indoor growing and plant growth research. The full analysis can found in appendix FIX ME and breaks down the growing process into systematic steps for the product. It not only paints a realistic picture of the product functionality, but also helps in determining which components and user steps are required to ensure the product works at an optimum. The “Implications” column, which is deduced from the analysis, can be regarded as a first step towards a list of requirements that later concepts will have to satisfy.

Using insights from the full analysis in appendix D, the system can also be illustrated as a collection of inputs and outputs - a system that consumes and produces. This type of depiction can be found to the right in figure 21. It has the advantage of splitting the technical components from the resources they require, looking at the former as a black box and the latter as inputs that need to be supplied to the product in one way or the other. This is interesting because it gives insight into potential user actions while still having the freedom to determine which components will be chosen to receive the inputs and produce the outputs.

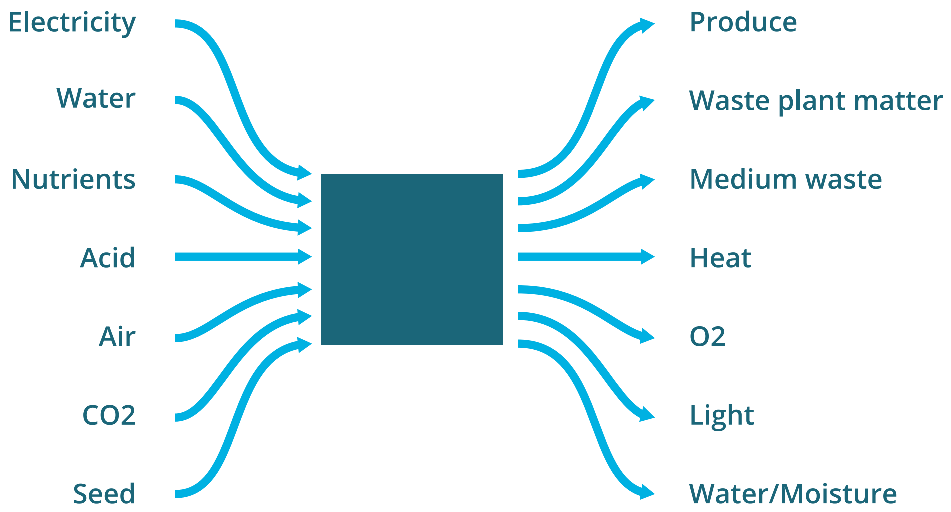


Image 21. Inputs and outputs of the black box

Looking at image 21, a possible distinction can be made regarding the abundance of the input. Finite resources, like seeds, nutrients, acid, and CO2 will have to be added by the user at regular intervals, whereas infinite resources, like electricity and water will likely require a one time set up. This is obviously not set in stone, because it is possible that a solution can arise where electricity and water could be in limited supply if batteries and water tanks were to be used. The finite resources pose design aspects that will have to be answered, the addition of nutrients, acid, and CO2 to the system are required from the user, but the exact amount, frequency, and the procedure will have to be determined according to the scenario of use.

On the right side of the figure, the outputs can also be split up. Harvesting the produce, cleaning up the plant and medium waste, and getting rid of the drain water are aspects that require user input. O2, heat, and light, on the other side, are by-products and require no additional action from the user. Regardless of user input, light and heat have the potential to pollute an environment if produced at certain levels, which should be avoided by taking it into consideration in the final design.

1.6 SIMILAR PRODUCTS

This section explores products that are similar to that envisioned in this project. It aims to better determine which market segment is interesting to explore for the user research and context mapping exercise.

Farmshelf

Farmshelf is a standalone indoor farm created for hotels and supermarkets, it is designed in such a way that it doesn't look like a typical indoor farm and is visually easy to understand by the user. Technologies like sensors and irrigation systems are embedded in the system, the product contains a shelf for germination and uses trays that allow for planting and harvesting of individual plants. It is not clear how the irrigation system works in the product, but it is assumed that the trays hook up to the irrigation similar to the growing container. How the product is further maintained and who is responsible for this is also unclear. [29]

Infarm

The Infarm concept is similar to that of Farmshelf, it is designed for use in supermarkets. Where Farmshelf can be considered a static standalone product, Infarm aims to create a central network from which each farm is controlled and monitored through data collection. Plants are grown externally till maturity before they are placed in it. In the product itself, the plants migrate outwards during maturation to give the leaves more space and the light is constantly rotating. Like Farmshelf, the website doesn't give much away about who is responsible for the maintenance and other user interactions with the product. [30]

Grove Ecosystem

Grove Ecosystem is an aquaponic home farm from Kickstarter. The product and app aim to make growing small amounts of vegetables and fruits as easy as possible by providing users all the information they need. It includes storage space and the possibility to grow seedlings. Because aquaponics allows for the nutrients to be supplied by fish and bacteria, the user doesn't have to worry about maintaining the fertilizer levels and the process runs itself. This looks ideal, however, it has to be noted that the user has to set up the entire system themselves before it is possible to run itself. The current status of the product is unknown. [31]

Replantable

Replantable's Plant Pad requires a pulp sheet ingrained with seeds to grow plants. It is self-watering, and can be combined with their Nanofarm to provide more space and lighting for restaurant applications. The only steps required to start up the process is adding water and the pad to the tray, which makes this product more suited for casual growers and restaurant applications. Like the Grove Ecosystem, the status of this kickstarter project is unknown. [32]

Image 22. Farmshelf
source: Pinterest

Image 23. Infarm
source: Innolabor.de (L), Artrprnr.com (R)

**Image 24.
Grove Ecosystem**
source: Kickstarter

Image 25. Replantable
source: Shopify

https://cdn.shopify.com/s/files/1/2214/2219/files/PlantPad_Envelope_168aaaf9-d00a-49d3-afe5-f347ff2125fc_600x600@2x.JPG?v=1517047572

GROWx

GROWx is an Amsterdam based vertical farm that grows and delivers fresh produce, such as salads and herbs, to restaurants as a service. The advantage of this set up is that restaurants only have to buy the fresh produce and don't have to invest into the technology themselves. This is a slightly different solution than is envisioned in this project, because it requires multiple parties to facilitate, grow, and transport the whole operation. Because Priva's core activities are delivering technology to enable such an operation, it is not expected that they will take care of the facilitation and growing of produce in such a construction. [33]

SuperCloset

SuperCloset is a compact integrated growing cabinet for home use. It combines several technologies, as seen in image X, and is likely meant for more experienced growers as certain steps have to be performed by the user to ensure that the process goes accordingly. While it isn't mentioned on the website, the cabinet is likely meant for growing cannabis as one of the features highlighted is a carbon filter to neutralize the smell. [34]

Smart Garden

Smart Garden by Click and Grow is a small but ingenious system that allows home users to grow small amounts of greens. The only steps that are necessary to start growing are inserting plant pods, filling up the reservoir with water, and turning on the light. Smart Garden's strength lies in their plant pods, not only are they easy to install new seeds in the device; the pods themselves contain the nutrients needed for the plant and are designed in such a way that it properly doses the nutrients, water, and air to the roots. This eliminates the need for a complex irrigation system, but likely limits the product to casual growers. It fully relies on these pods and makes it harder to grow and experiment with both the plant and process. [35]

Cressomatic

Cressomatic was developed by PB Techniek and Koppert Cress (large grower of cress) and is currently used on a cruiseship for the cultivation of cress on board. It has all functionality an indoor growing product needs to have, and the seed packaging is optimized for safe transport and storage. Other things that have been considered are the consumables the product uses.

Conclusion

The most interesting products have technical and automation systems, they're potentially interesting fields for Priva and optimally use horticultural techniques. In the next section, trends will be explored to better determine which market segment is the most appropriate for a small indoor farm.

Image 26. GROWx
source: GROWx

Image 27. SuperCloset
source: Supercloset

Image 28.
Smart Garden
source: Click and Grow

Image 29.
Cressomatic
source: Bertvanmeurs.com

1.7 TRENDS

In addition to looking at similar products, more specific trends regarding indoor farming and vegetable consumption are explored, using the DESTEP method, to understand where the market is heading and where there is demand for the indoor growing product envisioned in this graduation project. This section will describes the results generated from the DESTEP method.

Increasing produce purchases by restaurants

In 2017, 3% less fruits and vegetables were purchased in the Netherlands compared to the year before, although consumers spent 2% more on their produce purchases and 5% more on food labeled as biological. Restaurants, on the other hand, saw an increase in volume of 13% compared to the year before. [36]

Food Experience

Guests of restaurants want a more pure food experience, where the consumed products are considered to be fair, sustainable, and artisanal. The consumer pays more attention to quality, freshness, and origin of the produce, and this manifests itself in restaurants purchasing more locally sourced or biologically grown produce. In addition to this, restaurants are paying more attention to how their dishes are prepared and try to convey this as transparent as possible to the consumer through open concepts where the consumer can see their food being prepared.[37]

Indoor gardening as interior design

Indoor growing is becoming more part of interior design, and its ability to add aesthetic to commercial and residential spaces is a big push behind this. Tropical plants help in making an interior look more exotic and alive, and have health benefits related to cleaner air and better mental health. [38][39]

Indoor farming for supermarkets

Supermarkets are the main supplier of fresh foods to consumers and seem like an interesting field for indoor growing. Some stores of the Dutch chains Jumbo and Albert Heijn have started growing indoors and aim to enrich the experience of shoppers regarding food.

Fresh local food

The so-called local food movement allows indoor farms to thrive because they can be located close to their market. In the US, food travels an average of 2500 km before it is consumed, which makes consumers willing to pay a premium to ensure that their food is as fresh as possible. [15]

Food safety in the US

An E.Coli outbreak in the US involving romaine lettuce in late 2018 has increased demand for hydroponically grown lettuce and shows that this type of growing can effectively be marketed as a disease free alternative. The same trend can be seen in Asia, where consumers are becoming more critical as pollution, food scandals, and pesticide use increase. Considering that Asia accounted for about 75% of the world's vegetable consumption in 2014, this trend could potentially have a significant impact on the way fresh produce is produced and marketed. [40]

1.8 MARKET SEGMENTATION

The market is relatively new and Priva hasn't developed a small scale indoor farm yet, which means that the user and context are relatively unknown. To roughly determine which markets are appropriate for a small indoor farm, the market of existing products and trends will be used as input.

This is done by market segmentation, which is defined by Kotler and Armstrong (2012)[3] as "dividing a market into smaller segments with distinct needs, characteristics, or behavior" and is used in marketing for the strategic positioning of products. Taking into account Priva's current market, trends, and the products found in the section Similar Products, the following segments are found on the page to the right.

Retail and restaurants

There is a rising trend of restaurants and supermarkets wanting to grow their own plants for consumption and sales, and the concept could likely be extended to hospitals, office buildings, and schools. A product for such a segment could perhaps not only illustrate the freshness and authenticity of their fresh produce, but also serve as part of an experience of the overall location. The growing product itself would play a facilitating role in the growth and experience of the harvested food. This is where this product will differ from typical horticultural setups; it serves as a display and storage in one. This creates interesting opportunities from both a design viewpoint and for Priva, because a combination of user maintenance and technical and automation aspects play a major role in ensuring continual output of harvestable food. This would be a new market for Priva more oriented towards consumers, but doesn't necessarily imply B2C.

R&D departments

Priva's current market is that of professional horticulture, which could potentially consist of users who wish to downscale their current solution to the size determined by this project. R&D departments of companies like Rijk Zwaan, Koppert-Cress, and Greenhouse Seed Company or institutions like Wageningen University will likely have applications for such a product in their development process. However, there is no explicit demand from this market, nor as has Priva received any requests from such a party.

Household users

From the section Similar Products, it is clear that a range of products exist that allows users to grow at home using techniques from horticulture. Because many plants will just simply grow when given water and light, this type of activity doesn't necessarily require high tech equipment to ensure proper growth, however, there is a niche for high tech growing and experimenting in the DIY community. An indoor growing product using Priva's hardware and software is perhaps interesting for invested growers, because the technology enables these growers to push their process to the next level. There is not a lot of information readily available about this user group and Priva doesn't operate in a B2C market. There doesn't seem to be demand for such a product, which makes it less interesting for them to dive into.

Analysis

R&D departments and household users are potentially promising fields, there are products that currently cater to these semgnets, but there is ambiguity regarding the exact demand and respective user groups. Retail and supermarkets, however, have a clear user group and are supported by trends found in the previous section. From an industrial design viewpoint, restaurants and retail are interesting because it requires translating the relatively complex technology to an easy to use product. While the invested growers and R&D departments would likely embrace the complexity of such systems, retail and restaurants would have much different priorities regarding issues like the amount needed to use such a product and the overall applicability in a restaurant's serving process.

Distinguishing between retail and restaurant

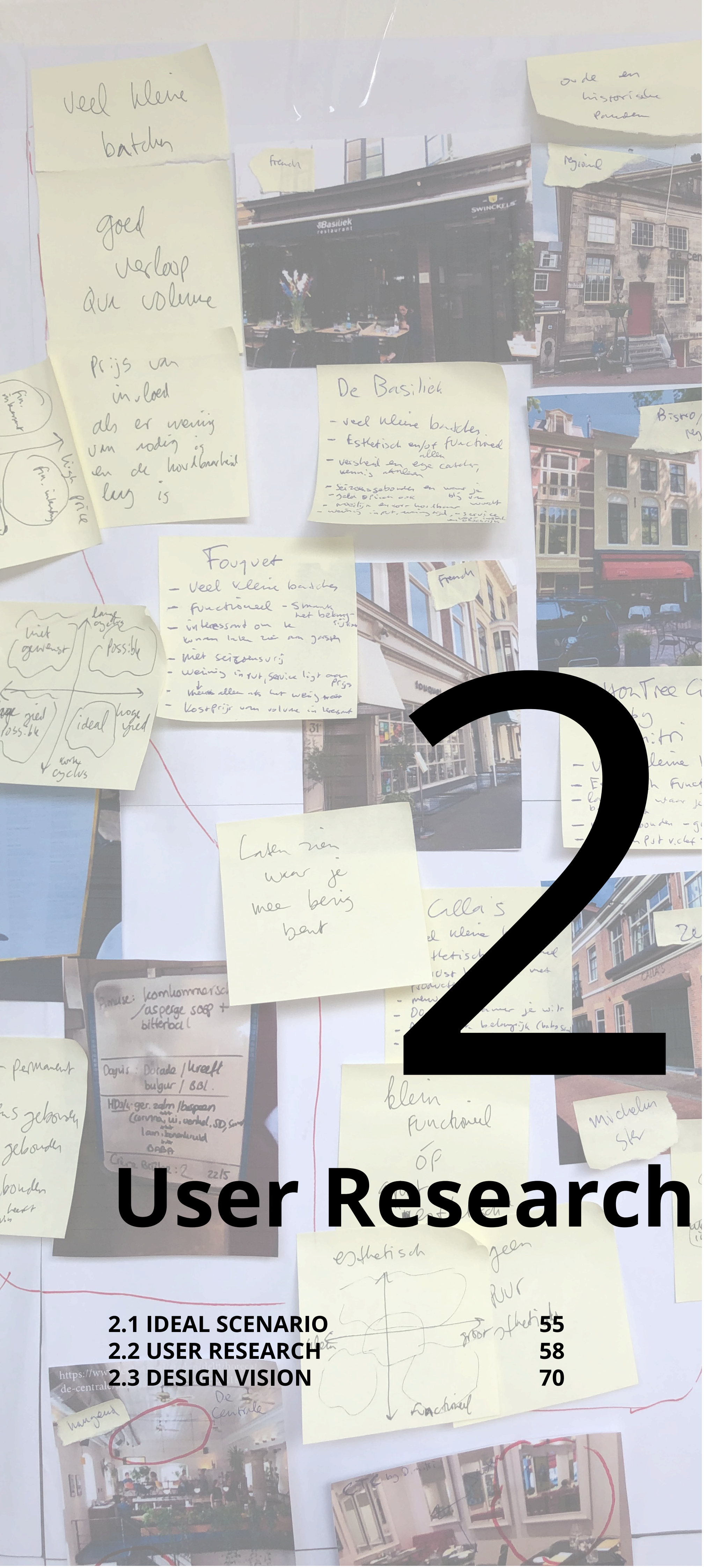
Retail and restaurants are still a bit too broad, however. A choice has to be made between the two based on how appropriate they are for a small scale indoor farm. Supermarkets sell their products at high volume, but a small scale indoor farm is likely not able to keep up with the demand because plants take time to grow. An indoor farm for restaurants seems to be much less prone to this because the volumes are much lower and there is more control over how much is taken out. Chosing for restaurants also likely means that there will be more emphasis on the experience of the product and how well it fits into its context.

Type of restaurant

Not every restaurant is the same, a product designed for casual dining restaurants would be much different than that of a Michelin star restaurant due to differences in menus, pricing, type of guests and staff, etc. Although it is possible that a casual dining restaurant would purchase an indoor growing product, volume of food and investment required are assumed to be two big reasons for such a restaurant to do so. For fine dining restaurants many of these aspects are more favorable, guests spend more money and receive smaller dishes that are more refined in their use ingredients. These restaurants not only want to deliver their guests food, but also experience it in the way the chef and restaurant desires.

Conclusion

The segment chosen for user research and further concept development are fine dining restaurants. The refinement in ingredient use, dish sizes, and higher budgets of both guest and restaurant all point to favorable circumstances that would enable an indoor farming product to work in these restaurants. In the next chapter, these restaurants will be subject of the user research.



2 User Research

This chapter involves user research in the high-end restaurant market using contextmapping and interviews. An ideal scenario is generated and serves as the basis for the ideation fase.

2.1 IDEAL SCENARIO

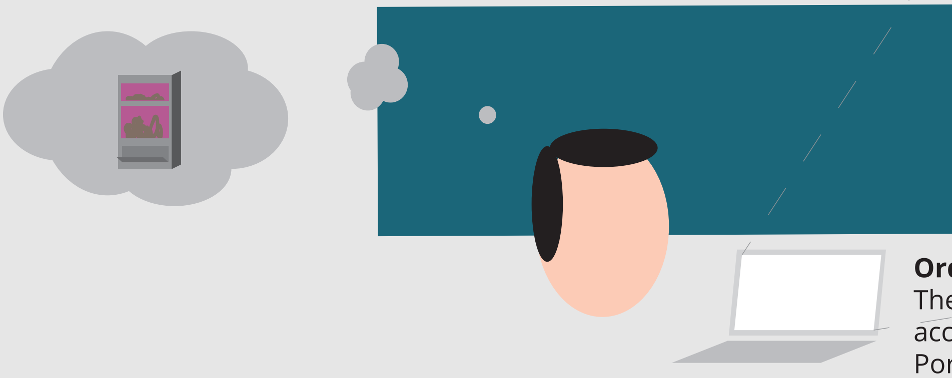
An ideal scenario is developed to understand the use of Microfarm over time, to generate topics for ideation, and to validate whether every step has been accounted for in the process of using the Microfarm.

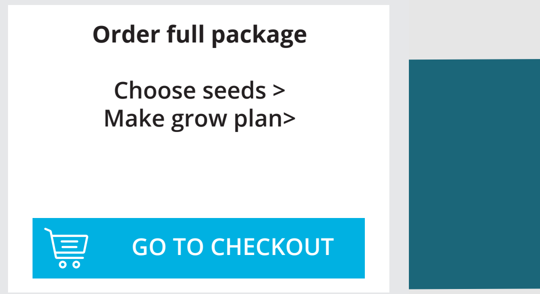
Each step represents a moment at which the user could interact with the product or a related service and is looked at from a little input, high service perspective that was put forward as result of the user research.

To make the overall use of Microfarm fit the context, Priva Portal is proposed as a one-stop for chefs to visit when any information or supplies are needed. User research found that restaurants generally have limited time to invest into the growing process and would like a helping hand when it comes to sourcing materials and knowledge. The scenario will serve as input to ideation and sets the basis for the product and service combination envisioned in it. The scenario can be found on page FIX ME, which is the next page.

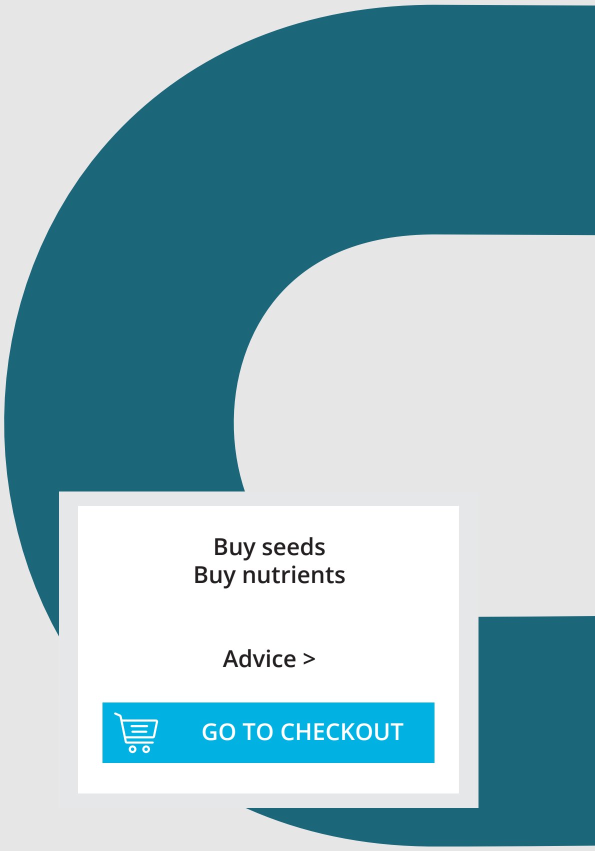
Please turn the page for the scenario

Contact
To start the process, the user browses their medium of choice to find the Microfarm



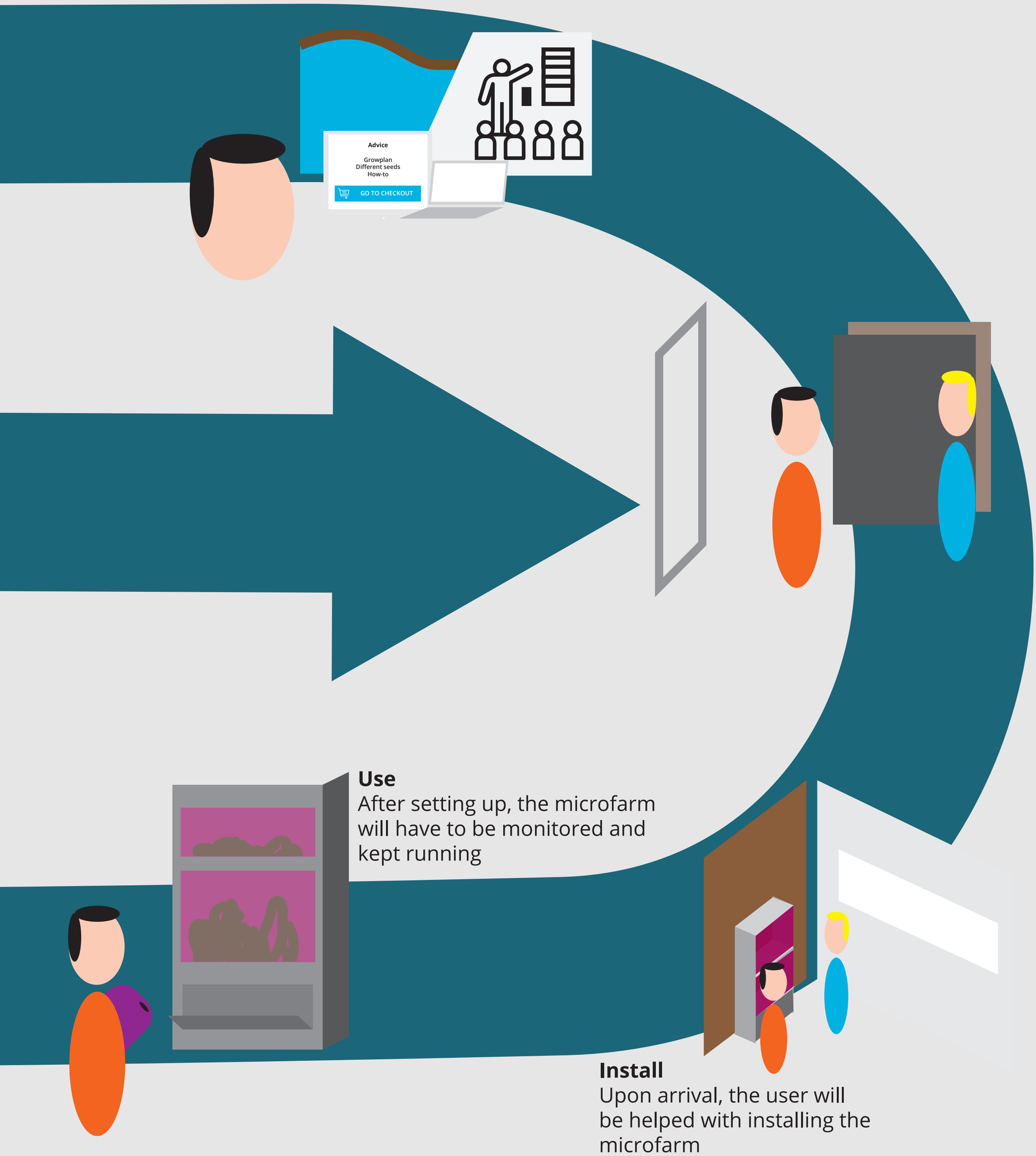


Order
The user orders the product and gets access to an online store, named Priva Portal



Re-up
Whether the user runs out of a certain consumable, starts a new growing cycle, or just needs advice, Priva portal can be consulted to keep the chef going

Learn
To learn how to use the Microfarm, there are multiple resources to gain knowledge: Priva academy, the so-called Priva Portal, or online tutorials



Receive
The microfarm is delivered to the restaurant

Use
After setting up, the microfarm will have to be monitored and kept running

Install
Upon arrival, the user will be helped with installing the microfarm

2.2 USER RESEARCH

To understand the context of a restaurant and how the future user would want to use the indoor farm, user research was conducted. Using interviews and techniques from context mapping, insights were found using the analysis on the wall technique described by Sanders & Stappers (2012) [4]. These insights will be used for the scenario and interaction vision, and also provide a large amount of practical knowledge for ideation.

Method

Two methods were used to conduct user research, context mapping (image 30) and interviews.To map the context of a restaurant, a sensitizer and two generative exercises were created for the user research. As will be described later in this section, these types of generative sessions proved difficult to conduct in the context of a restaurant. Taking this into consideration, a shorter informal interview format was set up that would allow the objectives to be answered in a similar fashion, while still learning about the context.

Objectives

The objectives of this research are defined below and reflect the research question:
"...what product characteristics are required to be fit for that context of use?":

What are important values to a chef and how is this reflected in their ingredients?
What do they use and what influences the use of fresh ingredients?
What will be grown in the product?
Where will it be located?
How much control does the user want to have over the growing process?
Roughly what size does the future product have to be?
What experience does the restaurant want to evoke with such a product?
Are functionality or aesthetics more or equally imporant?

To the right: Image 30. initial context mapping sheet


Slechte herinneringen
NEP VERS
KUNSTMATIG
POSITIEF
MISLUKKING
DEPRIMEREND
NIET VERS...
SLECHT
PLASTIC = SLECHT
VIND IK NIET NICE → LIEVER MAAR MES
AANGENAAM
DUURZAAM
MODERNE TECHNOLOGIE GEBRUIKEN VOOR BETERE GROENTE → ¡NICE!
THE ODD BUNCH
BUITEN BEENTJES → GOED INITIATIEF
WAAROM MOET ALLES ER PERFECT UIT ZIEN?
MARKT = VERS = DUURZAMER
BETER KIJKEN/VOELEN → WAT IN HET SEIZOEN IS LIGT ER VAAK
CHILLE LUI BIJ DE MARKT
COMPOST = GOED
SMAAK
EXPERT
DUBBEL (OOK NICE)
PRODUCE DEAL OF THE WEEK
KUNSTMATIG
→ KAN NIET DUURZAAM ZIJN...
Hoe ervaar jij het verkrijgen en gebruiken van groenten

Recruiting

There are many different types of restaurants, which make it impossible to design an indoor farm that will suit all of them. Initial recruitment looked at restaurants stating a preference for locally sourced produce and ingredients. Two restaurants were recruited for the pilot, which served as a testing ground for the context mapping exercise that was created, and were found by consulting the Internet and local network. After the pilot, the decision was made to shift focus to more high-end restaurants, and to specifically target the cook as subject for the interview. The recruitment involved showing up at the restaurants unannounced, which made it more efficient to explain the purpose of the interview, to determine whether it was possible to conduct the interview, and to make appointments to do so. This yielded five more participating restaurants in the user research.

Pilot

The pilot was conducted at two restaurants, the first session in Delft and the other in Den Haag. The first session took place at a restaurant that works mostly with locally sourced ingredients; the three participants (two cooks and manager) successfully completed the generative exercises. The second session took place in a restaurant that uses locally sourced vegetables and has a Big Gourmand, a good quality, good value recommendation by Michelin. It could be considered more refined and high end compared to the first restaurant. The generative exercises were impossible to conduct, while the head cook and host did have the time for an interview they were too physically occupied by their respective jobs to commit to such an exercise. The pilot did, however, confirm that fine dining restaurants are interested in a small scale indoor farm.

Interviews

As an alternative for the more elaborate context mapping exercise, a shorter interview was set up of about 10 to 15 minutes. It was found that most cooks and restaurant staff of fine dining restaurants have less time to commit to an interview, which makes the short timespan of the interview ideal because it doesn't have much of an impact on their work. Next to the interviews, pictures of the potential location and menus were taken to get a better grip on the location, size, and types of fresh produce that restaurants could likely want to grow.

Analysis on the wall

Having conducted interviews and generated information with 7 different participating restaurants, an easy and intuitive way had to be found to bundle all of the information and categorize it. Using the analysis on the wall method described by Sanders & Stappers, a half day was taken to conduct the analysis and create relevant insights useful for understanding and mapping user needs. A snippet of the analysis can be seen on the right in image 31.

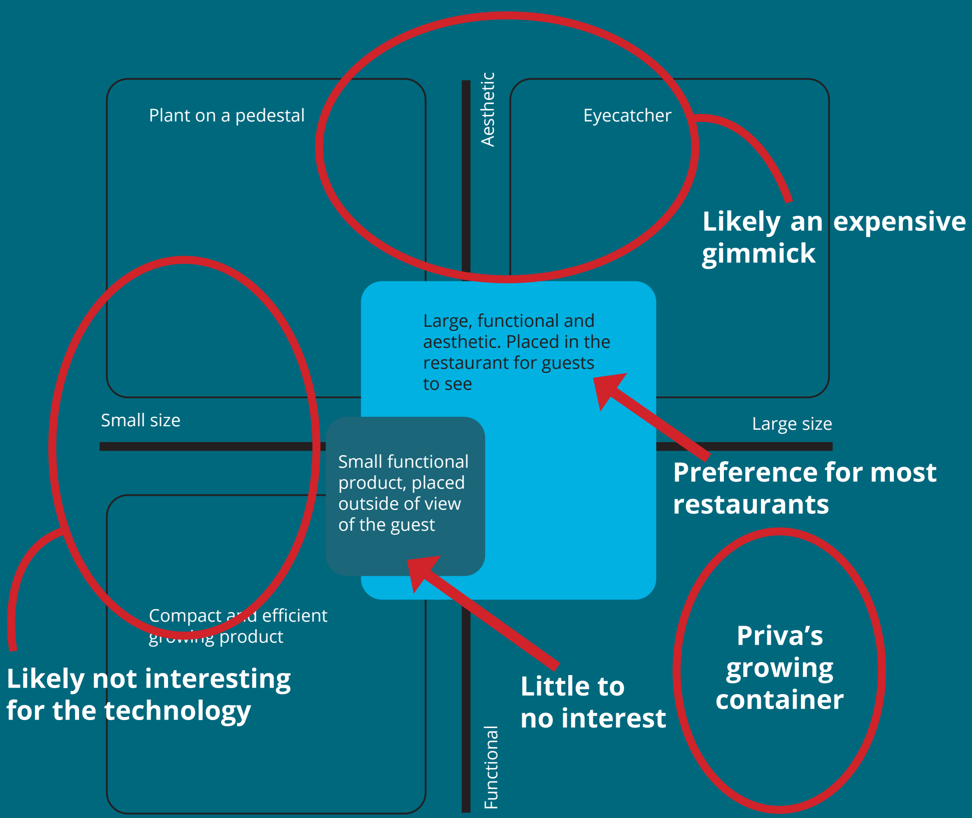
To the right: Image 31. Analysis on the wall

veel kleine batches
goed verloop qua volume
Prijs van invloed
De Basiliek
Fouquet
CottonTree City by Dimitri
Palmette
Calla's
De Centrale
Kruiden
Eetbare bloemen
Laten zien waar je mee bezig bent
klein functioneel op groot "esthetisch"
tussen Portaal hebben en eet Nimbe
allemaal in de buurt de keuken
moet mooi genoeg zijn om in een restaurant te plaatsen
6 cooks
Calla's
Asparagus
Sea lavender
Parsley
Rhubarb
Fennel
Star anise
Artichoke
Leek
Squash blossom
Watercress
Mint
Oogst
Dill
Scallion
Raddish
Asparagus
Tomato
Artichoke
Rapini
Edible flowers
Fouquet
Celery
Asparagus
Spinach
Forest mushroom
Watercress
Green pea
Tomato
Horseradish
Fennel
Maize
Lentils
Spring onion
Rhubarb
Seaweed
CottonTree city by Dimitri
Shallots
Cucumber
Tomato
Artichoke
Bok Choi
Red beet
Raddichio
Green asparagus
Pumpkin
Celeriac
Beans
White cabbage
Pickled cucumber
Fennel
Paprika
Maize
Eggplant
Zucchini
Chinese broccoli
Fig
Carrot
Palmette
Sweet potato
Spinach
Celery
Fava
Cauliflower
Dill
"Kruidentuintje"
Pickled cucumber
Chestnut mushrooms
Oyster mushroom
Basil
Carrot
Spring onion
Coriander
Mint
Asparagus
Parsley
Little gem (baby lettuce)
Onions
Celeriac
Samphire
Seaweed
Tomato
Lentil
Chick peas
Artichoke
Saffron
Leek
Avocado

Functionality/Aesthetic versus product size

Most restaurants agreed that the design would have to be both aesthetically pleasing and functional, and that the size would have to be big enough to properly grow enough for the purchase to be worth it. Aesthetically pleasing in the sense that it properly depicts the growing process, as well as being appropriate for being placed in a restaurant, and functional enough to grow their ingredients. Most restaurants noted that the size of roughly a person tall by 1 m deep would be an appropriate size, found as part of a small concept research run parallel to the interveiws. In the same research, it was found that a depth of roughly 30-50 cm would be visually appealing, while not taking up too much space.

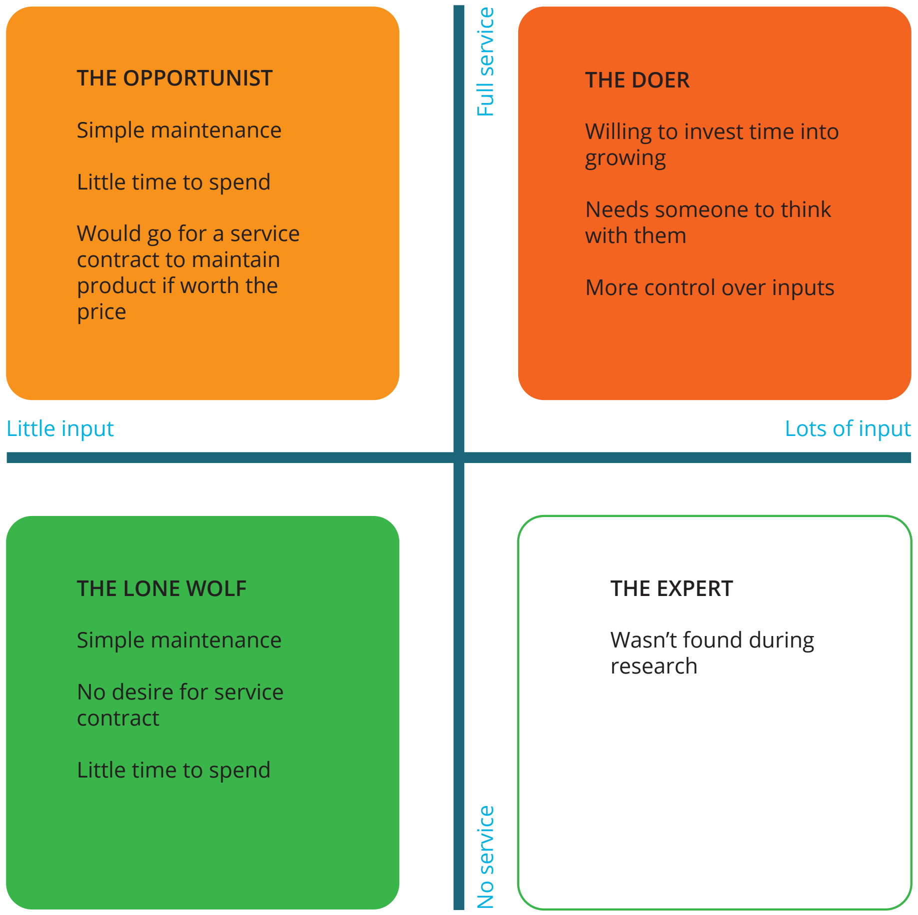
In graph 1, aesthetics is mapped against size. The preference for restaurants to choose a slightly larger and functional, yet aesthetically pleasing, design can also be a result of the restaurants and their respective locations chosen for the user research. These restaurants could be described as being situated in prime locations in and close to the city center where property values are relatively high; 6 out of 7 restaurants are located in a neighborhood where average property values are higher than €300.000, and two of those have an even higher average at €600.000 and €1.000.000. Excluding one (exceptionally large) restaurant, the average space is 132 m2, with the largest being 250 m2 and the smallest 71 m2. Taking cost per m2 into consideration gives more depth into the insights about the location and placement of the product as described later in this section.



Graph 1. Aesthetics vs. size comparison of microfarm

Level of engagement of the user

It was found that most restaurants had the preference for keeping the amount of effort put into handling to a minimum. Some showed interest in a service contract, but nearly all of them agreed that a service would be needed where supplies can be bought and help and knowledge can be provided. Graph 2 illustrates the different participants based on service versus input.



Graph 2. Input vs. service preferences of potential future users

While three different types of potential users were found, the majority of them can be found in the "opportunist" corner. Because it is not the user's primary job to do so, it is understandable that their priorities lay elsewhere. The little input and high service idea will be used as this seems to fit the context best at this moment; a product that requires

Location of the product - bridge between the kitchen and dining room

The chefs and hosts were asked to point towards a location where the indoor farm would be placed, taking in regard the size and visual properties of the design. A picture was taken of these locations and placed on the analysis on the wall sheet, a close up can be seen in image 32. Main takeaway from this part of the research is that the restaurants would place it between the kitchen and the dining area almost as a connecting element, illustrated in image 33 below. Another takeaway is that all the restaurants choose for the product to be placed against the wall, which likely reflects a limited amount of space and the need for a compact design. This also means that the product doesn't have to be observable from all sides, which helps in creating a logical front and back side of the product.

Image 32. Locations on wall

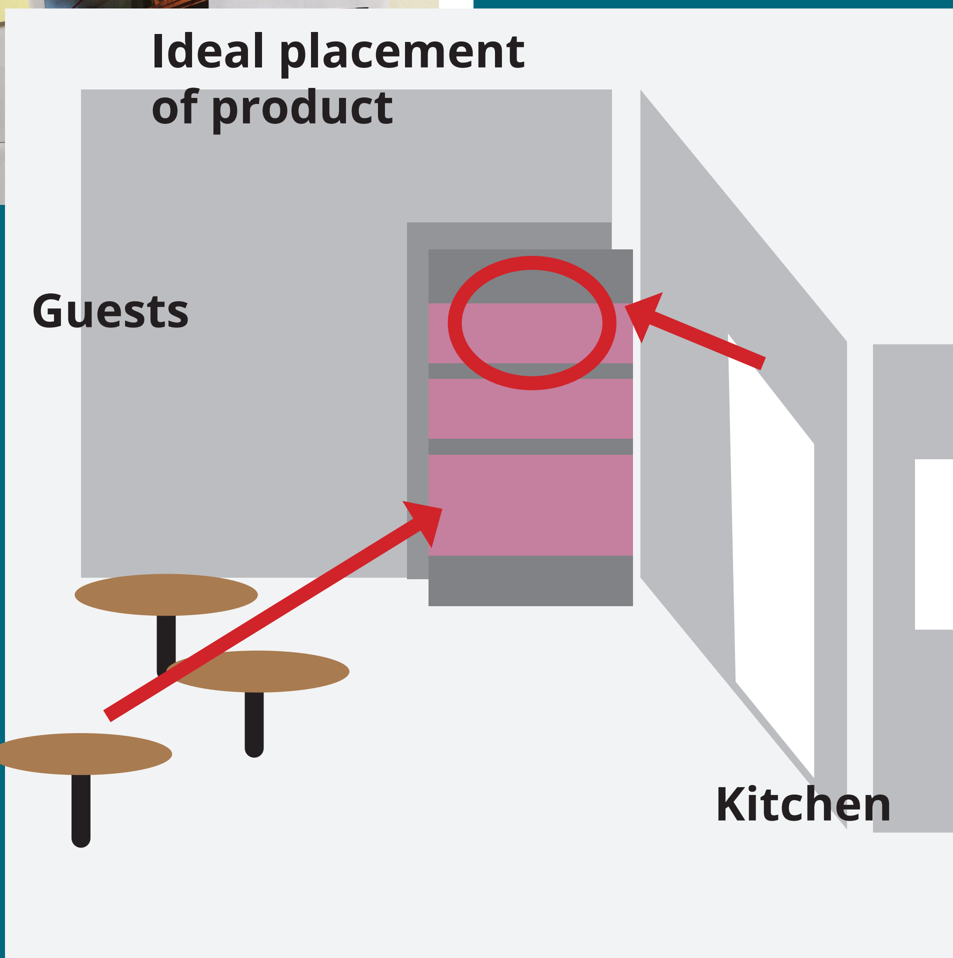


Image 33. Main takeaway

Batches and volume

All chefs expressed the desire to grow small batches of different produce in the indoor farm. Because they don't realistically expect to only harvest one type of produce, nor have it replace a considerable part of their supply, they would like to continuously be able to harvest from the indoor farm and not have it stand still. The idea of having slow and fast growing crops could be a good way of being able to provide this continuous harvesting.

Amount of produce used

If it was known how much a restaurant uses of a certain crop, or was going to, it would be easier to know whether the design is actually fit for delivering a satisfying yield of that certain crop. Because restaurants are dependent on the season and the menu changes with the season, their growing wishes will likely change. Therefor, making a conclusion regarding the amount of fresh ingredients used will be difficult, but the research found that chefs are quite flexible when it comes to the supply and use of fresh ingredients. In abundance, they will freely use the ingredient and find ways to use the ingredient to make sure none of it is wasted, where scarcity makes them more careful and selective of how and where the ingredient is used. To effectively satisfy the demand, crops should be chosen that allow for abundancy. On the next page, price, growth rate, and yield of used ingredients are displayed and a conclusion is made regarding which crops the design will focus on.

Menu and food mapping

Next to taking pictures of the potential locations, the menus of the restaurants were also photographed. These were analyzed using context mapping on the data level (Sanders & Stappers p.219)[4], filtering out the ingredients that can be grown in an indoor farm and combining this data with the growing wishes of the users yielded a list of potential candidates. Graphs 3 to 5 on page 67 and 69 display the results and a description of the graphs can also be found on the next page.

Yield vs harvest time

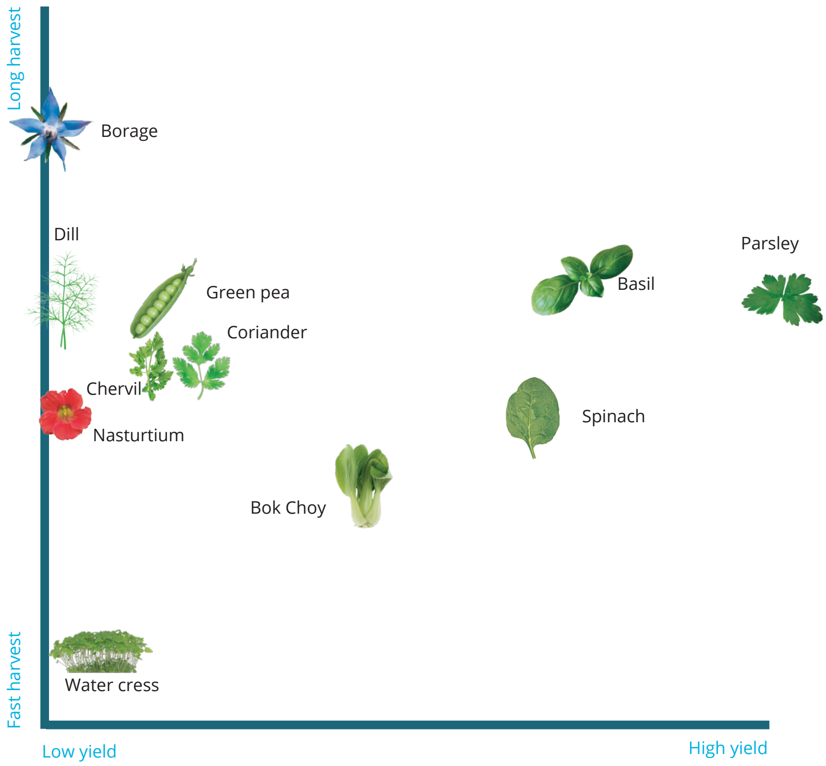
The first aspect to map in graph 3 and 4 is the yield per square meter (m2) versus the time it takes for that certain crop to reach the first moment of harvest (usually defined as maturity). The crops located in the upper-left quadrant are least interesting and the bottom-right the most, with the other two quadrants containing at least one favorable aspect. The graphs are split into annual and perennial crops, the latter being able to grow for more than one year, and is interesting to graph seperately because yield versus harvest time has different implications for perennial crops. For these crops, some time might be required for growth, but once a mature height is achieved, only periodic harvesting is required. The same rules as those of graph 3 hold, where the bottom-right quadrant is most favorable and the top-left is the least favorable quadrant. One interesting side note is that paprika (bell pepper) is a perennial plant if grown in tropical climates, the plant has a bad tolerance for the cold which makes it an annual plant outside of these regions.

Choosing between annual and perennial crops

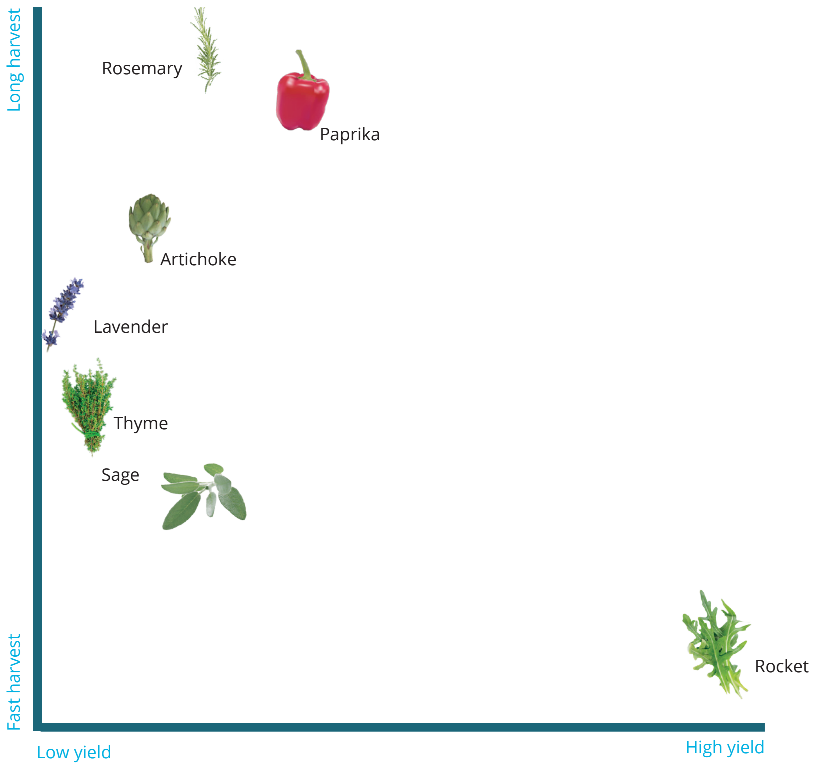
In graphs 3 and 4, a distinction is made between annual and perennial crops, and it seems that perennials are favorable to grow due to their ability to live longer than one growing cycle. While it is true that they are able to be grown indoors succesfully, perennials do require a cold climate in the winter to simulate the changing of the season, which leads to succesful flowering in the next year. Continuously growing these plants in warm conditions will likely accelerate their growth but also prevent the crop from flowering in the next year, which would require the product to actually cool during the winter. This would not be beneficial to the growth of annual crops that thrive on the warm conditions generally present inside of the growing chamber. There is no specific demand for only perennial plants in the user research, which leads to the conclusion that the product should be fit for annual plants and any perennial should be treated as an annual plant in the product. [FIX ME]

Harvest time vs length

In appendix E, comparison between maturity time and length can be found as well. Because it is not applicable at this moment it is omitted from this section.



Graph 3. Yield vs harvest time for annual growing plants



Graph 4. Yield vs harvest time for perennial plants

Cost of produce

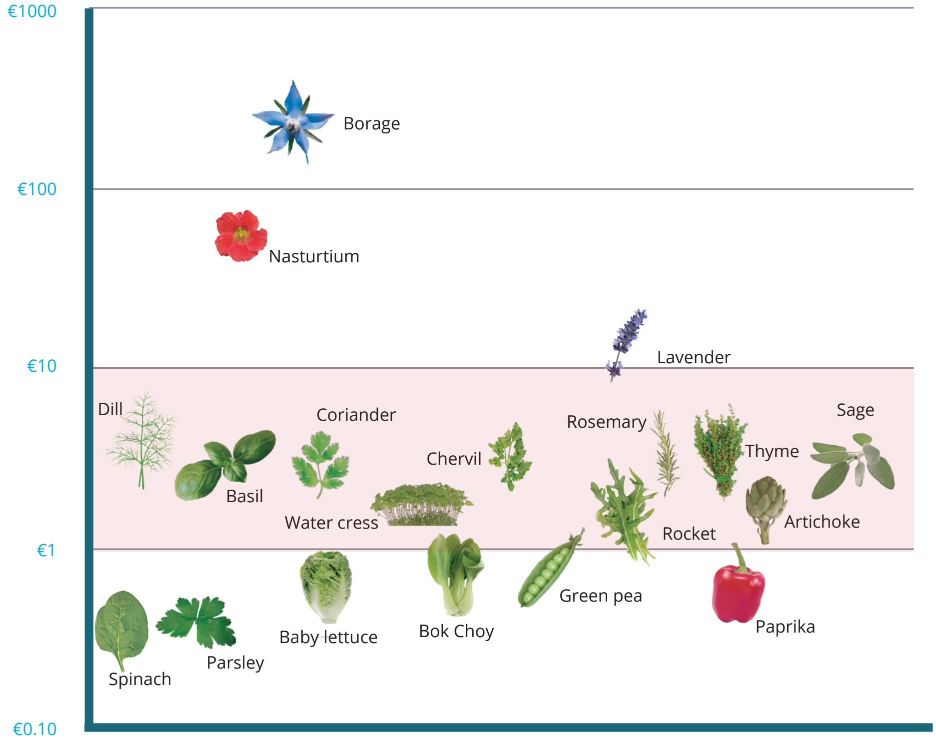
In graph 5, the cost of the crops from graphs 3 to 6 are mapped according to their cost in euro (€) per 100 gram. The sourced prices are retail costs that would be paid when ordered online, it was not possible to find the wholesale price due to these not being publicly available. It is assumed that the wholesale prices are likely lower, but the price differences between the crops likely the same. Outliers are the edible flowers, they have a light weight compared to their price, but are rarely sold in 100 gram amounts because nasturtium and borage flowers are a respective 0.91 and 0.29 gram per flower. Their price is also likely the least correct, stores and wholesalers generally don't sell them and they have to be sourced from dedicated websites with relatively little competition, while the other crops are sold at much larger volumes and many more channels, where there is more price competition and less price fluctuation.

Final remarks food mapping

It can be concluded that the design of the microfarm will mainly focus on the cultivation of annually grown herbs and small leafy vegetables. These have a cost benefit versus other crop types and decent cycle times and yields. Another benefit for the user is that such a setup would not exclude small leafy vegetables as crops that could be potentially grown, which is not the case if leafy vegetables or microgreens are chosen as the focus. While edible flowers are interesting from a cost perspective, their low yield in combination with long cycle times make them less appealing.

Conclusion user research

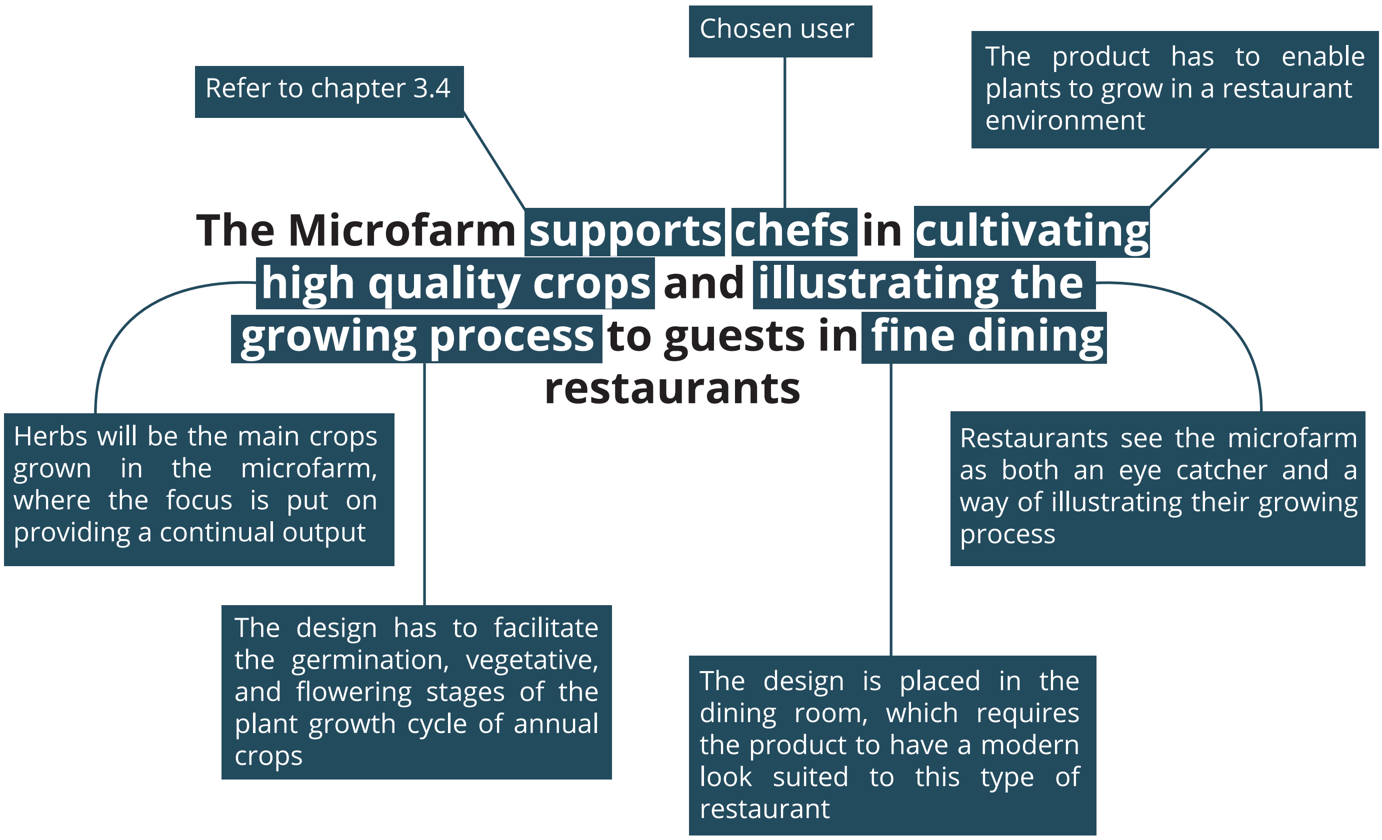
Functionality/aesthetics - Aesthetics important for placement in dining room and functionality important for efficient growth
Level of engagement - Users prefer less input and more service
Location of product - Located between kitchen and dining room
Batches and volumes used - Small, varying batches
Amount of volume required - Dependent on menu and season
Type of produce - Herbs and small leafy vegetables (for now)



Graph 5. Cost of produce (€) per 100 gram

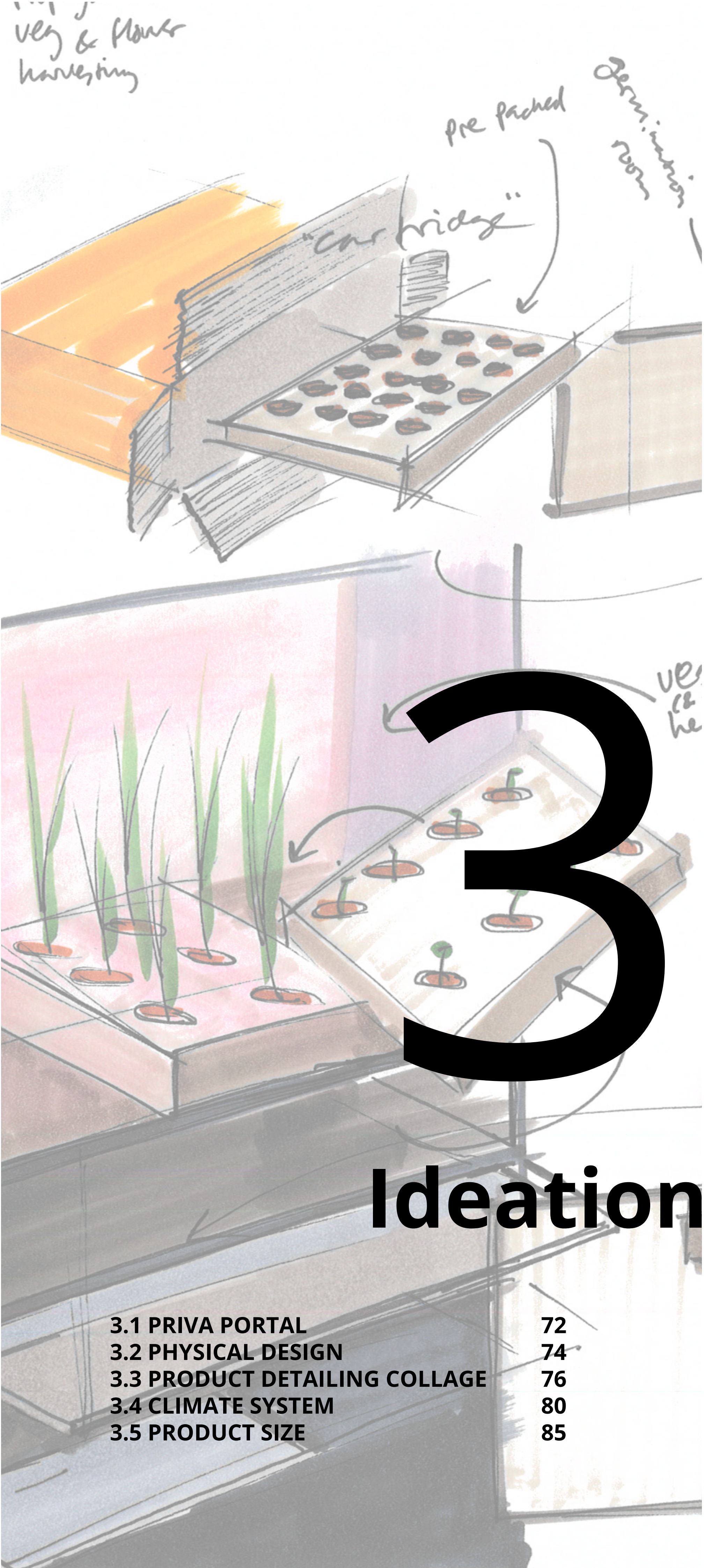
2.3 DESIGN VISION

To summarize the analysis and user research into one clear statement, a design vision is formulated that will serve as input to the conceptualization phase.



Future user

In appendix F, a persona can be found that represents the future user as a result of the user research. This is purely a reference, though, because not enough differences were found between participants to formulate distinct personas to choose from. The information contained within the persona is also slightly redundant taking into consideration it is mainly based on the conclusions from the user research.



3

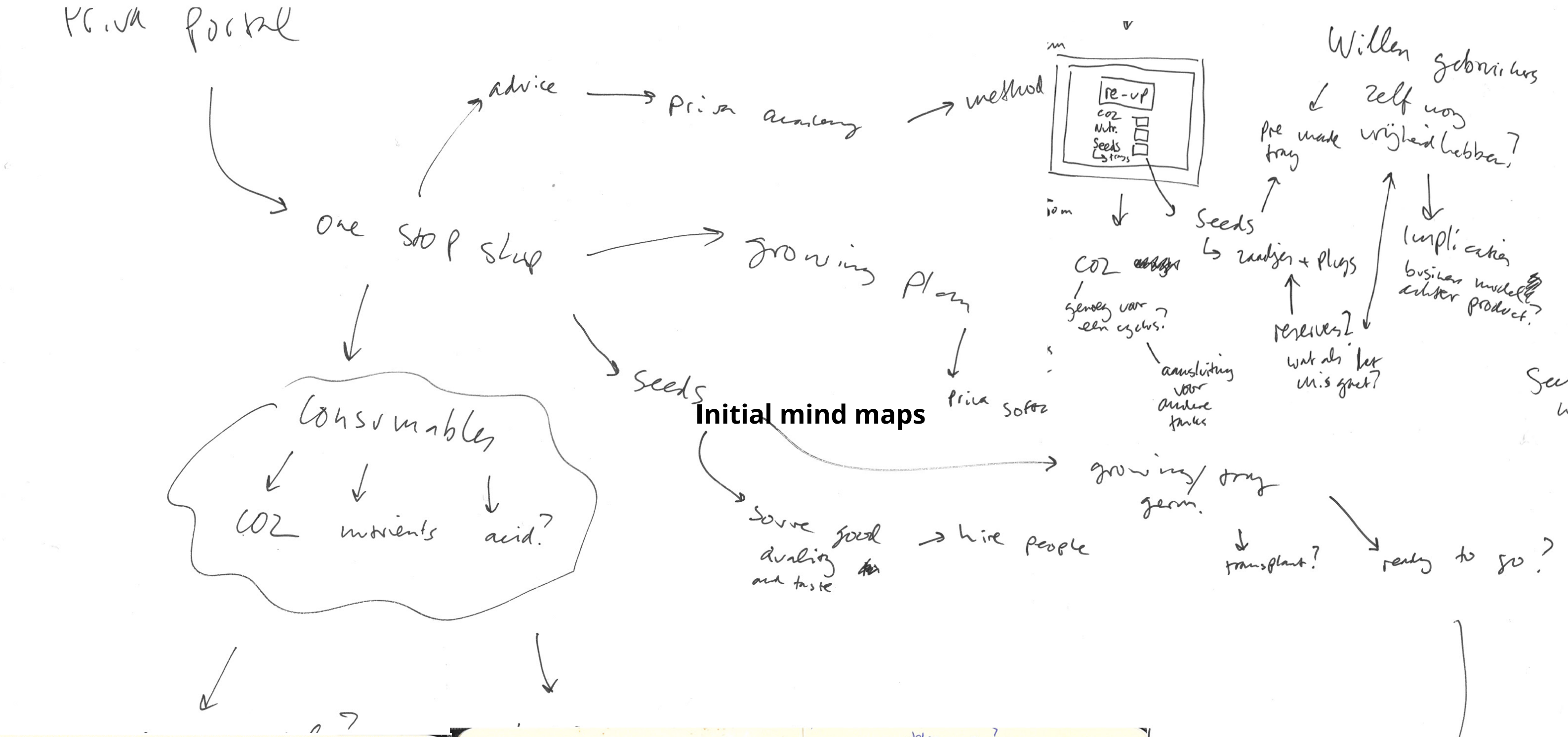
Ideation

During the ideation phase, several topics were explored through a mix of research, drawing, and 3D modeling in Solidworks. This creative work helped in laying the foundation for the three concepts proposed in the next chapter.

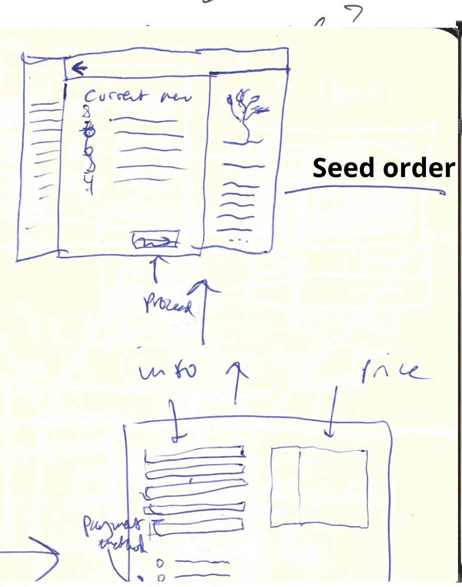
3.1 PRIVA PORTAL

One of the topics that had to be explored in the ideation phase was Priva Portal and how it will combine with the Microfarm to increase the value of the product and ensure users are provided service wherever they lack skills or time. Important was determining which functionality the Priva Portal service could provide in the scenario and which options the user are given. On the page to the right, several snippets from logbook entries and drawings can be found. The process first started with mindmapping which elements are important for maintaining the product and which actions the user has to perform to do so (from both the ideal scenario and the functional analysis in chapter 2.1 and appendix D).

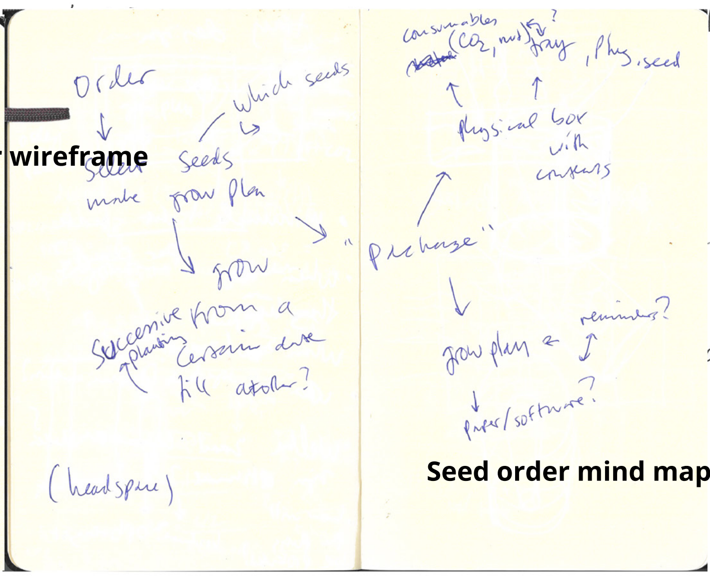
Early in the ideation of Priva Portal, the focus was on figuring out where value could be added through the service. Besides being a store, it can also function as a help desk for the user. Such functionality would likely make it more convenient for the user to find. After roughly determining which elements had to be present, wireframes were developed, which can be seen directly to the page on the right. Based on these wireframes, each element is worked out and visualized. The result can be found in chapter 5.4.



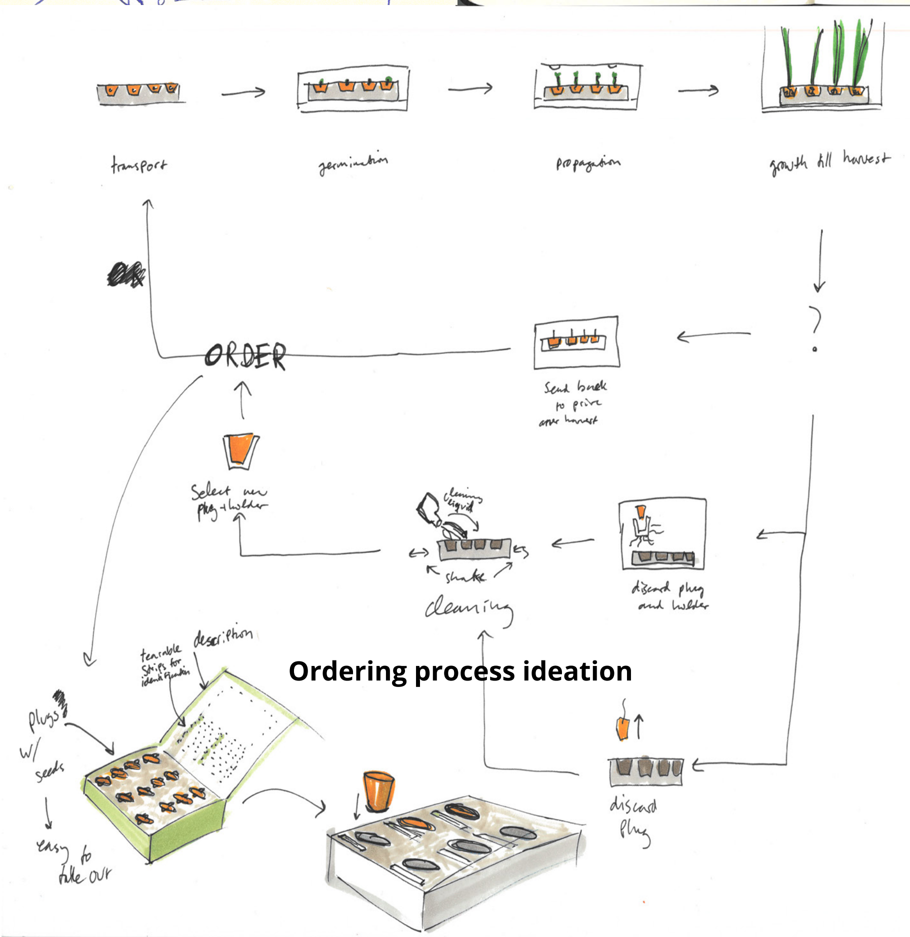
Initial mind maps



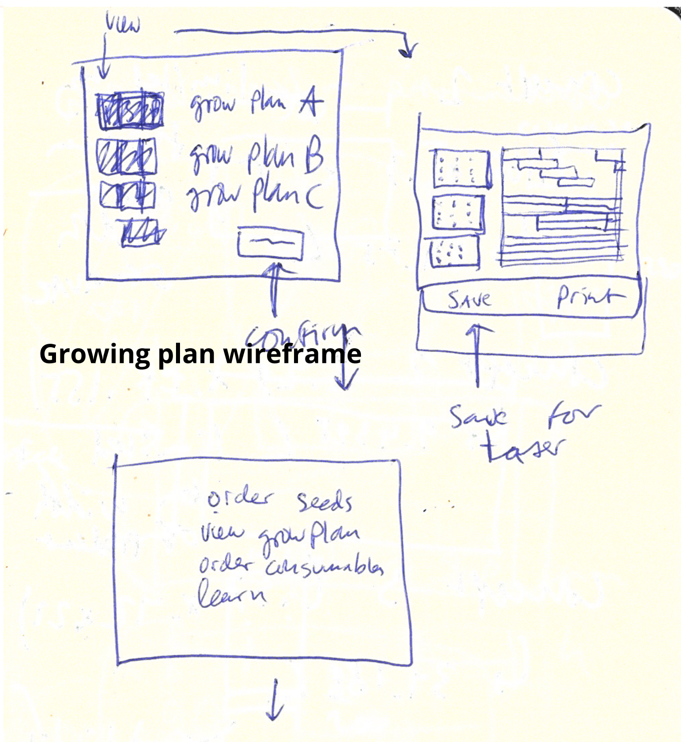
Seed order wireframe



Seed order mind map



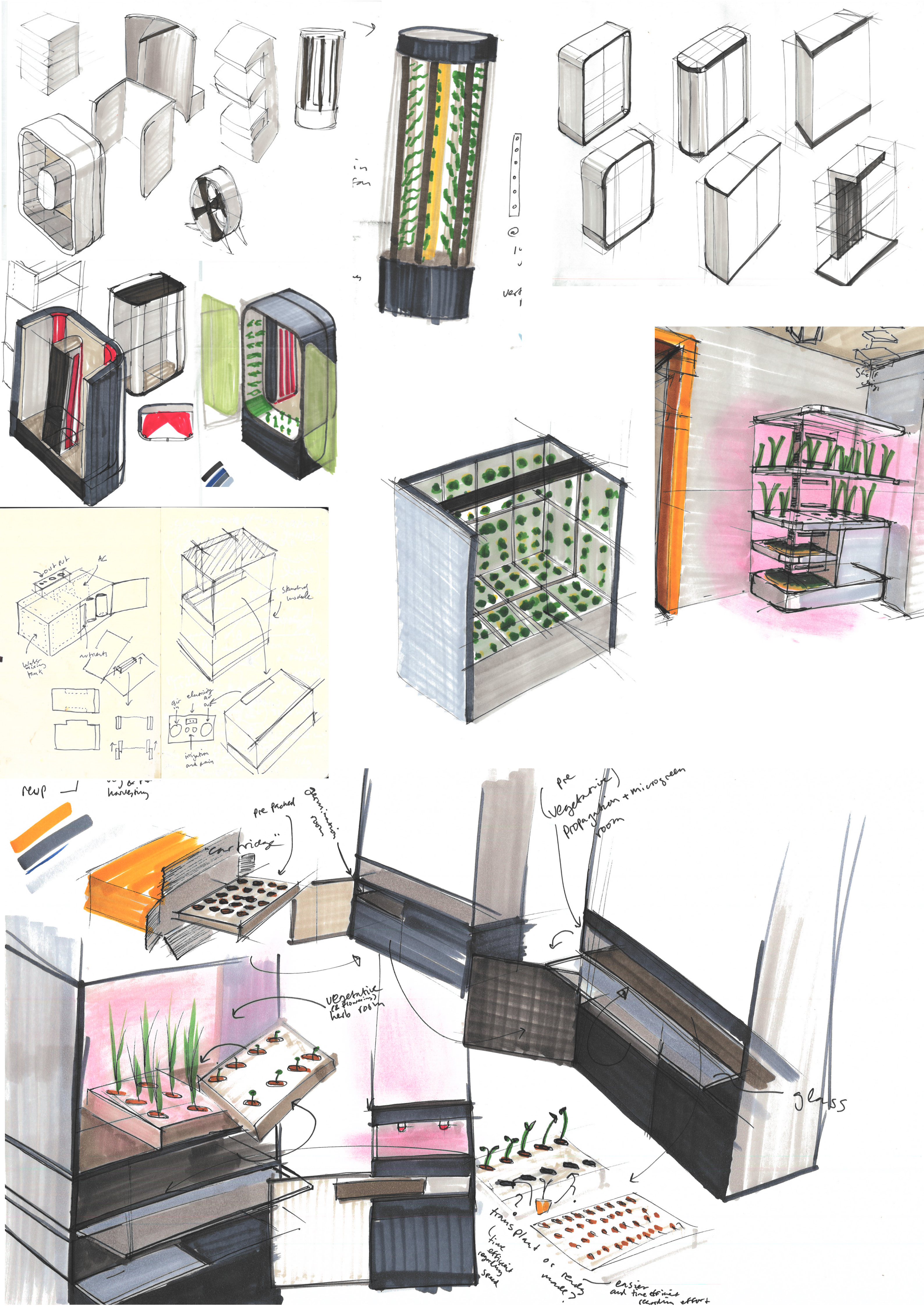
Ordering process ideation



Growing plan wireframe

3.2 PHYSICAL DESIGN

Different types of Microfarms were sketched out during the ideation phase to provide input for the concepts found in the next chapter. Early in the process it was decided to focus on a product of medium size that could be placed on the ground and inside of the dining room of a restaurant. This was motivated by the idea of maximizing the amount of growing space to be able to harvest more fresh produce every day. With this in mind, product ideas were sketched out and three ideas were worked out further, resulting in the three concepts found in chapter 4



output
AC
Water mixing tank
nutrients
Standard module
air in
electricity
air out
irrigation and drain
Shelf
harvesting
Pre packed
"cartridge"
germination room
pre (vegetative) propagation + microgreen room
vegetative (& flowering) herb room
glass
transplant or ready made?
(time efficient regarding seed)
easier and time efficient

3.3 PRODUCT DETAILING COLLAGE

Aesthetics were determined to be an important factor for restaurants when deciding to place the Microfarm in the dining room or not. By looking at the form language, colors, and materials used in the restaurants the user group works in, inspiration can be found for the embodiment of the concepts and final design to fit their dining rooms. A collage showing the images analyzed can be found on the right on page 76.


Aan de Poel - Amstelveen
Pattern
Dark elements
Apollo Hotel - Amsterdam
Outspoken color
Round elements
Pattern
Restaurant Mos - Amsterdam
Lighting
Dark elements
Round elements
Outspoken color
Round elements
Cottontree city by Dimitri - Den Haag
Pattern
Lighting
Repetition
Dark elements
FG Foodlabs - Rotterdam
Lighting
Dark elements
Round elements
De Librije - Zwolle
Dark elements
Round elements
Rijks - Amsterdam
Resaurant Fred - Rotterdam
Lighting
Dark elements
Round elements
The Millen - Rotterdam
Dark elements
Round elements
Restaurant 212 - Amsterdam
Dark elements
Lighting
Repetition
Round elements

The restaurants analyzed were found by looking at the Michelin star guide of 2018 in the Netherlands, resulting in the following insights:

Form

While there is some variation in the form language being used, they are unanimously geometric. This makes sense from an architectural perspective, where the shape of the room and its vertical elements define what can be done with the space given. Odd shaped organic furniture is likely not practical for such restaurants and can be too much of a statement for otherwise sober establishments. To create hierarchy and make the room more interesting many furniture pieces contain elements that contrast their background, such as rounded elements and the patterns in which they are placed. These rounded elements are subtle, but do their part in making each restaurant look slightly different, which is interesting to apply to the Microfarm as well.

Color

Most restaurants shown in the collage have a defined color palette that is being applied, which reflects the use of interior design in such places. While some have an outspoken use of color, most restaurants are more subtle and instead focus on lighting to accentuate the colors already present. Interiors are either uniform in color, or apply a dark color on the wall and light on the ceiling depending on the lighting, architecture, and use of furniture in the dining room. The Microfarm will contain lighting for plant growth, which could make it interesting to make elements of the Microfarm (ie. outer housing) that aren't lit of a darker grey or black color for instance. This shifts the focus to what is happening inside, while having a color that is relatively neutral to blend into restaurant surrounding.

Materials

There are many different places in which materials are used inside a restaurant; they are easier to adjust than the overall architectural design of a dining room while adding more depth than just changing a certain color. Many of the seats are made of suede, leather, or cloth, while the tables and structural elements of the chairs are mostly of wood. Some use more interesting materials on the walls as well, such as an original brick structure or geometric wood patterns, which work well in combination with the chosen lighting, although most restaurants rely on attributes to make their walls more interesting. Although materials are interesting to experiment with, their practicality depends on the final design and the colors used in this design. In color, the conclusion was to make the non-lit elements darker to shift the focus to what is happening inside, which would mean that the materials used for these elements would also not be as visible.

Conclusion

The colors and forms used in the interiors of these restaurants give direct input for the ideation and concepts, while the materials used are less useful for the materials of the Microfarm. It can be concluded that there is not a single style that these restaurants all adhere to, which means that the Microfarm styling should fit in all of the restaurants shown. This can be achieved, for instance, by adding rounded elements to the product and choosing a color that is not too outspoken, with the preference perhaps being on black-white. This will ensure that the Microfarm has a sober look, while being aesthetically pleasing enough to be placed in most restaurants without making too much of a statement.

However, it is imaginable that restaurants would want to adjust details of the product to increase its fit to the (dining) location and it should be kept in mind that the product could end up containing several different versions.

3.4 CLIMATE SYSTEM

The hydroponic working principle and technological functioning of Priva's container, as described in appendix B, could likely be scaled down to the format intended for the Microfarm. However, would scaling down the climate system be logical considering the size of the product and the context of a restaurant? This section looks at the current climate system, and poses alternatives to it. As conclusion, a new working principle will be proposed.

Why is a climate system needed?

A climate system is required for the following aspects of the growing process:

Remove heat produced by the growing lights and ensure a stable temperature for optimal growing conditions

Regulating the relative humidity at 70%-80%

Replenishing the CO2 converted to O2 to keep up the rate of photosynthesis.

Climate system concepts

Three technical concepts are suggested; concept 1 is a scaled down version of the growing container, concept 2 is a simplified version of the same technical concept, and concept 3 proposes a stripped down, alternative version of the system. They are summarized in image 34, 35, and 36 on the right page, and is explained in full detail in appendix G.

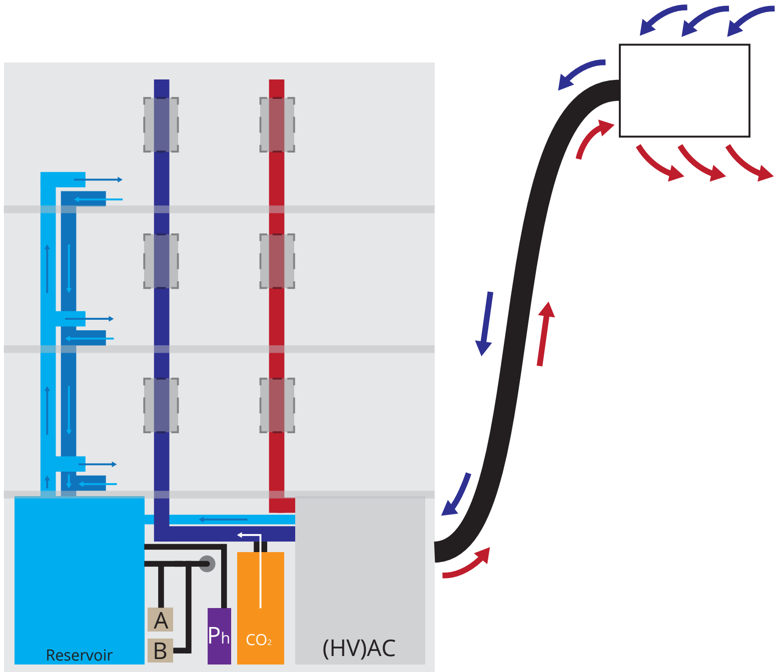


Image 34.
Concept 1 - HVAC + added CO2

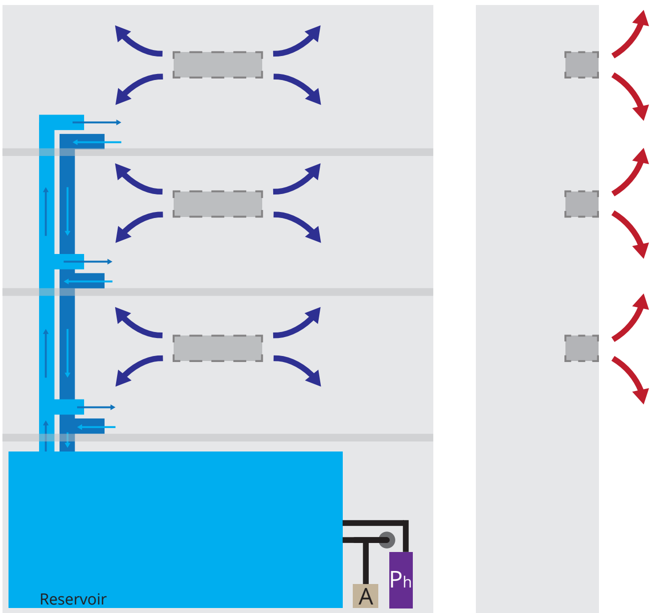


Image 35.
Concept 2 - AC

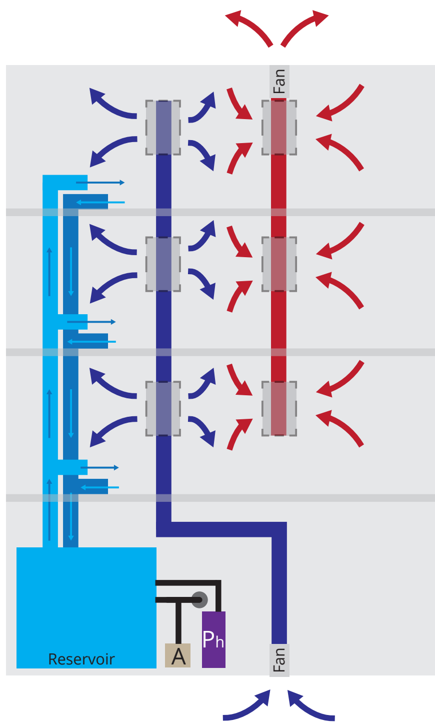


Image 36.
Concept 3 - Ventilation

Environmental context

Climate systems regulate the environment for optimal plant growth in indoor farms like the growing container and its larger neighbor. This is needed because the outside environment has effect on the climate inside. The HVAC system allows the container to be placed in any environment with minimal effect on what is happening inside of the container and the system is chosen for this purpose. To effectively judge which climate system is suited for Microfarm, its environment will be explored. Below in image 37,

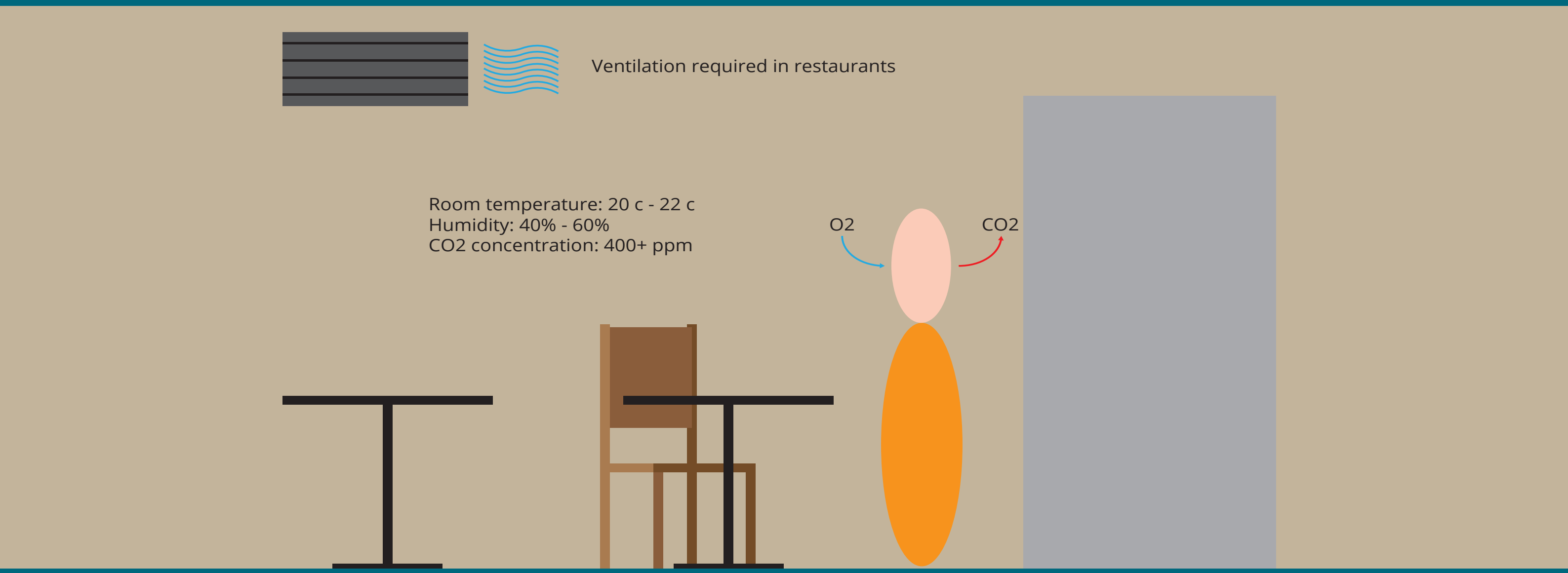


Image 37. Environmental context in restaurant

It is assumed that a restaurant will have room temperature, which is comfortable for guests to dine in. Because humans inhale oxygen and exhale carbon dioxide the air has to be refreshed occasionally. In Dutch law, the Drank- en Horecawet sets requirements for restaurants regarding ventilation. The law states that a restaurant requires a functioning mechanical ventilation that has direct connection to outside air and capable of refreshing 3.8×10^{-3} cubic meters of air per second, per square meter in the restaurant [41]. It is assumed that the ventilation also regulates the moisture level, anything above 60% would be uncomfortable to guests [42].

How to choose

Looking at the pros and cons of the climate systems, the best solution can be formulated by looking at why a climate system is needed and what is available in the context where the product will be placed.

Remove heat produced by the growing lights to ensure the temperature stays around 20-25 degrees

It was calculated for concept 1, which requires the most lights, the amount of heat to be ventilated away to roughly equal 900W based on 100W per lamp. This is the same as having 9 people in the same room, which should not be difficult for any restaurant with proper ventilation. The temperature inside of a restaurant is assumed to be comfortable for humans (around room temperature), thus the air being directed into the growing room will not have to be changed in temperature. If the air and temperature inside of the restaurant were to not be maintained (which is not allowed according to the Drank- en Horecawet, northern European weather rarely exceeds maximum temperatures, which takes away the necessity for cooling. If these temperatures were to be exceeded, the plants wouldn't die but photosynthesis would slow down.

Removing moisture and keeping it at 70%-85% relative humidity

Average relative humidity is 82% in the Netherlands, but this accounts for the outside air. Inside of a restaurant this amount will be below 60%, or else it would not be comfortable for the guests. Because the humidity inside of the product can always go over 85% if it's not ventilated, the less humid restaurant air can be used to lower the relative humidity of the product.

Replenish the CO_2 converted to O_2, to keep up the rate of photosynthesis.

Calculating the amount of CO_2 that has to be replenished in the system is generally difficult without knowing the exact amount of gas the plants take up and the amount that is lost to the outside. Normal atmospheric CO_2 content is roughly 400 ppm, but increasing it to 800 ppm can increase production by 40% with favorable conditions [43]. These levels can easily be reached in a restaurant by simply having the guests breathe in and out.

Conclusion

Taking into account that the average environmental conditions needed inside of the growing room are also available inside of the restaurant removes the necessity of using a sophisticated climate control. Although a climate system would ensure optimal conditions that maximize yield, the gain compared to simply using ventilation is likely small and not worth the additional investment as yield maximization is not the main goal of the product. Therefor, the climate system will be limited to ventilation.

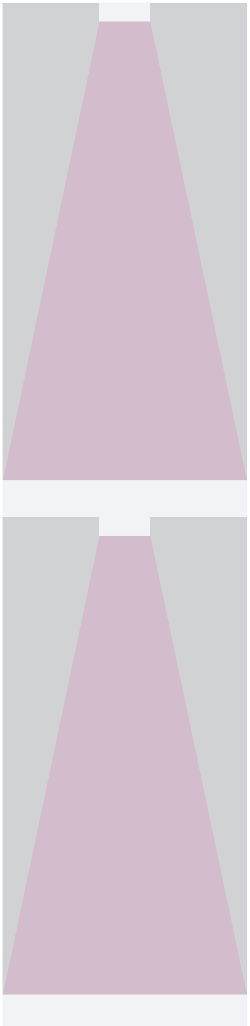
3.5 PRODUCT SIZE

In the user research phase, a part of the research was to determine which product shape, dimensions, and placement were most acceptable for a restaurant regarding the use of a microfarm. While one restaurant noted otherwise, six restaurants placed their microfarm against the wall in a location between the dining room and kitchen, and opted for a “thin” space efficient product. In this section, important dimensions from plant growth and ergonomics will be discussed and used for concept development.

Growing chamber size from a horticultural perspective

Height

The height of the product is determined by the height of the growing room, the amount of levels used, and in case the irrigation equipment is placed under the product, the dimensions of this system. On the page to the right, design considerations are proposed for choosing either a tall or a short growing room. From the plant research conducted in parallel with the user research in appendix E, it was found that most herbs can reach a height of 60 cm at full maturity given that it isn't harvested too intensly. Many other plants grow taller, like certain edible flowers and vines like cucumbers, tomatoes, and bell peppers. Priva's growing container has a height of 50 cm, their grow module 3 meters, and the urban farm on top of QO Hotel in Amsterdam (described on page 120) varied with their heights, with herbs at a height of 40 cm and edible flowers ranging up to 80 cm.



Tall (~80 cm)

+

Grow plants that are too large for the short room

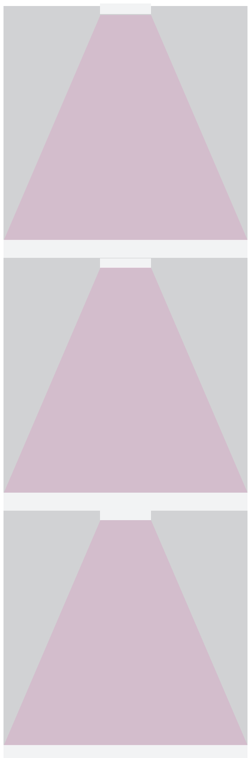
Keep plants for longer time, more space to grow taller

Cheaper and less energy intensive than short growing rooms stacked to equivalent height

-

Wasted space if plant doesn’t reach height due to physiology or harvesting

Less growing levels compared to short growing rooms at an equivalent height due to ergonomics and ceiling height



Short (~40 cm)

+

Additional surface area when stacked, more yield or variety

Stack more growing rooms within acceptable handling range

-

Excludes plants of certain height

Plants have to be harvested quicker

More expensive and energy intensive than tall growing rooms stacked to equivalent height

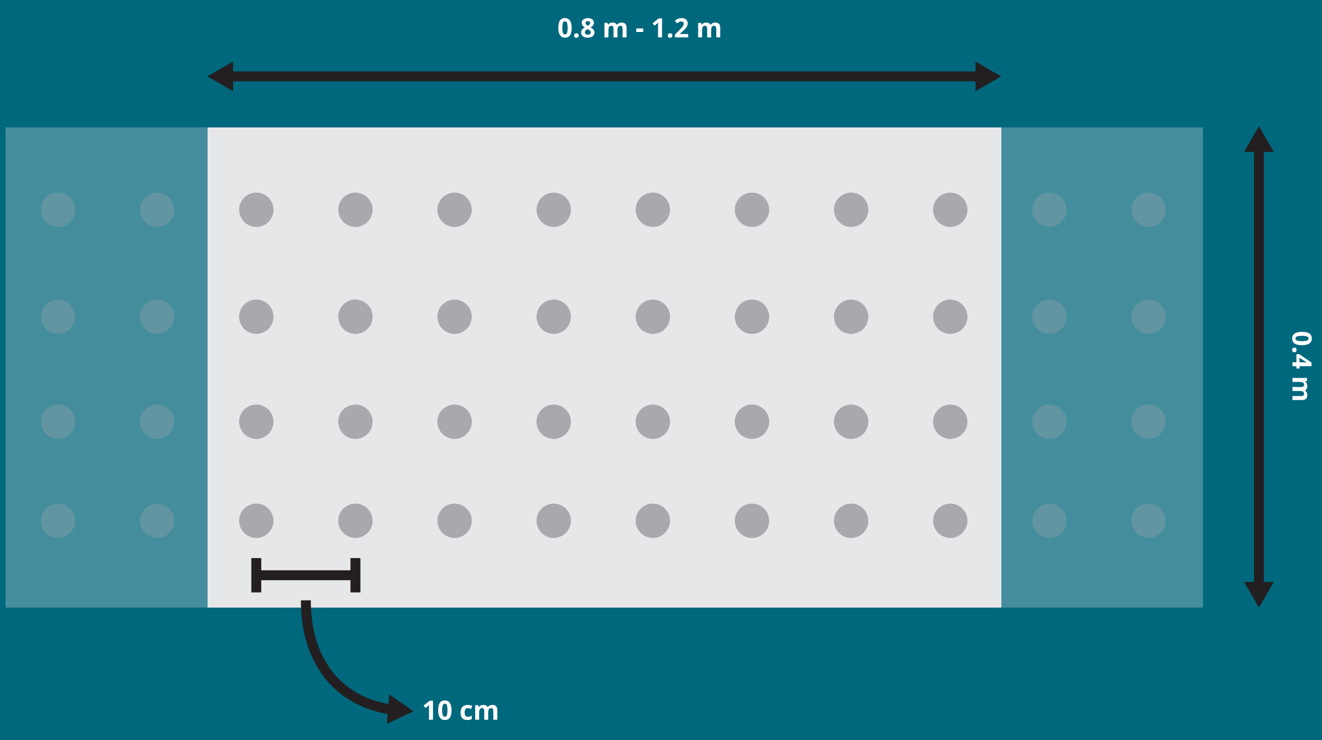
Width

The width and depth of the grow room mainly determines how many plants can be cultivated in that space, where the spacing between plants is also important. During the user research, the exact width of the product wasn't determined, but subjects did gave an indication using references like a table size, a rack, or the size of the seat the interview was conducted on to indicate a maximum allowable size. Making a ballpark estimate, this range was determined to be around 0.8 m to 1.20 m in width.

The spacing between the plants was determined to be 4 inches, or roughly 10 cm, and this also corresponds with the current growing trays used in the container. Plants could theoretically be moved even closer, this would increase yield but make less attractive plants as they would enter a rat race to outcompete their neighbors for light once they become more mature. Making the spacing larger will likely produce more attractive plants but decreases the amount of plants and yield per m2.

Depth

For aesthetic purposes, the depth should be roughly half of the width to prevent the product from looking too bulky. Given the current width dimensions this is roughly 0.5 m, however, considering tolerances and other parts present inside of the product, the growing surface will more likely have a depth of 0.4 m. From a user perspective, the depth should not be too large because it will be difficult to reach into the product and it makes the growing trays more heavy to handle. More depth will also make the product portrude into the restaurant, which prevents them from placing tables or creating a space to walk past.



Current solutions

The plastic reservoirs currently used for the ebb and flood system in the container are known as Danish trays, which are commonly used in greenhouses as well. Seen in image 38 below, these types of trays have channels in them that allow the water to drain properly and come in a variety of sizes. It is possible that if the Microfarm were to be developed into a proper embodiment design, there aren't any Danish trays of the dimensions determined for the final concept. This is because these types of trays are used in much larger grow settings, where a few centimeters more or less isn't a big deal, and come in standard sizes. This gives two options, either custom order to size or adapt the design to the available sizes. The last option has the preference as it costs less and takes less effort for acquiring them, but it is important to take into consideration what effect this has on the overall ergonomics of reaching inside, the aesthetics of the product, and the plant capacity.

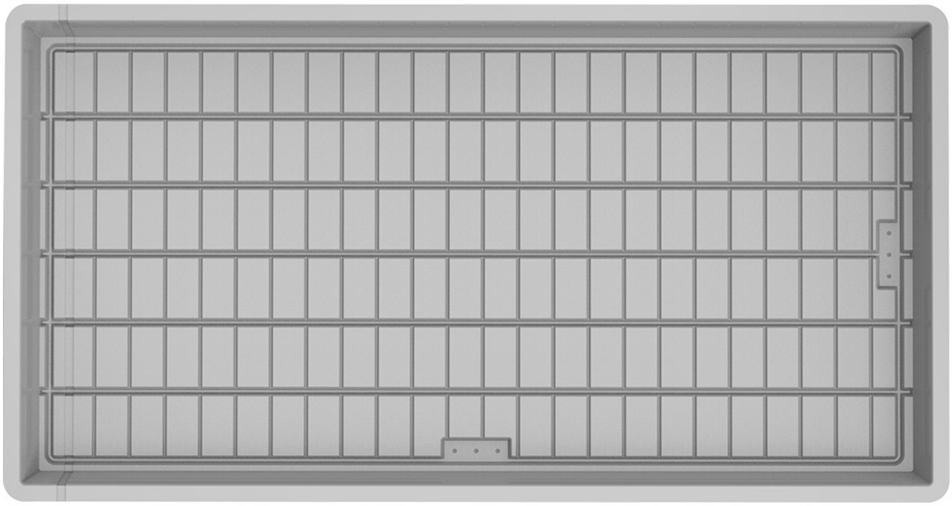


Image 38. Example of a 120 cm by 240 cm tray

Conclusion

By looking at how dimensioning the growing area affects plant growth, it can be concluded that the solution requires an optimization that is based on what the user wants to grow. Smaller dimensions and spacing will take up less overall space and are optimal for short cycle crops, but on the long term will exclude certain crops and limit the growth of the ones being contained. Larger dimensioning and spacing will produce more attractive plants and enable more types of plants to be grown, and to grow taller, but will take up more space and time.

Growing chamber size from an ergonomic perspective

The height of the product will be determined by the length and amount of growing rooms, including any extra space for germination and an irrigation system. 6 of the 7 chefs interviewed in the user research were male and none of them displayed significantly outliers in terms of anthropometrics (in other terms; very short or tall), however, their occupation doesn't exclude female users or extreme body dimensions. This makes it difficult to exactly benchmark what is acceptable and what is not. By varying the size of the growing room, insights can be gained regarding the amount of users that would be able to see inside the product and whether this is an acceptable amount or not. To the right in image 39, the effect of three differing growing room sizes is explored on the dimensions of a female Dutch adult between 31-60 years of age: eye height (red line), shoulder height (green line), and arm length. All grow rooms include an extra 50 mm for the water reservoir and lamp depth. Below that, image 40 shows how the arm length and elbow grip length would work in a product that is 500 mm deep, including the distributions of the ergonomic values found in the research.

The following assumptions were made:

The utility space under the product is 200 mm

In case of a multi-story product, the reservoir depth and light thickness are 50 mm

The full arm length can be used

Possible disabilities of the user preventing from reaching the height are ignored

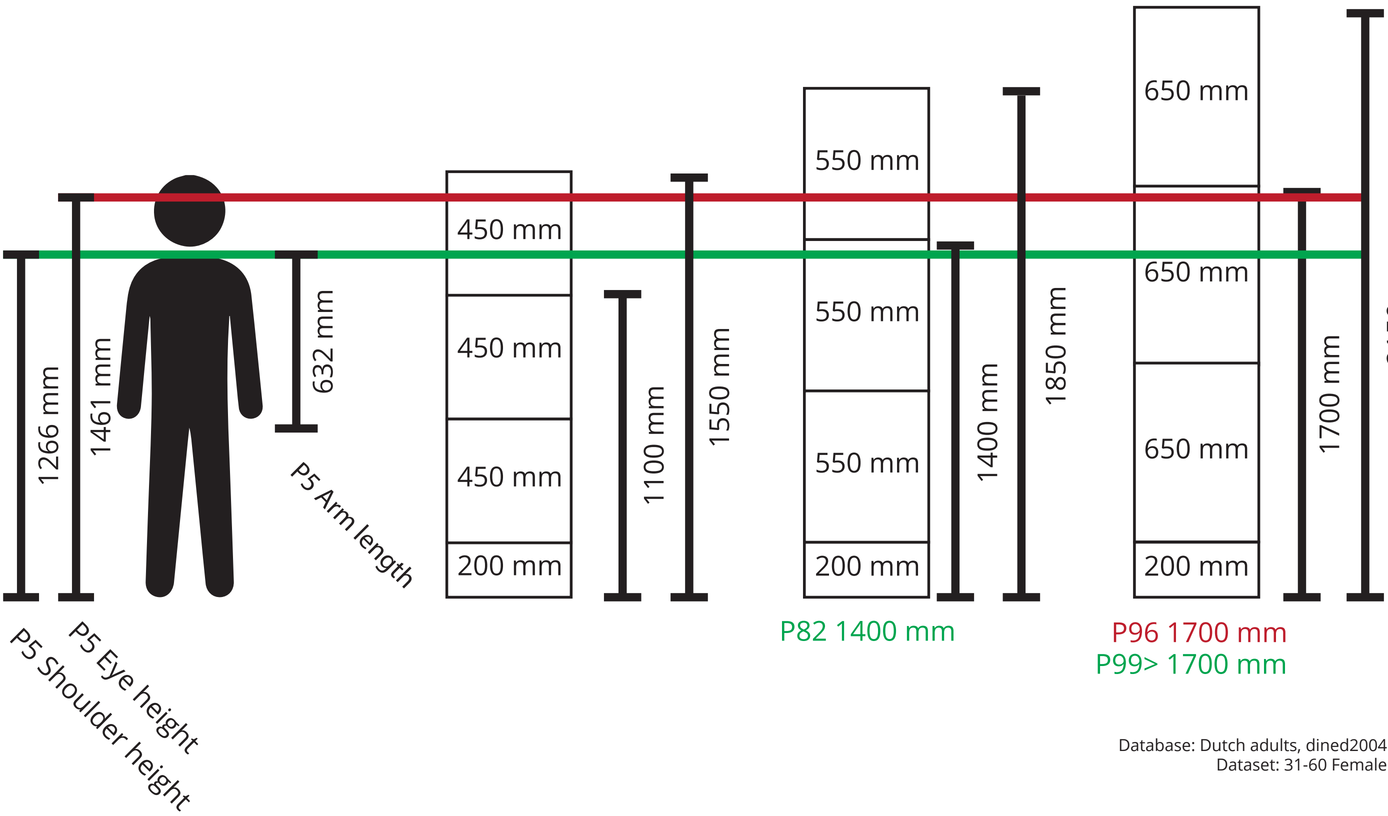
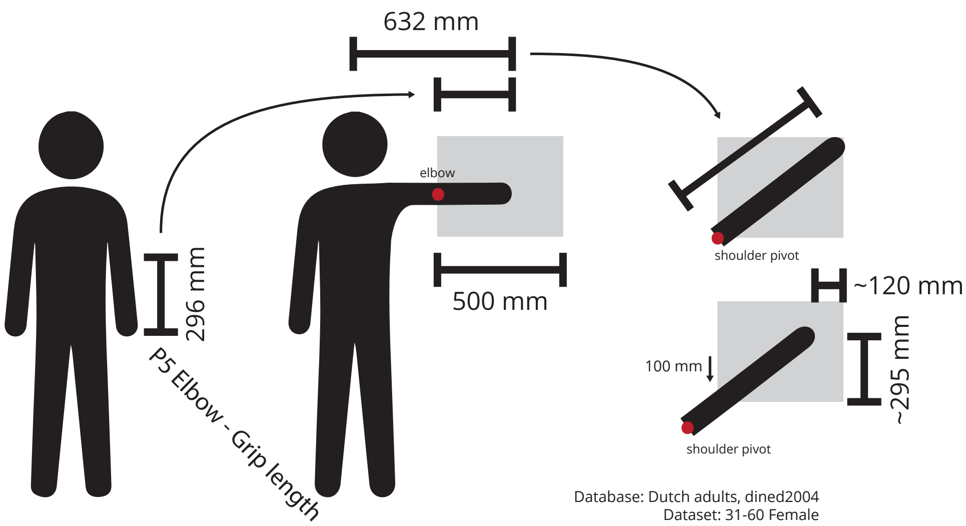


Image 39. Product height effect on P5 anthropometrics



Distribution for dined2004 female 31-60:

Arm length
P5 - 632 mm
P95 - 744 mm

Elbow - grip length
P5 - 296 mm
P95 - 346 mm

Eye height
P5 - 1461 mm
P95 - 1641 mm

Shoulder height
P5 - 1266 mm
P95 - 1438 mm

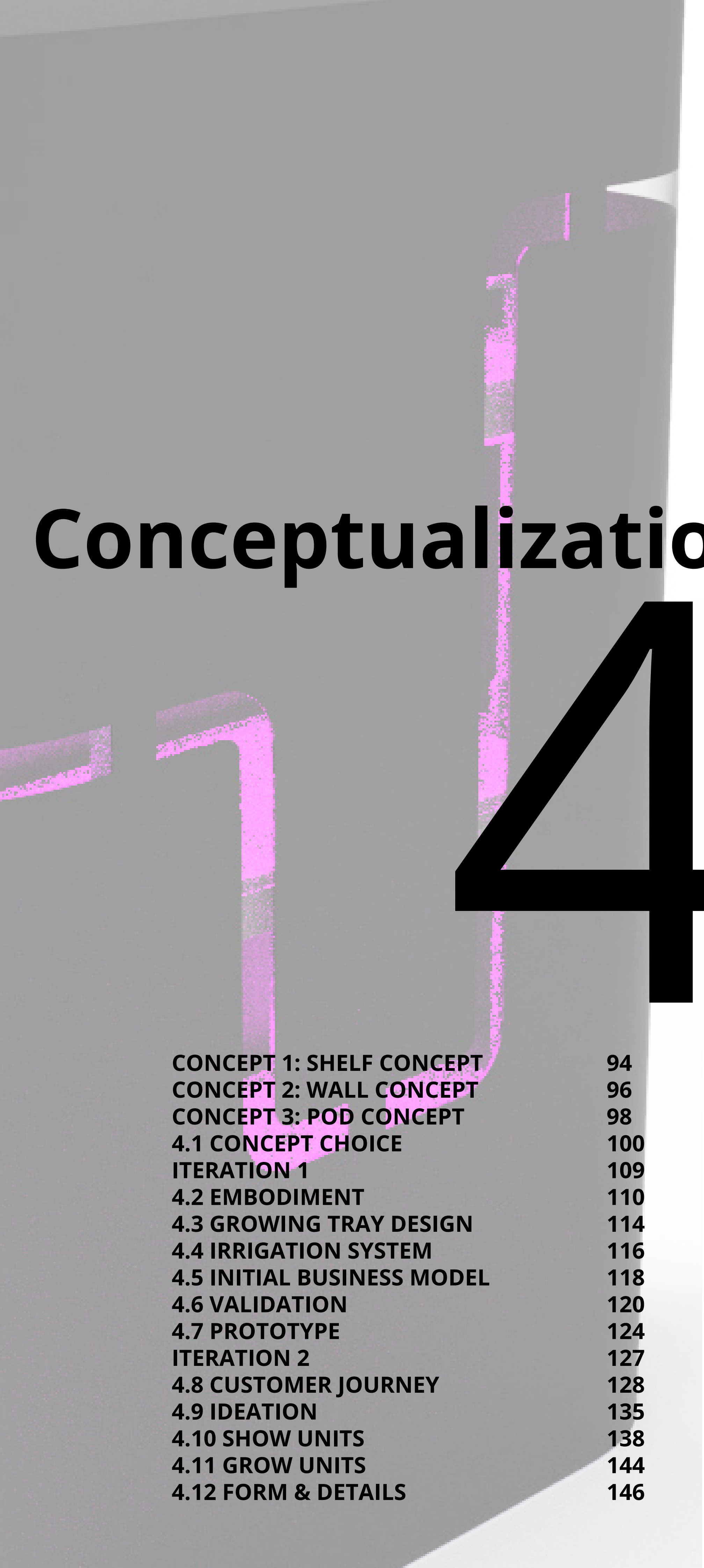
Image 40. Product depth effect on P5 anthropometrics

Evaluation

A product of 1550 mm tall, based on three growing rooms of 400 mm, will pose no problem to the usability of the product for a Dutch female between 31 and 60 years of age with P5 values for either eye height or shoulder height. A person with P5 arm length could extend it fully into the product. If their arms were to only extend in from the elbows on, their arm and hand would reach in 296 mm, which is 3/5 of the way in. If the shoulder pivot were to be at the level of the 3rd level growing tray (seen at the bottom right of image 40), a person could still reach into the product completely. However, if the shoulder height were to be 100 mm lower, this person would have difficulties completely reaching in, as can be seen at the bottom right corner of image 40. This shows that when the shoulder height gets below the 3rd level, reaching in will become more difficult because the user's shoulder pivot will have to move backwards to enable the person to reach over the 3rd level tray. When looking at a product of 1850 mm with three growing rooms of 500 mm, this user is still able to look into the product at the third growing room but the shoulder height will be below the third chamber. Most of the users will have the same fate; only those above the 82nd percentile of shoulder height (P82) will be able to reach into the product without having to reach up (statistically only 18% of the female population between 31-60). At 2150 mm, or 600 mm per growing chamber, virtually all users will not be able to see into the third growing room and will have to reach up even more than the second option. User who are able to do so are part of a very small group (>P95).

Conclusion

With the research conducted in this section, enough dimensions are available to get a rough understanding for what the limits of the product's dimensions are in respect to its user and the space required for plant growth.



Conceptualization

4

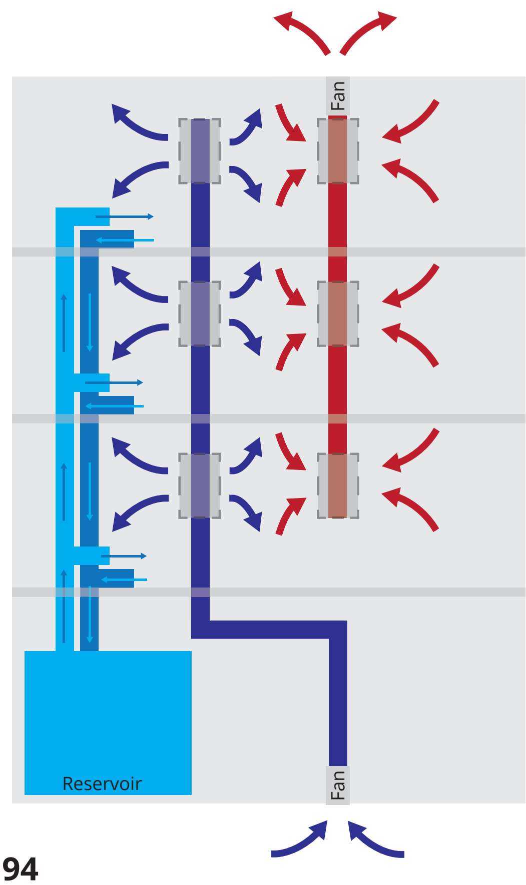
In this chapter the concept that will be known as Microfarm starts to come alive. First three concepts are proposed, after which one is chosen using the objective criteria method. This design is then worked out further and validated, prompting a final 2nd iteration from which the final design is deduced.

Concept 1:
Shelf concept

The shelf concept is inspired by the working principle of the container; growing trays are placed in an ebb and flood reservoir that is flooded and drained a few times per day. The ventilation and irrigation is guided through the central column, and the bottom of the product contains the irrigation system including pumps and water/nutrient reservoir.

As seen in the scenario of use on page X to the right, the black trays hold the seed and plug combination that can be placed in the germination area and moved up without much effort.

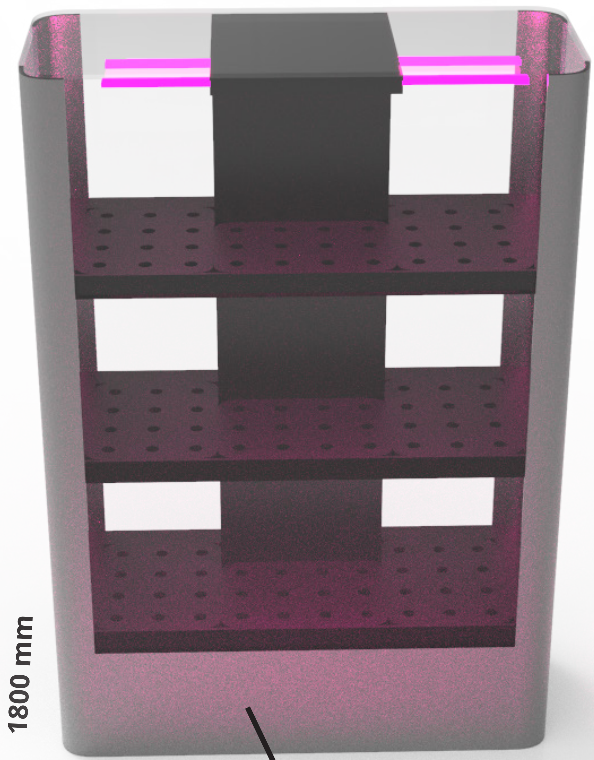
Fits: 108 plants
Cost: $$



Top:
Simple usability
Time efficient handling

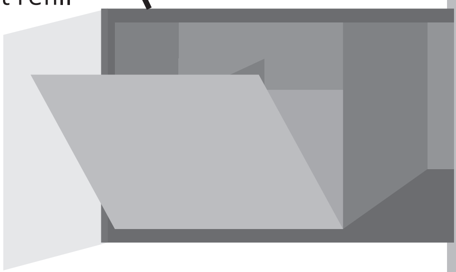
Flop:
Least exciting design
Light pollution and loss

Eb and flood irrigation with down / up ventilation

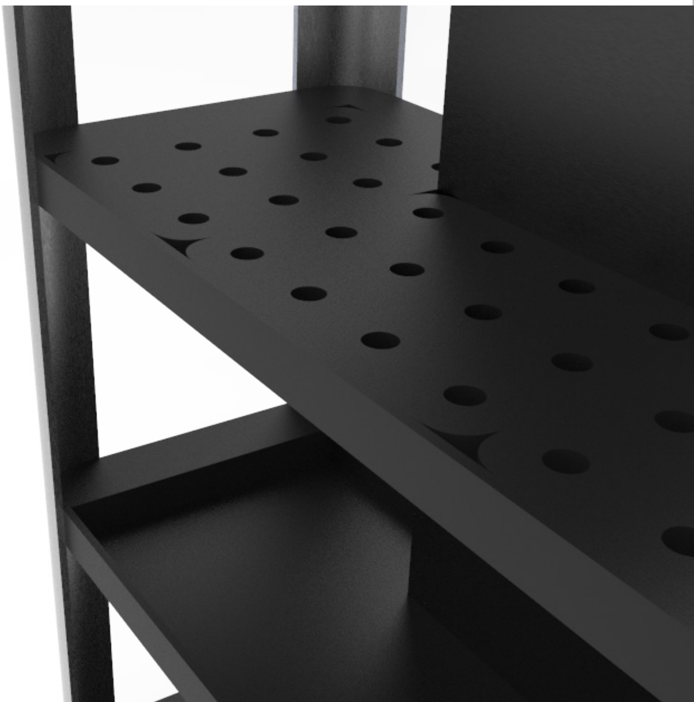


Lights on

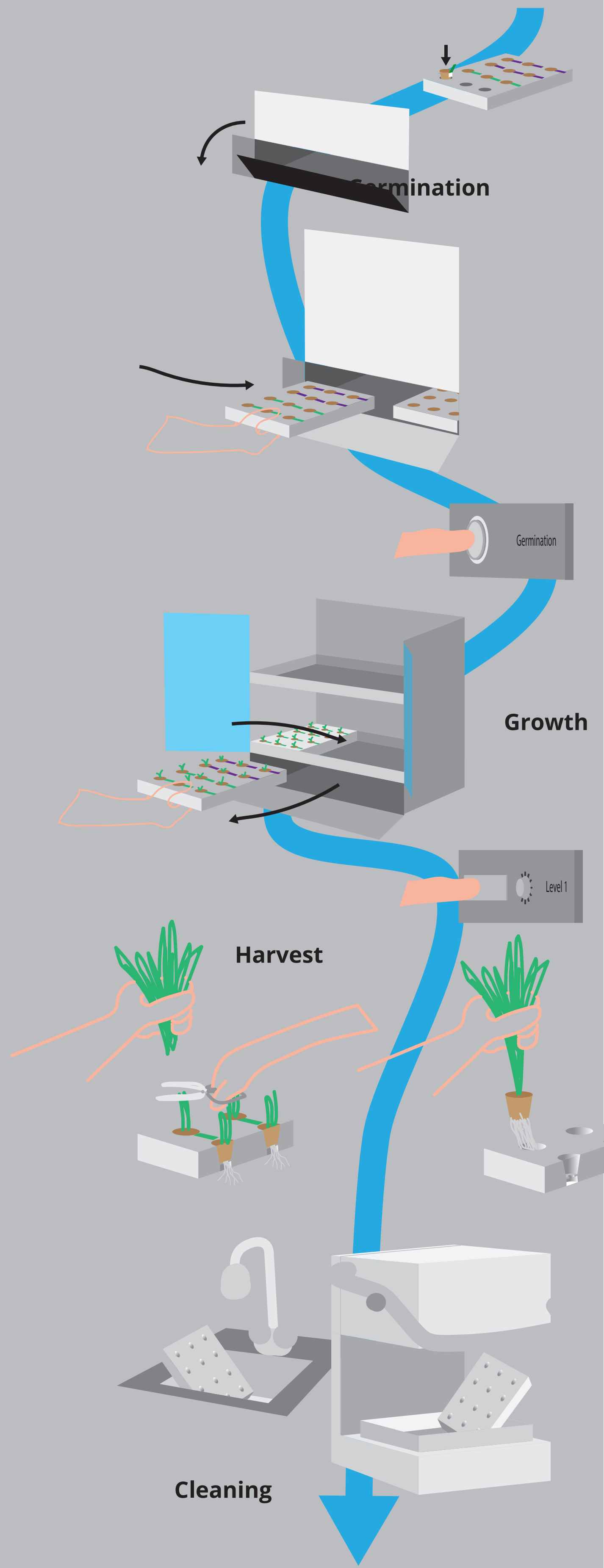
Water &
nutrient refill



Plug trays



Scenario of use

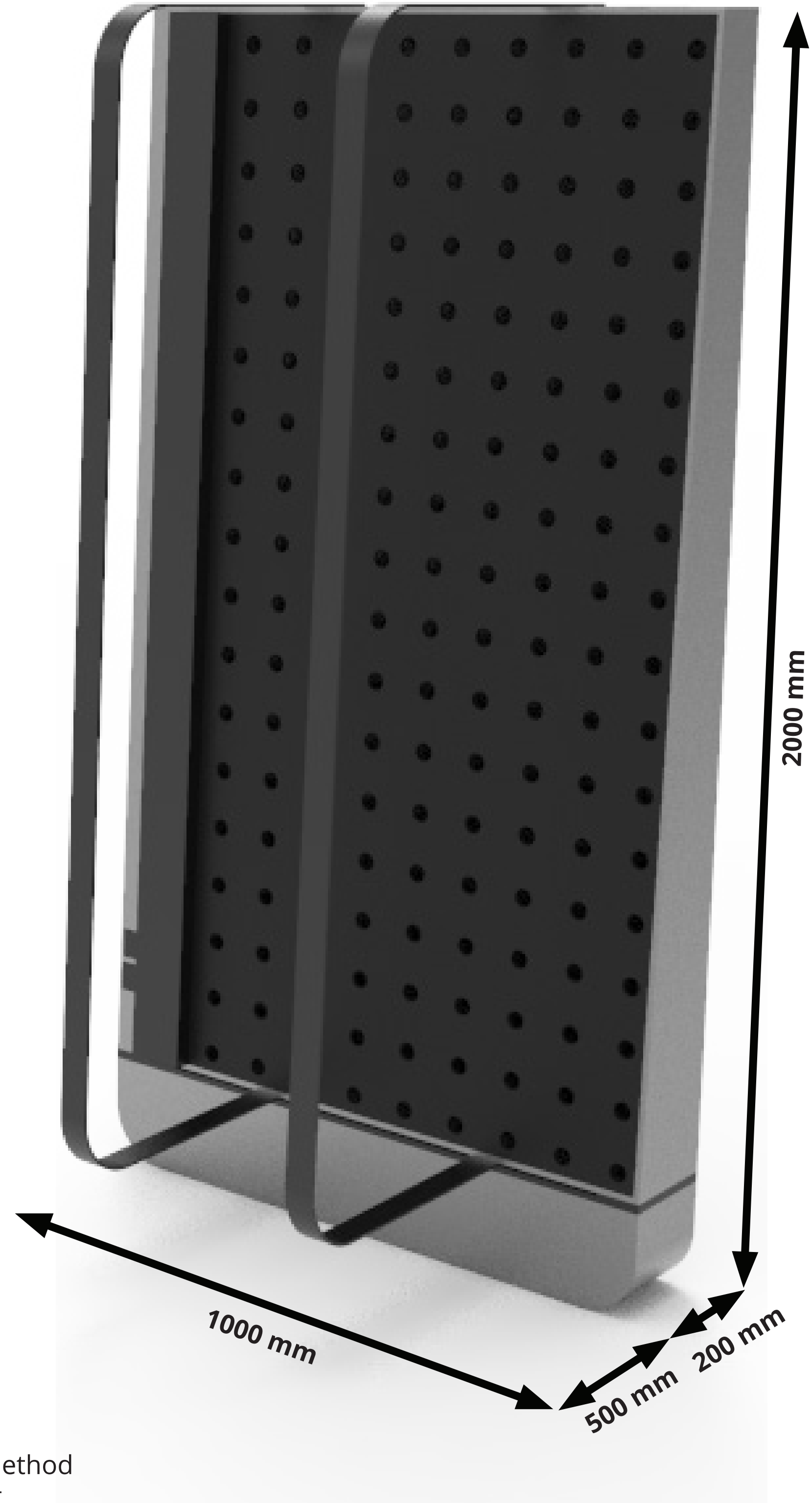


Concept 2:
Wall concept

The wall concept is inspired by the nutrient film technique (NFT) irrigation method of supplying plants with a continuous small layer of water. By placing the growing surface at an angle of roughly 93 degrees, the water only has to be pumped up and accumulates at the bottom in a reservoir.

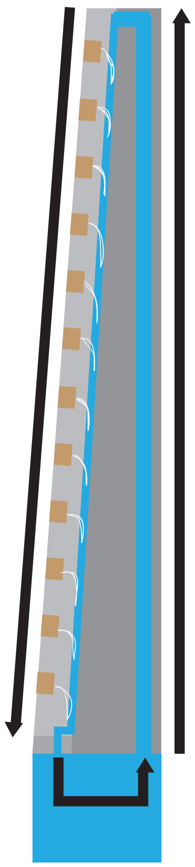
As seen in the scenario of use on page X to the right, the black surface contains spaces for the plug/seed combination very much like the shelf concept. Under the dark strip on the left, the plants can be germinated. After this step, they have to be transplanted laterally to their final position. The two black spots on the left provide access to the water/nutrient input.

Fits: 162 plants
Cost: $

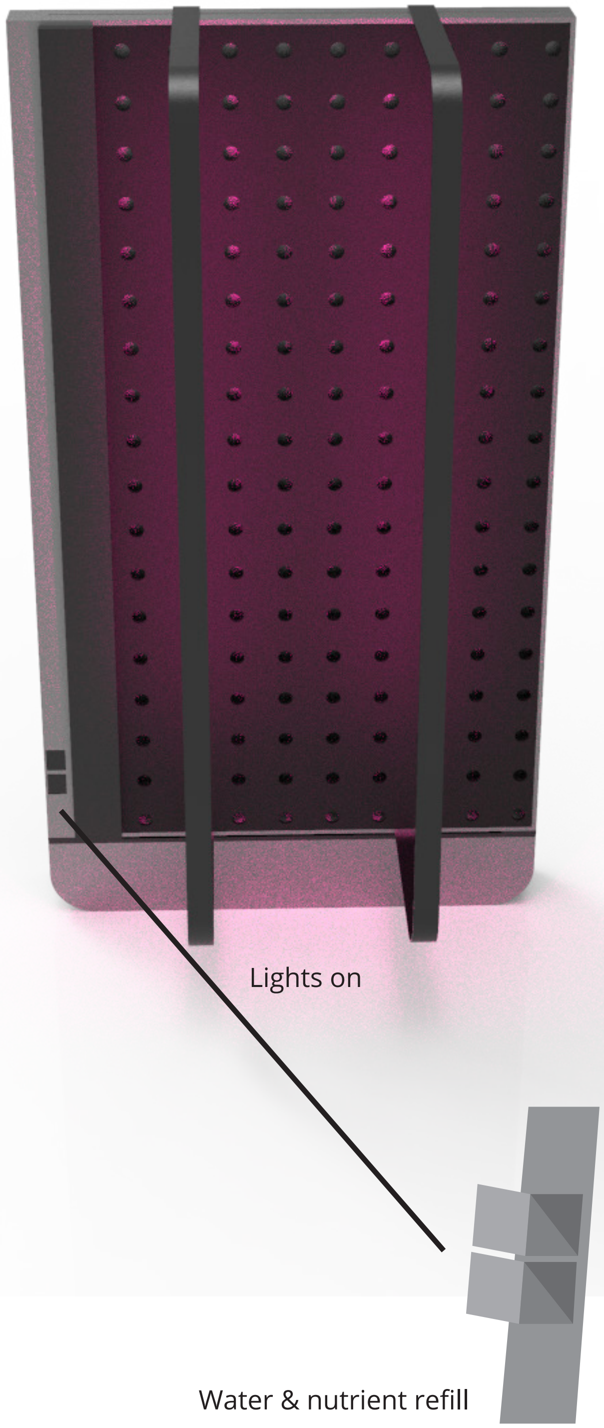


Top:
Simple irrigation method
Likely the cheapest
No ventilation required

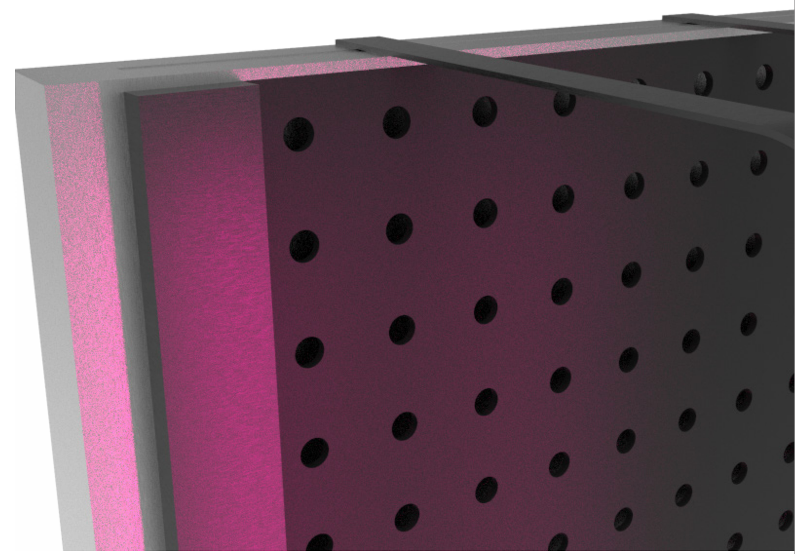
Flop:
Time consuming handling
Not user friendly in terms of ergonomics



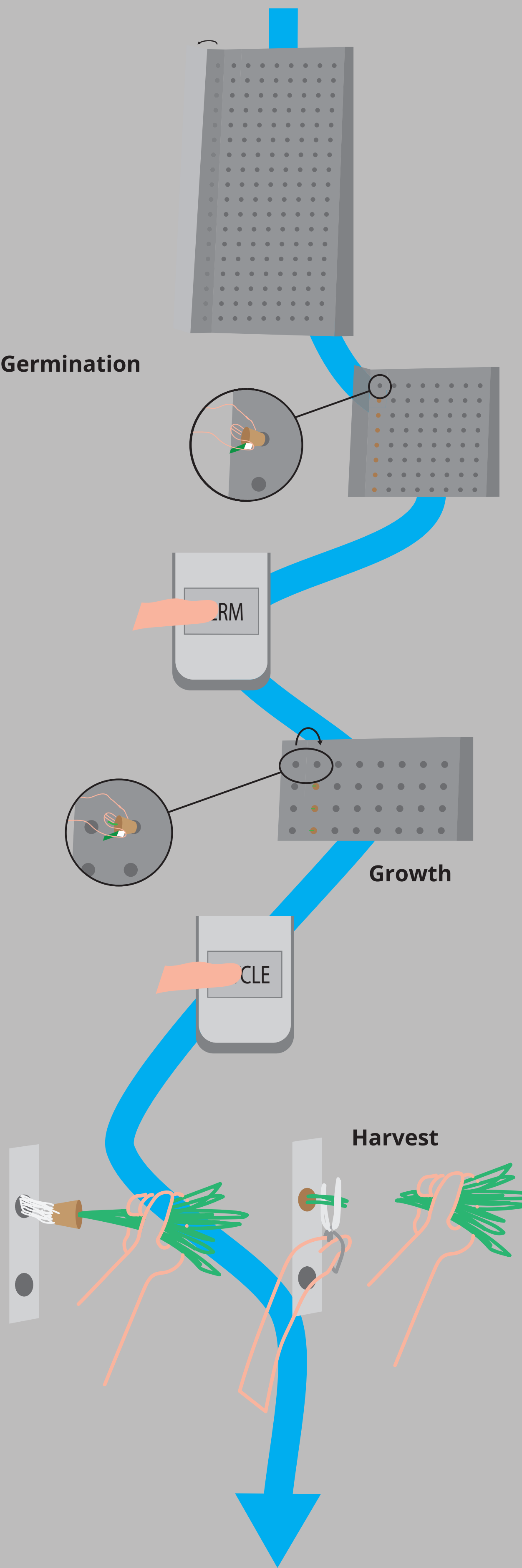
Vertically recirculating irrigation (NFT), without ventilation



Slanted plug wall

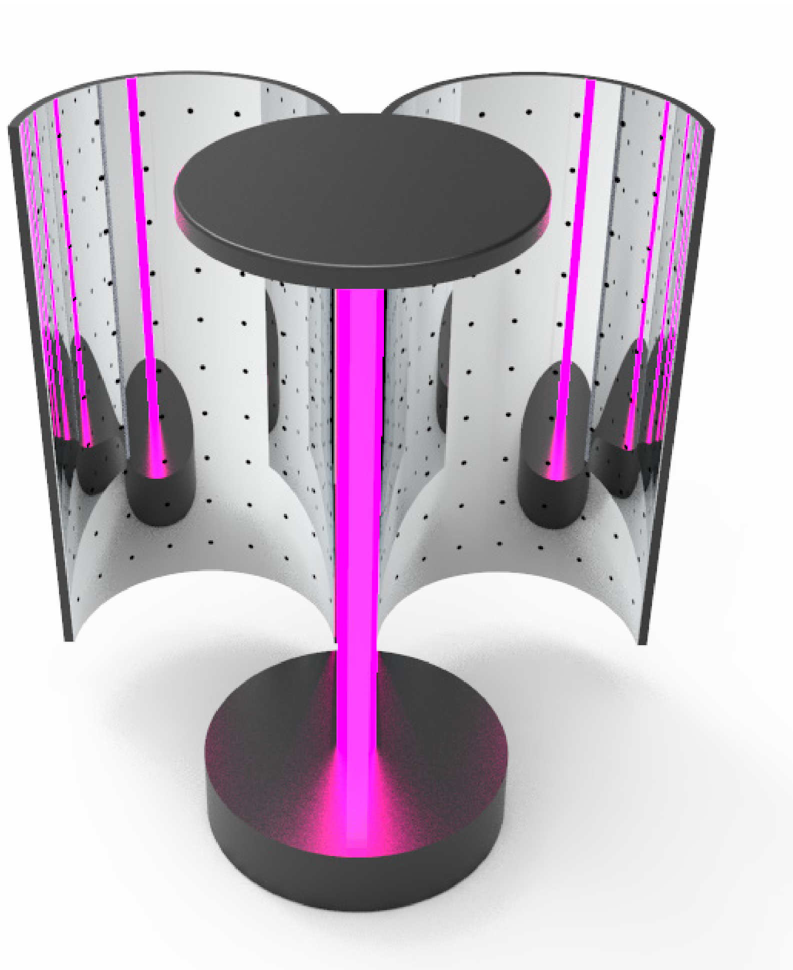


Scenario of use



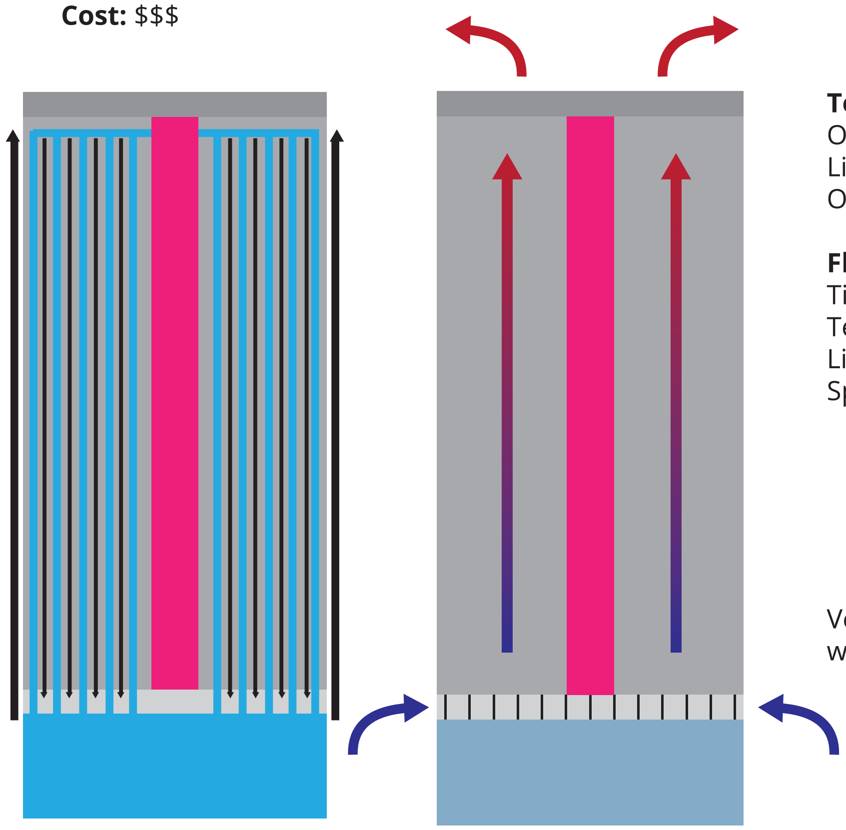
Concept 3:
Pod concept

The pod concept is part inspired by the nutrient film technique (NFT) irrigation method from the wall concept as well as formulating a concept that is completely opposite that of the shelf concept. Instead of providing a flat surface, the irrigation channels feeding the plants are placed in the curved doors. The ventilation (not displayed in the render) will provide airflow from bottom to top, and the growing light is placed in the middle. The benefit of this system is that the distance between the growing light and plants remains the same everywhere and little light is lost due to the reflective nature of the inside and the small window placed for observation.



As seen in the scenario of use on page X to the right, access to the growing space requires opening the door. The seed/ plug combination can be germinated by opening a small hatch in the bottom and placing a filled tray in it. When this is complete, the user can hold this tray and place the germinated plugs in the wall.

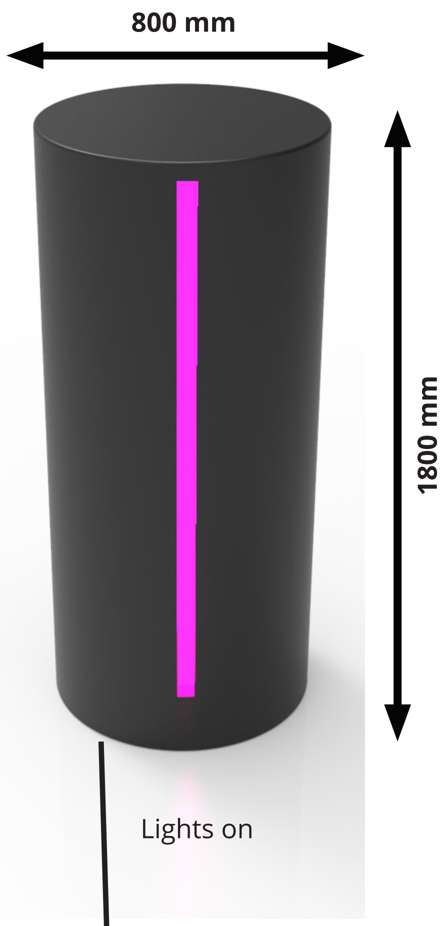
Fits: 180 plants
Cost: $$$

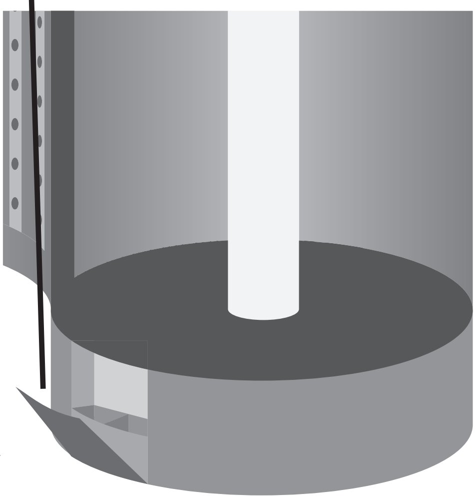


Top:
Outspoken design
Little to no light pollution
Optimal growing distance

Flop:
Time consuming handling
Technically complicated and challenging
Likely most expensive
Space consuming when doors opened

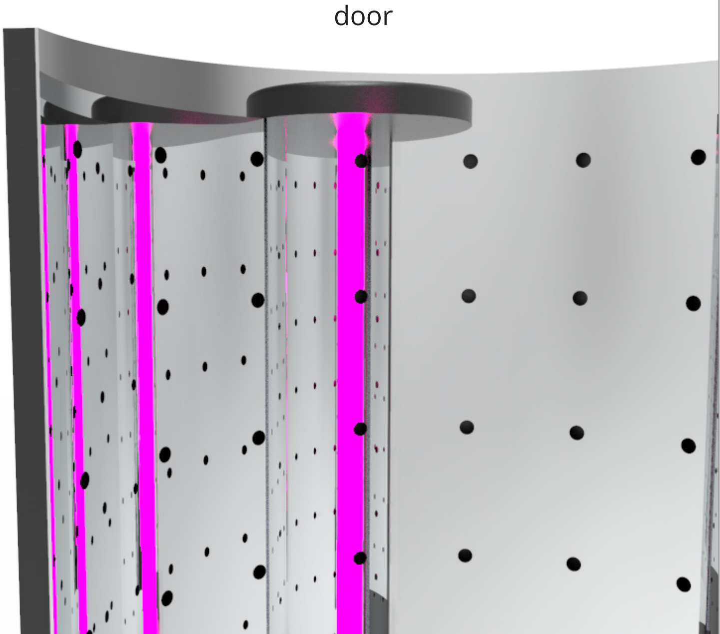
Vertically recirculating irrigation (NFT) with down / up airflow



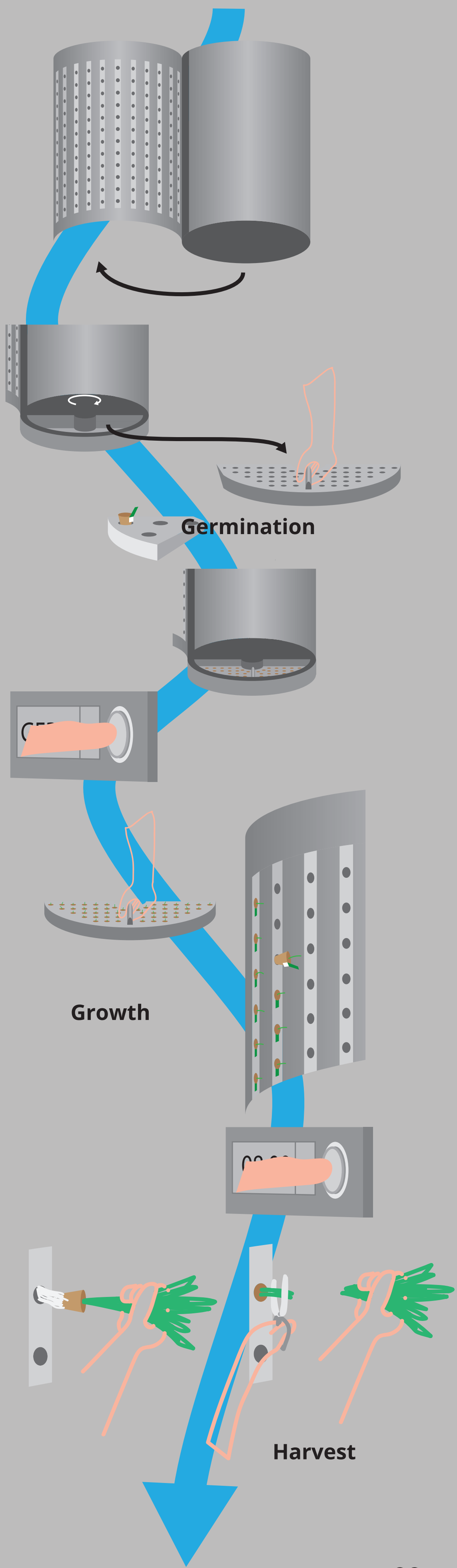


Water & nutrient refill

Curved plug door



Scenario of use



4.1 CONCEPT CHOICE

To select a final concept, a rational decision regarding the three concepts has to be made. Using the weighted criteria method (Roozenburg & Eekels, 199X and Delft Design Guide, 2013), all the important criteria are given a weight and scored according to their performance. What follows is not only a concept choice, but also aspects of the other concepts that are favorable to incorporate into the final concept. Below, the method including scores can be found in figure 41. On page 102 and 103 the criteria used are described and includes a brief explanation of how each concept performs per criteria. These explanations serve as substantiation for the scoring in figure 41.

From the weighted criteria method, it can be determined that concept 1 - the shelf concept - is best suited according to the score it receives. However, there are aspects from the other concepts which are likely interesting to incorporate, which can found on page 101, to the right.

	Weight	Concept 1		Concept 2		Concept 3	
Criteria 1 - Time & effort	40	9	360	5	200	6	240
Criteria 2 - Accessibility	30	7	210	4	120	6	180
Criteria 3 - Light pollution	20	3	60	6	120	8	160
Criteria 4 - Grow experience	15	8	120	9	135	4	60
Criteria 5 - Yield	10	5	50	7	70	8	80
Criteria 6 - Space consumption	5	8	40	7	35	5	25
Criteria 7 - Complexity	5	6	30	8	40	5	25
			870		720		770

Winner ↑ (Concept 1)

Figure 41. Weighted criteria method

Concept 2 (wall concept): The irrigation method applied in the wall concept is relatively the most simple of the three to realize. It involves pumping the water up, distributing it like a waterfall at the top, and collecting it at the bottom after having been forced down by gravity. If it is possible to integrate this type of irrigation system, it would make the irrigation system much easier to install and maintain than is currently the case with the chosen final concept.

Concept 3 (pod concept): Although the pod concept doesn't score too well on complexity, space consumption, and user friendliness (time & effort and accessibility), it does well in preventing light pollution and overall aesthetics. Incorporating this small window reduces the amount of light lost and makes a statement in terms of aesthetics. It gives the product something more mysterious, which embodies the eye-catcher effect that the product needs without being too intrusive for the guest of the restaurant.

On page 104, after the explanation of each criteria, the aspects discussed above are incorporated into the chosen final concept and evaluated whether or not they work.

Criteria and explanation

Time and effort: Derived from the user research, the amount of effort the user has to put into using and mainting the product has to be minimal. Concept 1 is by far the least effort, after depositing the plug/seed combination the tray only has to be moved from germination to the grow area in its whole life cycle. Concept 2 is a bit more effort, because while the germination is the same as concept 1, each individual plug still has to be removed from the tray and planted individually. Concept 3 is the most effort, every plug has to be placed and transplanted individually between germination and growth.

Accessibility: How well the user can access all parts of the product has impact on how well each user can use the product and tolerate the activities that are required. Concept 1 has decent accessibility, it can be accessed by most users, but the bottom levels and utility access will require the user to lower their posture and reach in order to do so. Concept 2 is easy to reach, but has bad accessibility because only a few rows will be easily accessible while standing without stretching. The rows above require the user to reach and is preferable for tall users, while the rows below require the user to either squat or bend through the knees, which is less intensive for shorter users. Taking into account the amount of plants the product holds, this can become a nuisance and source of bodily discomfort. Concept 3 has much better accessibility than concept 2, but still requires the user to travel a certain distance to complete their tasks.

Light pollution: The intensity of the lighting used can be both a nuisance and a safety hazard to the people around it. The light will illuminate the area around it, which can be bothersome for seated guests, and the blue light used in horticultural lighting, like certain wavelengths of light from computer and phone screens, is known to have an impact on people's biological clocks [44]. During the day this is not a problem, but at night (which is a realistic time for guests to be at a restaurant) this could have an impact. Another important aspect of light pollution is more practical for plant growth; the more light lost to the environment, the less light that arrives at the plant. In concept 1, there is little to no protection from light pollution, whereas concept 2's light pollution is mostly reflected off of the product. Concept 3 does the best, where light can only come through a tiny slot, ensuring to keep pollution to a minimum, without taking away the possibility to see inside of the growing room.

Grow experience: Being able to see what is growing in the product adds to the overall restaurant experience and gives the user the possibility to observe the plants without opening the product. Concept 1 gives a good experience of what is growing, but its outer embodiment might block it at some points. Concept 2 does it the best, where all plants not blocked by the light are visible. Concept 3 performs the worst on this criteria, because a limited view is possible of whatever is going on inside and the light might be blinding.

Yield: The Microfarm is intended for harvesting fresh produce, the more the better. Concept 1 has the least capacity at 108 plants, concept 2 considerably more at 162 plant capacity, and concept 3 has the most at 180 plant capacity. Although yield is important, accepting that the product will not supply a substantial amount of a restaurant's fresh produce and focussing on the usability of such a product has the priority.

Space consumption: Space in the dining room is mostly reserved for tables and chairs, which ensures that an acceptable amount of guests can be seated. The product therefor has to take up as little as possible to accommodate guests and leave ample room for the restaurant staff to move through the dining room. Concept 1 surprisingly takes up the least space, it is slightly wider than concept 3, but not as deep due to the lighting fixtures in this concept. Concept 2 is the most compact while closed, but when the doors open it requires almost as much depth as width.

Complexity: Technical complexity is important when the product doesn't work as it is supposed to. Concept 1 requires three pumps that pump the same amount of water to three different levels, if any of these pumps fail there will be trouble. The seperate germination compartment also adds to the complexity of the system. Concept 2 scores the worst, its inside consists of multiple tubes and the irrigation system has to be guided through a small space, and the product contains a seperate germination compartment. Concept 3 is technically the least complex, it only requires one pump and has no seperate germination compartment, rather a dedicated channel and cover to achieve the same.

Application of wall concept working principle on shelf concept

Adapting the vertical NFT principle to the shelf concept and incorporating the removable tray is no problem on paper. Above in image FIX ME, a potential solution is given for fully integrating the two concepts together. There are some aspects with this solution that are worth mentioning:

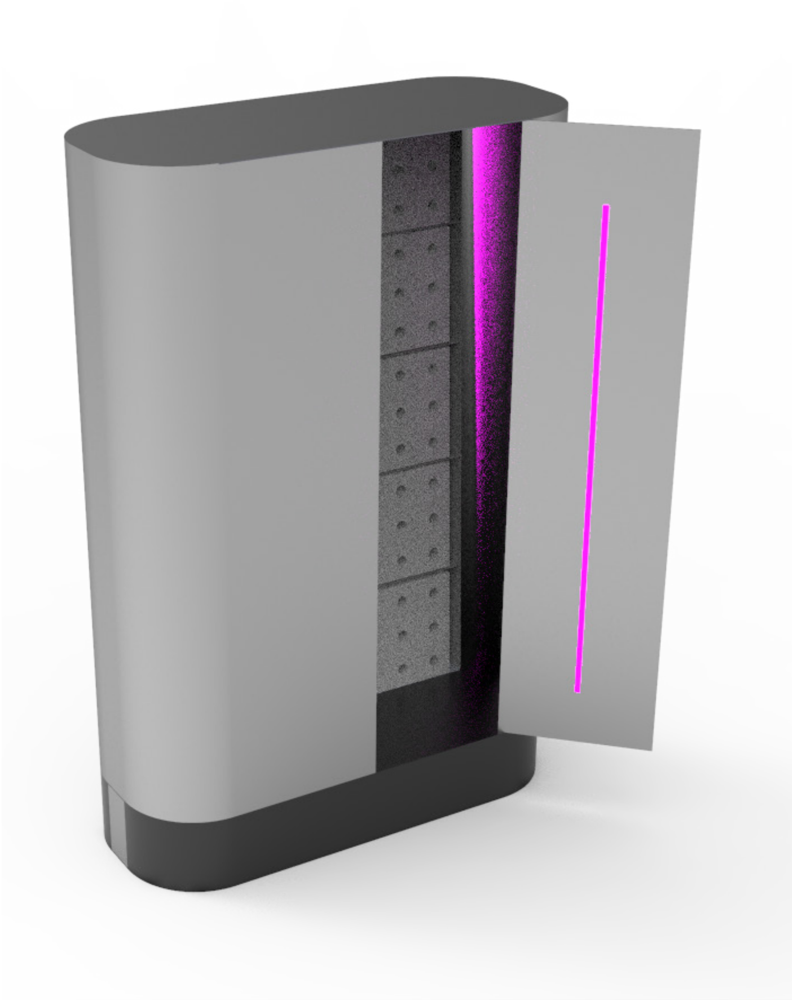
A latching system or larger angle will be needed once the plants become long and heavy enough. At some point, the combined mass of all plants contained in a tray could make it fall out of the product.

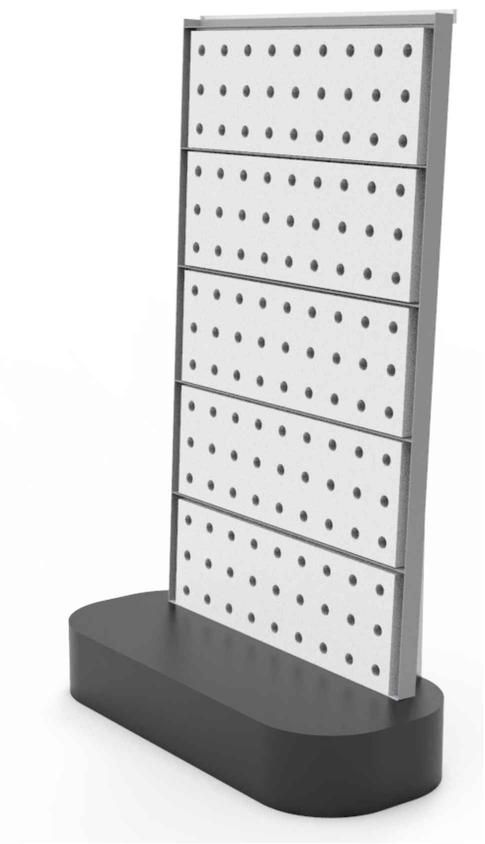
The thickness of the product will likely increase to ensure that the spacing of 400 mm is maintained between growing surface and light. There will be a difference between the spacing at the top and the bottom due to the 3 degree angle of the wall. A 3 degree slope on an estimated length of 1500 mm results in a 94.3 mm horizontal difference at the bottom.

The rounding (fillet) of the corners has positive impact on the aesthetics, but forces the product to become much wider without being able to use much of this space for growing. At a radius of 200 mm, it is estimated that about 3/4 of the width of this corner has no practical use for plant growth, which adds up to roughly 25% (300 mm) of the width if the product were to be 1200 mm wide.

This system can hold 135 plants - 27 more than the shelf concept, but 45 less than the original wall concept

To the right: Image 41. Vertical NFT adaptation on shelf concept





Application of pod concept aesthetics on shelf concept

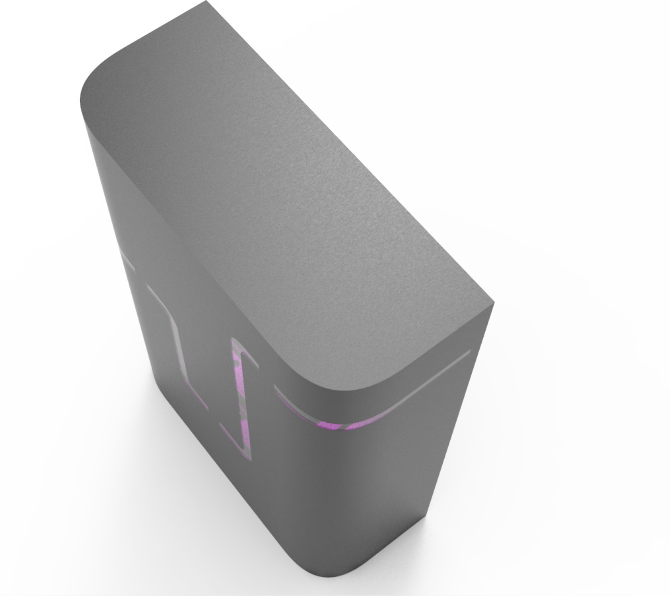
Adapting the aesthetics of the pod concept does not change much to the functionality of the concept. Having learned lessons from the previous page, where the fillet (rounding) was found to negatively impact the use of space, the fillet is removed at the back. This is no problem considering the product will likely be placed against the wall. There are some aspects with this solution that are worth mentioning:

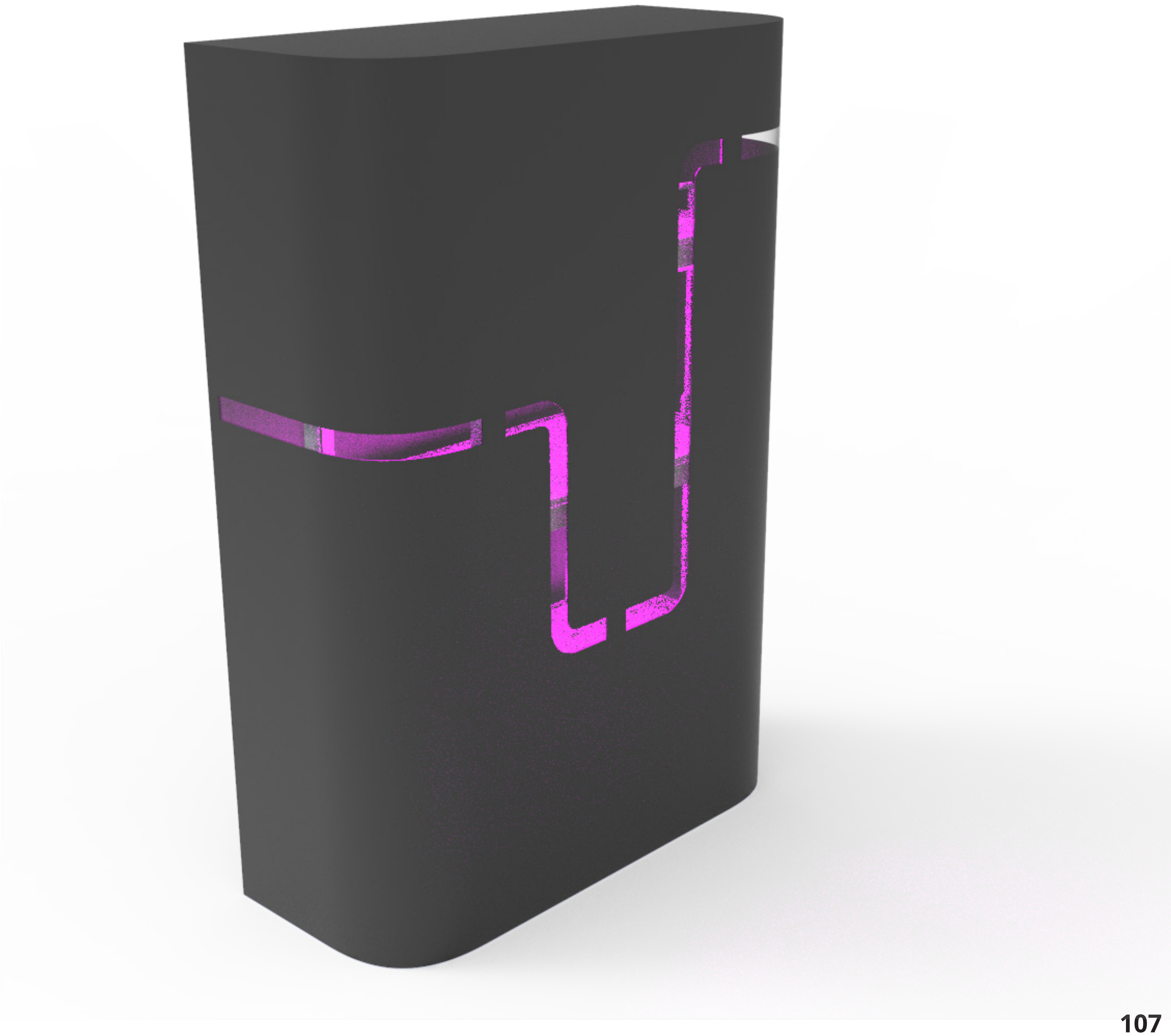
The aluminium sheets used as the outer housing require extra work to incorporate the “windows”, which will require extra steps in both the manufacturing process of the sheets as well as the manual labor needed to install the window material.

Structurally, these sheets will lose some strength due to this extra step. If this is the case, more elements can be added to the frame or a thicker material can be used. This will either way also cost extra money.

The contrast between window and outside housing is big enough for the window itself to make a statement as well.

To the right: Image 42. Pod aesthetics adapted to shelf concept





Final remarks on application of wall concept principle on shelf concept

It is possible, but gives rise to a whole set of new issues that would have to be solved. It is questionable whether such a change would truly add to the value of the concept.

Final remarks on application of pod concept aesthetics on shelf concept

The execution is very important for both the manufacturing process and the interaction between product and guest. Some optimalization is likely required to satisfy both. It would be possible to create a window without using extra steps or materials by creating a mesh in the sheet that would serve the same purpose, while variation in this mesh and outer color could be user tested.

Conclusion

The shelf concept will be worked out into a final design and incorporates aesthetic aspects of the pod concept. The final design will have to explore the impact of the aesthetics of the so-called “window” and how well the future user responds to it.

Iteration 1

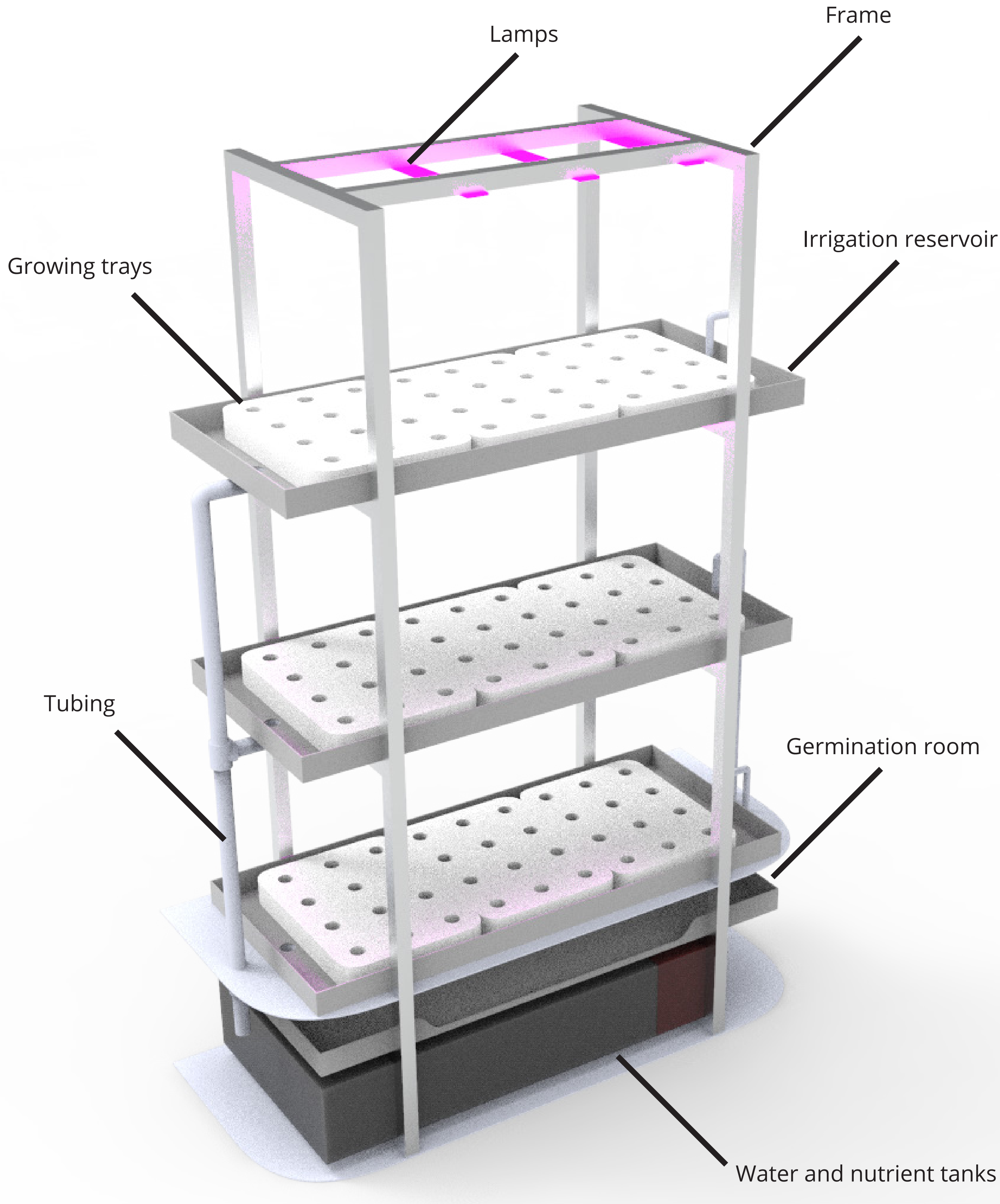
4.2 EMBODIMENT

A conceptual design is meant to illustrate how it addresses certain needs and values of the user, not necessarily to be ready for production and manufacturing. However, illustrating how the Microfarm could be made on a global scale would add value for Priva both in terms of realism and feasibility. This section displays and describes all the parts of the conceptual design and how they could be realized.

Inner embodiment

While the outer embodiment has the potential for customization and different manufacturing techniques, the parts of the inner embodiment will likely contain the same shape and production process regardless of the dimensions. The inner embodiment is displayed in image 43 on the page to the right. In appendix H each part described in more detail.

Image 43. Inner ebodiment


Lamps
Frame
Irrigation reservoir
Growing trays
Tubing
Germination room
Water and nutrient tanks

Outer embodiment

The inner embodiment is derived from Priva's growing container, but its outer embodiment will be much different because it has to be both aesthetically pleasing and interesting to look at when placed in a restaurant.

In chapter 3.3, it was found that restaurants have differing styles and that it might be difficult to design a single solution that fits all dining rooms. However, there is also another issue that has to be resolved, which is about how much can be seen in the product from the outside. Having a completely open product allows guests to look inside, but is also a source of light pollution and results in less efficient use of the light that isn't reflected back in.

Depending on if transparant or non see through materials are used the product will also look different and will likely be perceived in a different way as well. To the right, three potential outer embodiments can be found that vary in how much can be seen inside.

To make a decision regarding the embodiment, these three choices will be presented to and validated with one of the participants from the user research.

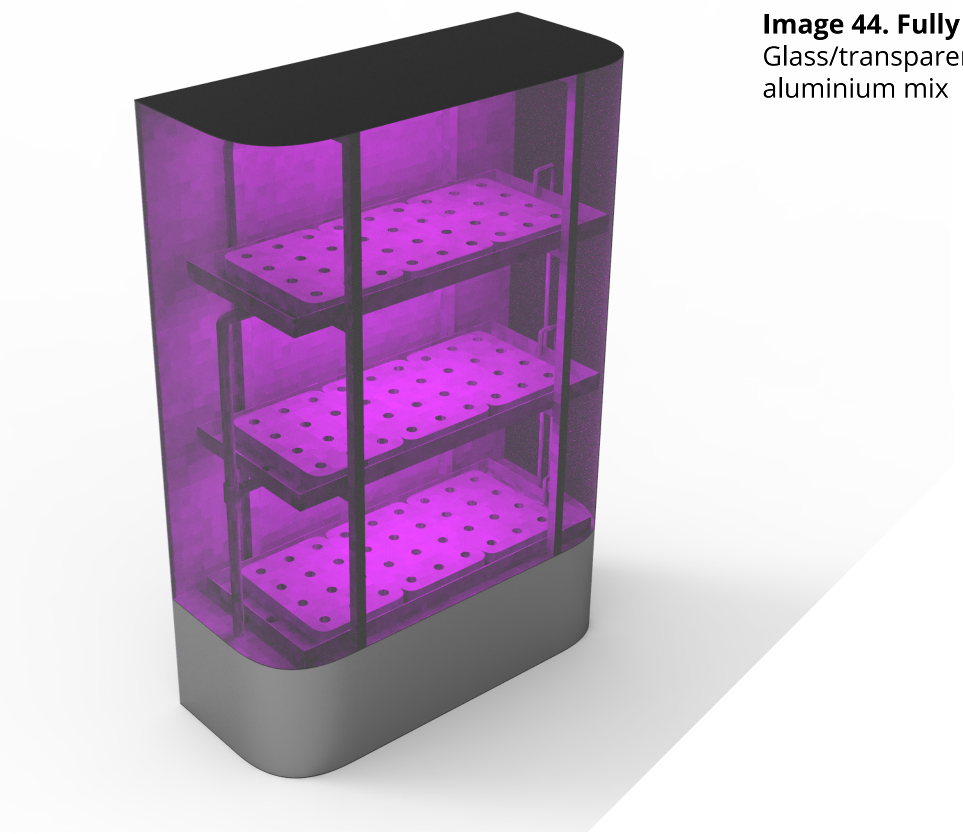


Image 44. Fully see through
Glass/transparent plastic and sheet aluminium mix

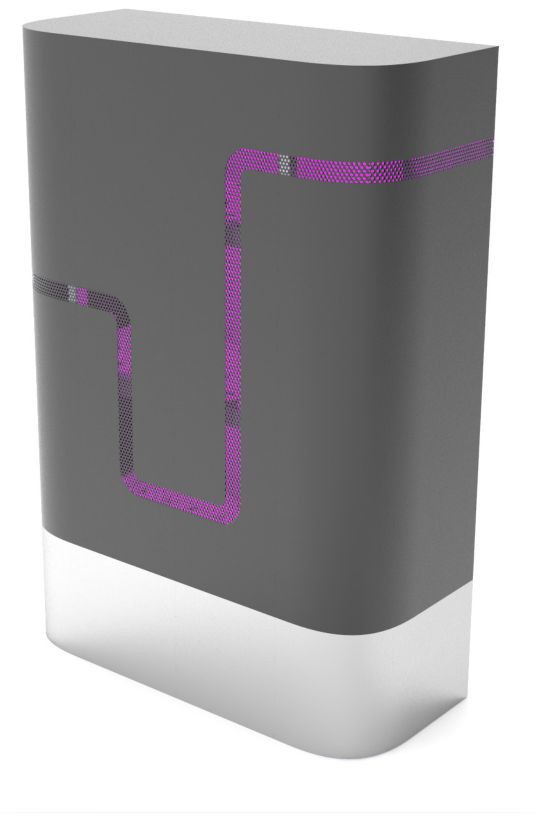


Image 45. Line
Perforated aluminium sheet

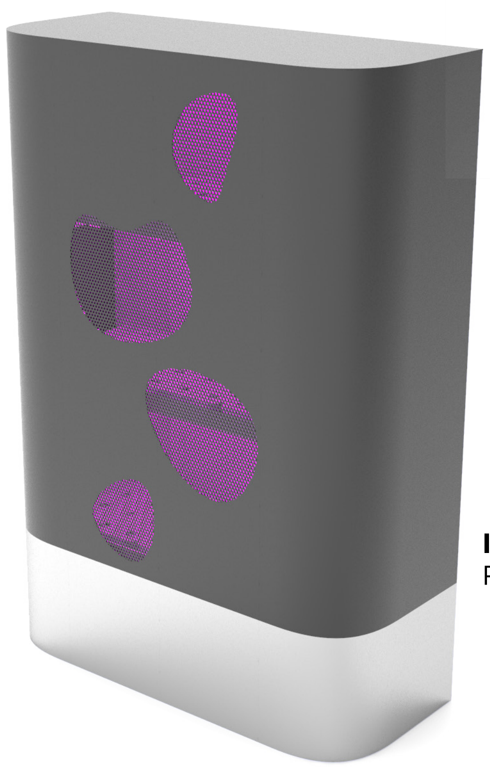


Image 46. Blobs
Perforated aluminium sheet

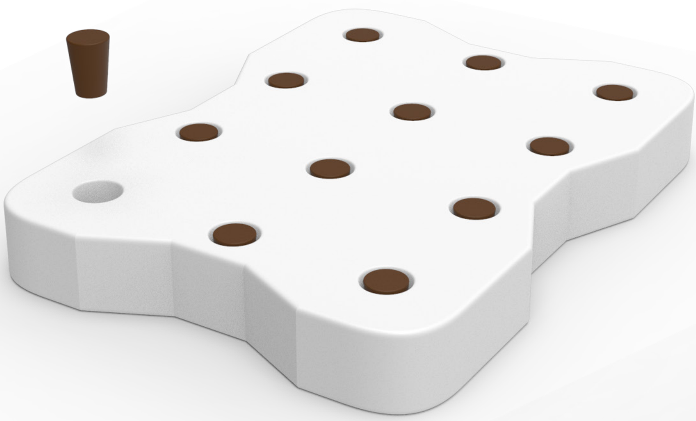
4.3 GROWING TRAY DESIGN

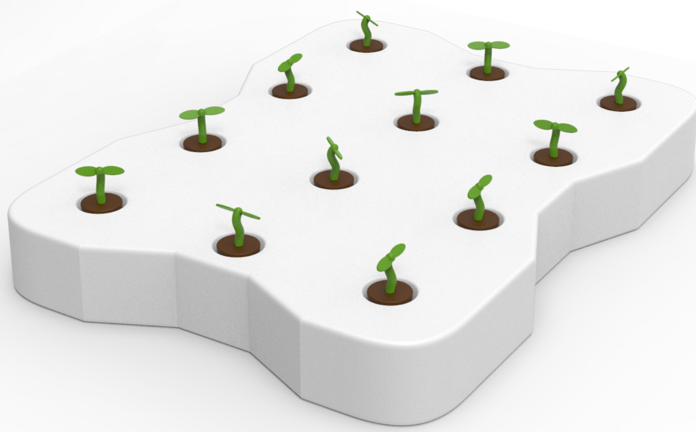
When constructing indoor farms and greenhouses, the tolerances are much larger compared to Microfarm. A compact design will make a better fit for a restaurant because it saves space, but will also make the space in which the handling has to take place more compact.

One component that is very much impacted by this efficiency is the growing tray. Currently, picking up the growing tray involves grasping the tray on the sides, placing fingers under it to get a grip, after which it can be lifted up. In a compact design the tolerances required to place fingers on both sides would be dependent on an average finger thickness. This seems tedious to figure out and is, in fact, not necessary because the growing tray itself can also be redesigned to better aid handling. Although plants require around 10 cm distance for efficient growth, what is under those 10 cm doesn't really matter.

Following this logic a new growing tray design is proposed and can be seen on the right page. This solution will be validated in the prototype.

To the right:
Image 47. Growing tray design





4.4 IRRIGATION SYSTEM

Microfarm's ebb and flood concept requires an irrigation system to fill each of the irrigation reservoirs up to a height of about 2 cm in the current setup (based on similar value for the growing container). The irrigation system ensures the water and concentrated nutrient solution get mixed and delivered to the plants by pumping this mix up to the irrigation trays that contain the growing trays. In appendix I, the working principle of the irrigation system is worked out and important consideration that have influenced the design of this system are shared. In this section, the conclusions will be presented in a brief manner.

Important aspects

The following aspects have effect on the size, functioning, and user inputs required for the system:

Volume requirements for irrigation

The total volume requirement per day is calculated to be roughly 7 liter per m2 and 75 liter for 8 days of irrigation for a single level irrigation system.

Maintaining pH and EC levels in the water/nutrient solution

The easiest method for the user and size of the product is to dispose the drain water in a seperate container when the water has to be refilled, which is about 12 liter for a single level irrigation system and 30 liter for multi level.

Dosing of nutrients

Either automatically or by hand, the latter has the preference because the effort required differs slightly but the difference technical complexity is big.

Disposing of used water/nutrient solution

Used drain water cannot be discarded through the sink in The Netherlands because it is considered to be chemical waste and has to be discarded accordingly.

As stated above, these topics are elaborated in appendix I and displayed to the right in image 48 is an example of what the system would look like if all these points were to be implemented.

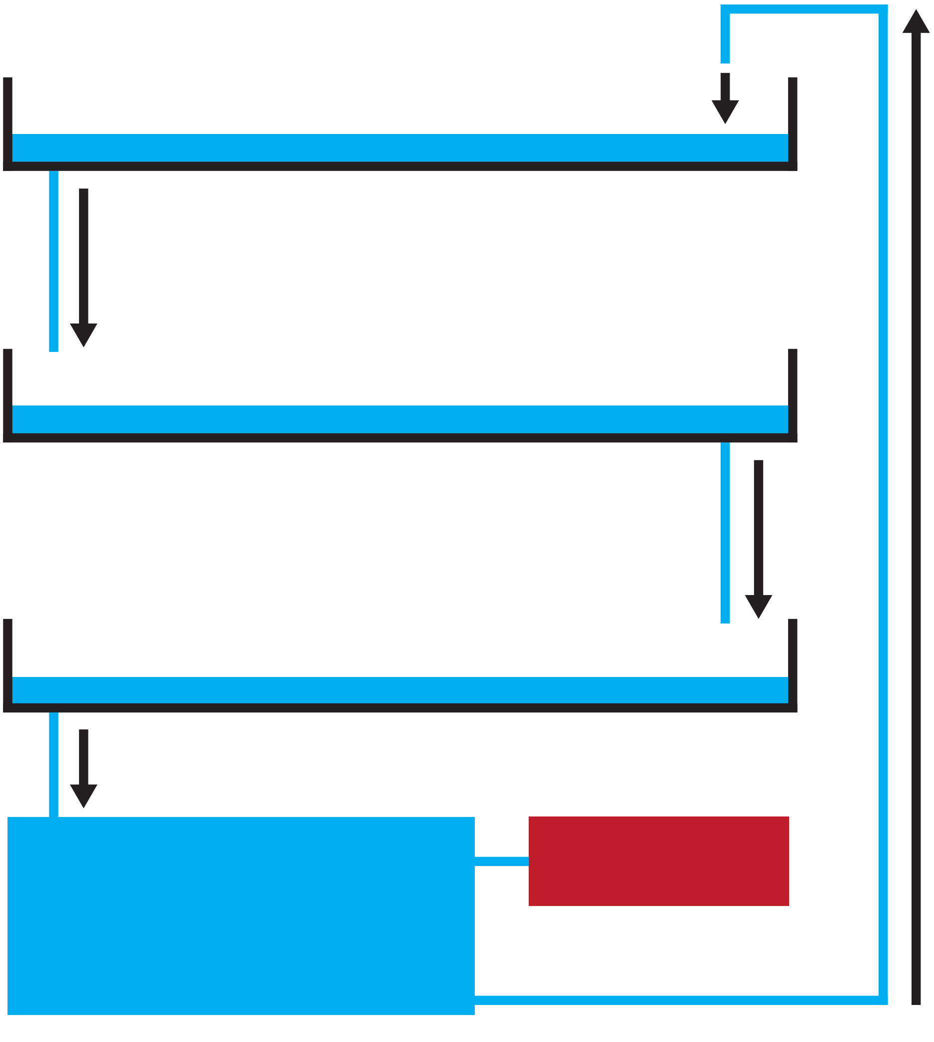


Image 48. Envisioned irrigation system for Microfarm

4.5 INITIAL BUSINESS MODEL

Using the previously conducted user research and having chosen concept to continue with, it is possible to make a business case for the Microfarm. With aid of the Business Model Canvas (Osterwalder, Pigneur et al. 2010) [45], this section describes the underlying business model of the Microfarm. Conclusions from this business model aid in understanding the value for the user as well as the implications this has for the final design.

Relevant design aspects

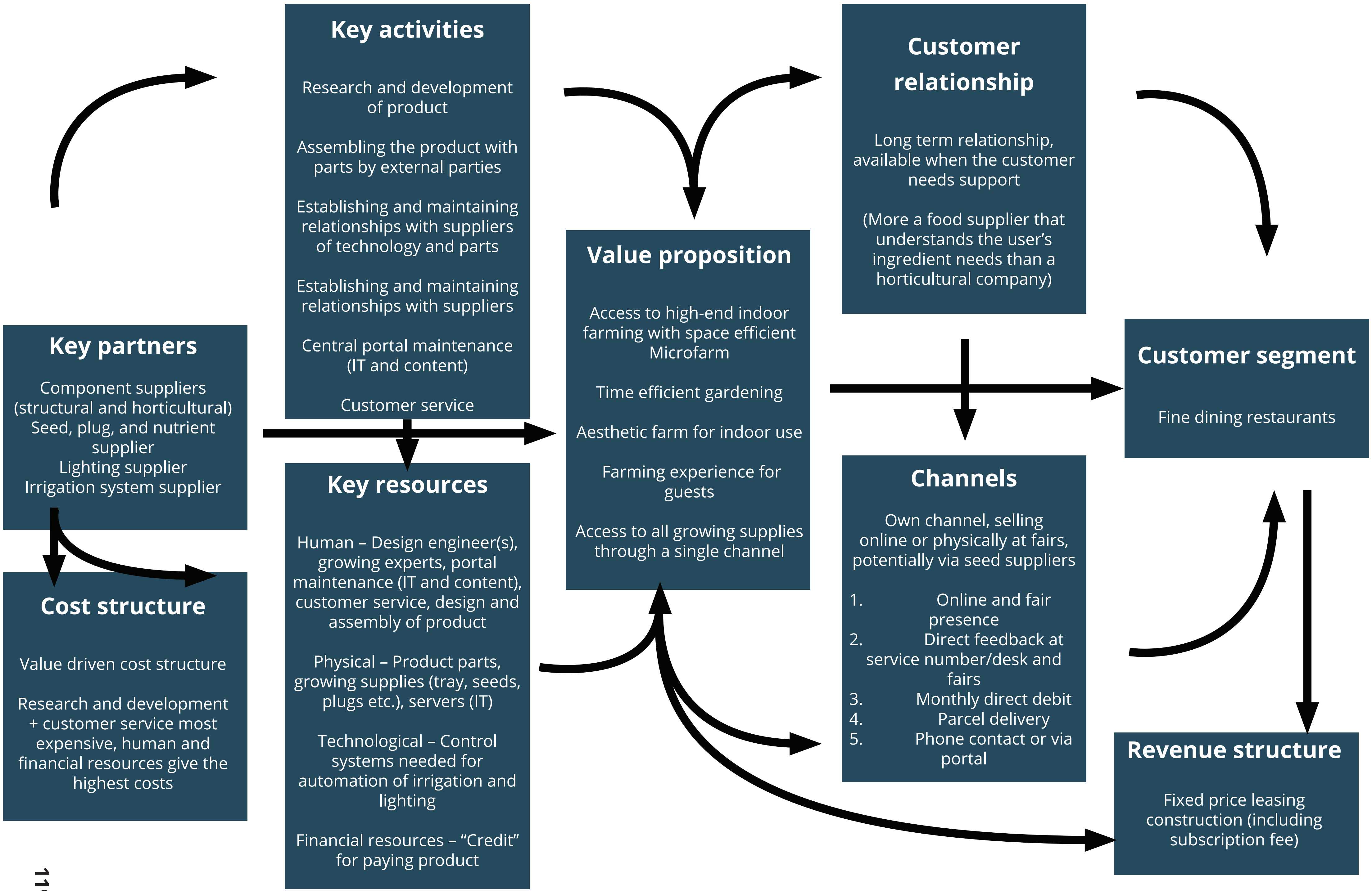
To understand the choices made on the Business Model Canvas, there are some important aspects of the Microfarm to be consider:

<u>Low capacity, large investment product</u>

It is certain that the product will not supply all of the fresh produce a restaurant requires for daily operation, and that the Microfarm will likely be "expensive". Without having yet calculated the cost of the concept, other solutions can give a ballpark estimate of what is to be expected; competitor "Farmshelf" is sold for $7000,- (excluding a mandatory subscription fee of roughly $100 per month and a minimum purchases of two units), and Matthias van den Berg of QO Hotel gave a rough estimate of €1200,- for a very rudementary design, which excludes most features currently present in the concept, based on own experiences of making such solutions for clients. Realistically, the product can not be sold as an alternative to their current food supply, which implies that the business model will have to be value-driven as opposed to cost-driven.

<u>Leasing or selling</u>

Selling the product would bring the quickest return on investment, but considering that the product will likely require an investment of somewhere between €5000,- and €10.000,- by the user, it is possible that this user finds the price too high for a product that supplies a relatively small amount of fresh produce regardless of the user value. Leasing, on the other hand, will lower the threshold cost-wise and make it more financially attractive on the short term, but will require long-term relationships between Priva and the customer. This long-term relationship requires extra investment into resources from Priva's side and have to be dictated by a minimal leasing period that is both realistic in terms of the return-on-investment and reasonable for termination by the user. Considering the current user group and the presence of the so-called Priva Portal (which the user will have to pay for regardless of the revenue structure) a leasing structure would better compliment the service-oriented character of the Microfarm. Inspiration for this can be found in Swapfiets, which is a Dutch-based bike leasing company, that supplies their bikes for a flat-rate and heavily emphasizes on the service aspect of keeping their users on the road. Just like the Microfarm, Swapfiets minimizes the effort their users have to put into using and maintaining their products, and their leasing structure reflects the relationship the company has built up with its users.


Key partners
Component suppliers (structural and horticultural)
Seed, plug, and nutrient supplier
Lighting supplier
Irrigation system supplier
Cost structure
Value driven cost structure
Research and development + customer service most expensive, human and financial resources give the highest costs
Key activities
Research and development of product
Assembling the product with parts by external parties
Establishing and maintaining relationships with suppliers of technology and parts
Establishing and maintaining relationships with suppliers
Central portal maintenance (IT and content)
Customer service
Key resources
Human – Design engineer(s), growing experts, portal maintenance (IT and content), customer service, design and assembly of product
Physical – Product parts, growing supplies (tray, seeds, plugs etc.), servers (IT)
Technological – Control systems needed for automation of irrigation and lighting
Financial resources – "Credit" for paying product
Value proposition
Access to high-end indoor farming with space efficient Microfarm
Time efficient gardening
Aesthetic farm for indoor use
Farming experience for guests
Access to all growing supplies through a single channel
Customer relationship
Long term relationship, available when the customer needs support
(More a food supplier that understands the user's ingredient needs than a horticultural company)
Channels
Own channel, selling online or physically at fairs, potentially via seed suppliers
1. Online and fair presence
2. Direct feedback at service number/desk and fairs
3. Monthly direct debit
4. Parcel delivery
5. Phone contact or via portal
Customer segment
Fine dining restaurants
Revenue structure
Fixed price leasing construction (including subscription fee)

4.6 VALIDATION

QO Hotel visit

Matthias van den Berg was interviewed at QO Hotel in Amsterdam, where he is in charge of an urban farm at the top of the building. This greenhouse supplies the two restaurants in the building with freshly harvested greens. Although he is not the intended user of the product, his experience in growing produce for the two restaurants in the building gives insights into what the chefs of these restaurants would likely also expect of the Microfarm.

<u>Validation of concept</u>

Matthias did not see any trouble with the chosen concept, nor the other two concepts, as he has had experience with both types of working principles. He noted that he enjoyed being able to look inside of the product without too much effort, but also acknowledged the potential nuisance for dinner guests when this is the case. One of his remarks was that the detailing will likely make the concepts much more expensive than is needed.

<u>Unit cost</u>

Because the microfarm is not a pure production facility like a greenhouse, Matthias recognizes the difficulty of putting an actual price on it. Out of own experience, he stated that small scale growing solutions are generally expensive (roughly €1200,- for a simple 3 level cart with lights).

<u>Business model</u>

When asked whether restaurants would rather lease or buy the product, he noted that given the potentially high unit cost less restaurants would probably buy it than if it were to be leased.

<u>Added value for chef and restaurant</u>

When asked what would make the product interesting for use in a restaurants Matthias noted that the product would have to enable the user to grow something that is more unique and costly to acquire compared to what is available. As an example, he brought up facilitating the growth of edible flowers as a way of creating value for the end user, because these crops are more unique taste sensations and generally expensive to buy in larger amounts.

Conclusion

From the interview with Matthias, it was concluded that Microfarm could increase its added value by facilitating more specific crops like edible flowers. In chapter 2.2 it was decided that herbs would be the focus of Microfarm, but with the business model now generated this decision will be reverted. Another interesting point it raises is how much restaurants are actually willing to spend on the product and whether the product in its current form would justify the purchase.





Restaurant validation

One of the participants from the pilot research in chapter 2.2 was revisited for validation of the concept. This participant is the manager and owner of De Centrale in Delft, and was shown the final design, business model, and Priva Portal as displayed here in iteration 1. What is interesting about this validation test as well, is that this participant was part of the pilot testing, but not the interviews that followed after. This gives an opportunity to validate whether the results

Overall design

The participant was shown the design, both inside and out, and asked about their opinion. The following answers were given:

When seeing the design of the Microfarm, the participant noted that they would prefer to look into the product, as opposed to having a small window through which the inside can be observed. The design of the current window makes the product look like a design object rather than an indoor farm and they noted that being able to easily look inside was one of the key reasons to buy the product.

The participant also told that being able to grow many different batches of crops is interesting, but difficult to communicate to guests both in terms of menu as well as before their visit.

The assumption that a restaurant wouldn't want to dispose their leftover irrigation water themselves is confirmed. The participant noted they would rather not have to waste the time on the disposal of it by going to waste processing facility.

Due to the size, there were not a lot of places where the product could be placed in the restaurant.

Priva Portal

Regarding Priva Portal, the participant had very little to say other than that they were positive about the idea of such platform and that its ideal because it means less time and maintenance they have to spend on it.

Business Model

It was noted that being able to grow edible flowers in the product (as suggested by Matthias van den Berg) would not increase the value of the product for the partcipant because they're not too much interested into edible flowers and see it more as a trend.

When asked whether the participant would pay €500,- per month to use the product and Priva Portal service, they stated that it would be too much money because the product is looked at from a promotional viewpoint. Because €3000,- already is a large amount of their promotional budget for a year, the participant noted that half of that price, €250,- per month or €1500 per year would be more reasonable to consider.

Conclusion

By interviewing the owner of restaurant De Centrale, it is clear that Priva Portal contains elements that are perceived by the user as convenient and as something which adds value. The product and its underlying business model, on the other hand, require a critical review of whether the product's added value in its current form justifies the price. In the next iteration, it is likely that adding value and reducing cost will have a large part in shaping the final design.

4.7 PROTOTYPE

To validate relevant aspects of the design, a prototype was constructed that emulates a single level of Microfarm. The prototype, which can be seen in image 48 to the right, is made of mainly wood and contains a steel structure and stand that enable the growing lamps to be held and the prototype to be moved around. To the page on the right, a selection of images taken during the prototyping process can be found.

Tray design

The tray in which the plugs are placed is tested. As opposed to being regular squares, the trays have a cut-outs and it is hypthosized that it enables the user to more conveniently grab the trays when they are placed in close proximity of each other in Microfarm. It can be concluded that such cut-out enables the user to stick their hands between trays more easily, but doesn't make picking up the trays themselves easier. To solve this a part of the bottom of the tray was removed, which enables fingers to find their way under the tray. Robert Schouten, innovator at Priva, noted that having the top of the tray cut-out allows light to reach places where it could interact with irrigation water, which is a feeding ground for algae.

Size

Dimensioning the prototype on a 1:1 scale allows certain assumptions to be tested. The tolerances applied, for instance, are very royal and could be reduced by a few times. The envisioned frame, which is virtually indicated with the two vertical wooden parts at the front, should be widened a bit to enable the trays to be taken out properly. In this configuration only the middle one comes out easily. As a last remark, the actual size chosen is likely too large because it is the size of decent closet at the moment.

Ergonomic validation

An attempt was made to adjust the height of the prototype exactly to what was found in chapter 3.5, however, due to modifications the height is 5 to 10 cm lower than the top level of the design-. Therefor this aspect is not tested, but informally it can be claimed that the current placement does provide a good height to work with. In the ergonomic research it was claimed that the depth would not pose a problem, and this can be confirmed by reaching into the product.

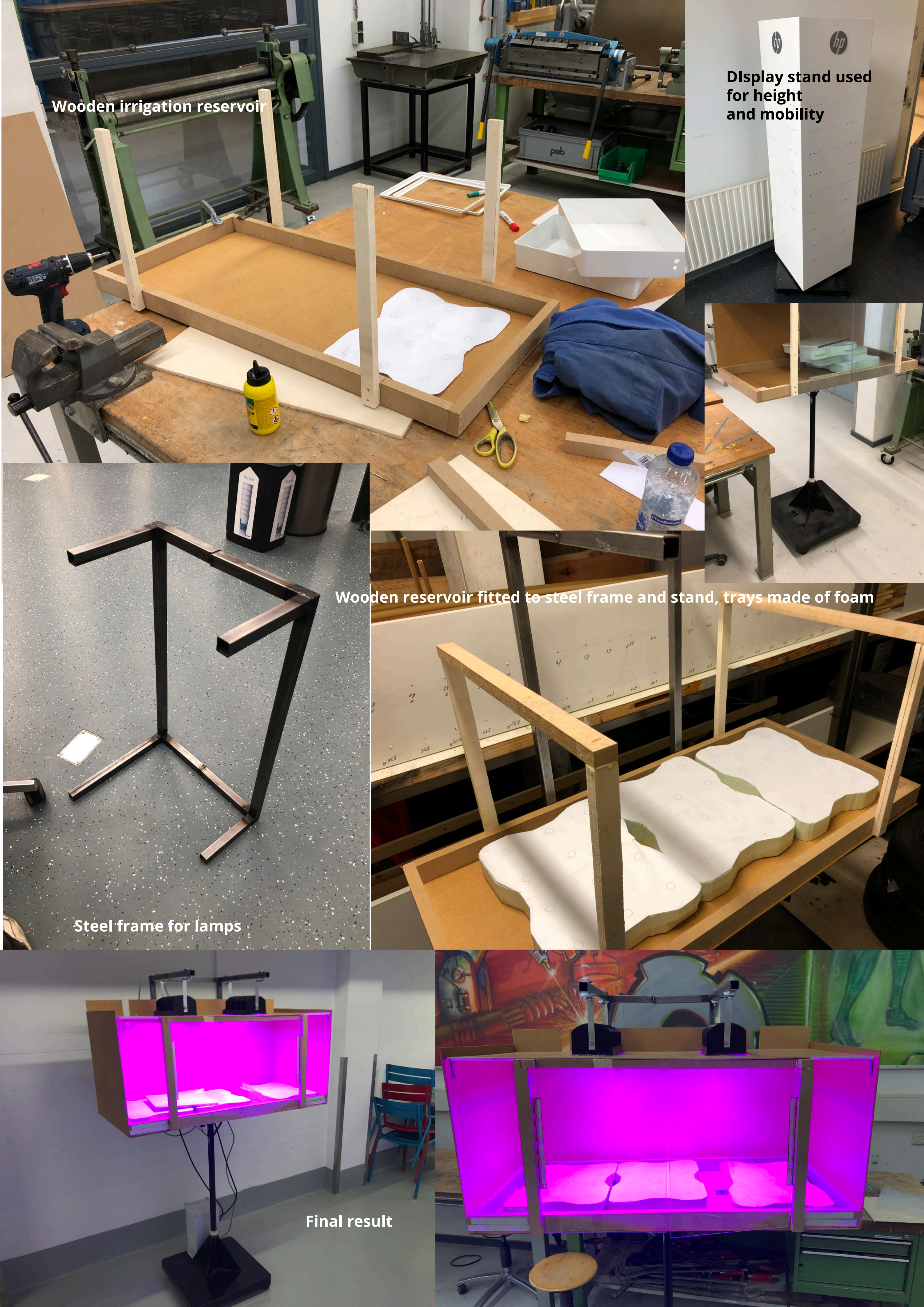
Lights

By installing actual growing lights, the brightness of the light can be observed on a small scale. Although not exactly the same as envisioned for the final design, the color and intensity are very similar and reiterate the need for some sort shielding of the light as the color and intensity are very invasive and discolor the vision for a few seconds after observation.

Conclusion

The prototype testing yielded useful input for the next iteration, aspects such as size have to be critically reviewed and likely reduced to allow Microfarm to

Image 48. Prototype building collage


Wooden irrigation reservoir
DIsplay stand used
for height
and mobility
Wooden reservoir fitted to steel frame and stand, trays made of foam
Steel frame for lamps
Final result

Reflection on iteration 1

As a moment of formal assessment, a green light meeting was held which gave the supervisory team the chance to voice their opinions and guide the process as they see fit. The meeting concludes the first iteration of Microfarm and this section will reflect on this first iteration, based on the mentioned meeting and previously conducted validation testing. These remarks shall be used to improve the second iteration of Microfarm.

Improve restaurant experience

Although Microfarm is optimized for use in restaurants and maximizes the growing space available to a restaurant, the product doesn't reflect that it is specfically designed for a restaurant nor does it evoke a real experience. It is difficult for a restaurant to bring the experience of indoor farming to a guest with simply the shelf design that is currently present. Because the product in its current shape is designed to be placed somewhere between the kitchen and dining room, the restaurant will have to find their own way of doing so. In the second iteration, the product should also facilitate experiencing indoor farming at a guest's table without them having to necessarily observe the product as it currently is.

Value and cost

The chosen business plan is heavily dependent on the user wanting to pay for the value that is received from the product. Although value is created by enabling the user to easily grow their own produce, the previously mentioned restaurant experience is not really present yet but is likely a larger reason for purchase as it would improve the experience of the guests and likely translate into higher incomes. From the restaurant interview it was clear that if the product were to be sold at €500 per month, this would be too expensive considering that the product is more of a promotional item than a food factory. In the second iteration, reducing the estimated cost price of the product while creating the previously mentioned experience is recommended to increase the overall value of the Microfarm concept and make it more accessible for restaurants to use.

Iteration 2

At the start of the second iteration it was decided to ideate on how the product could improve the restaurant experience and how it could be brought to the guest.

One notion that was created is that Microfarm has to evoke a so-called wow effect that makes a guest feel as if they're really experiencing all of the benefits of indoor farming in that restaurant. The better the restaurant is able at creating a wow effect with the Microfarm, the more likely the guests will be satisfied. This increases the chances of a restaurant generating more income because guests would be more satisfied with their visit, and perhaps increases the chance of them visiting again. Next to making the concept better fit its context, such moments add value for a restaurant and likely positively influences the amount of money and effort they are willing to invest into Microfarm.

4.8 CUSTOMER JOURNEY

To better understand the moments of experience, where a guest can be introduced to an indoor farming experience, a customer journey is generated that describes the dining experience of a guest and the actions performed by the restaurant staff. On the page to the right, in image 49, the complete customer journey can be found. The conclusions of the customer journey will be used as input for ideation of this to-be developed product.

Guest timeline

The colored bars on the left describe the overall phase of the restaurant visit. To the right of that are the events a guest goes through and how they react to it on an emotional level.

Waiting staff and kitchen timeline

Similar to the guest timeline the colored bars indicate the phase of work they are in and include the actions they perform for the restaurant guests.

Line of interaction and visibility

The waiting staff is concerned with the guests and dining room, which makes them the point of interaction between guest and restaurant for the duration of the visit. A guest is less likely to interact with a chef because their activities

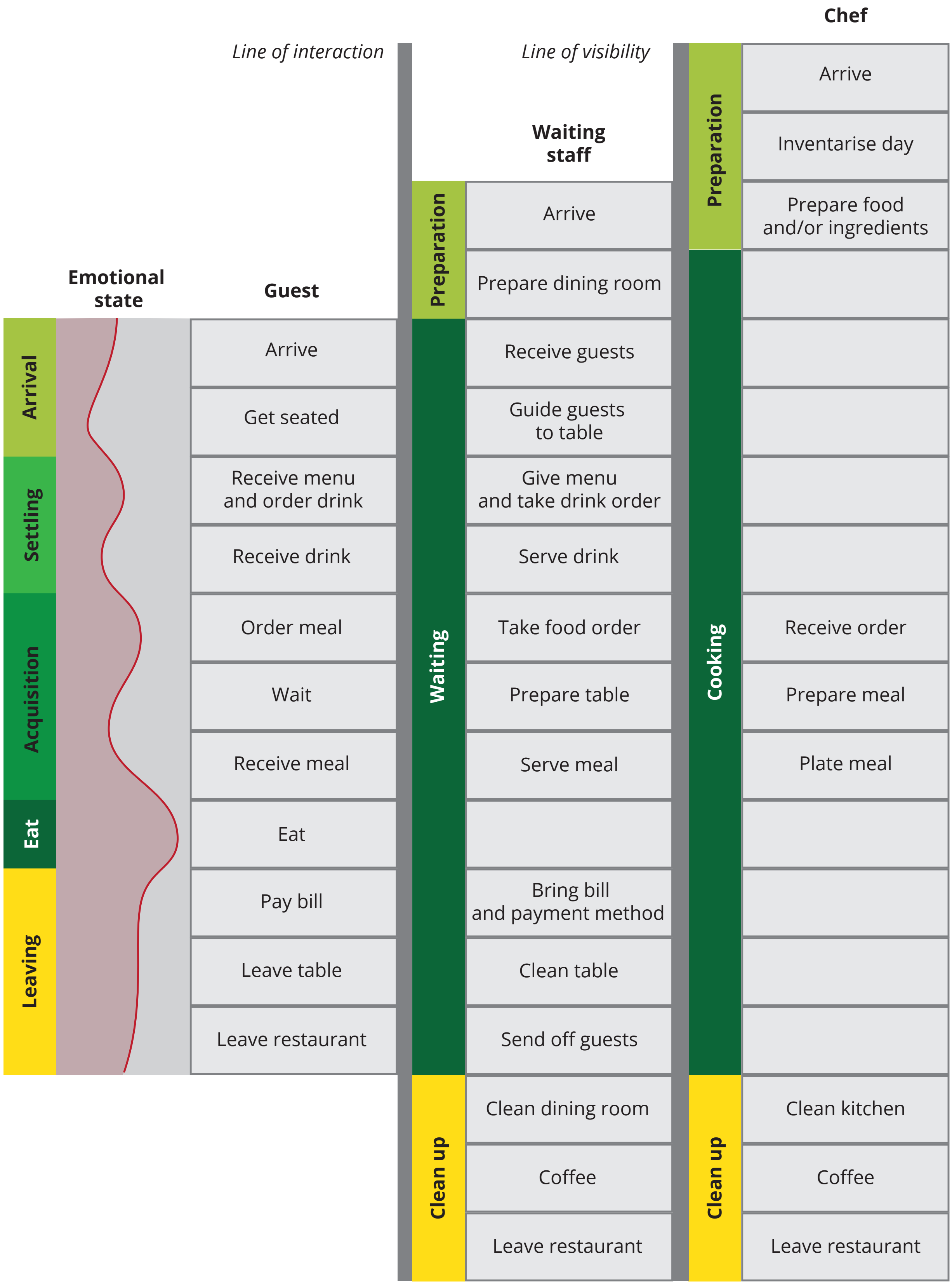


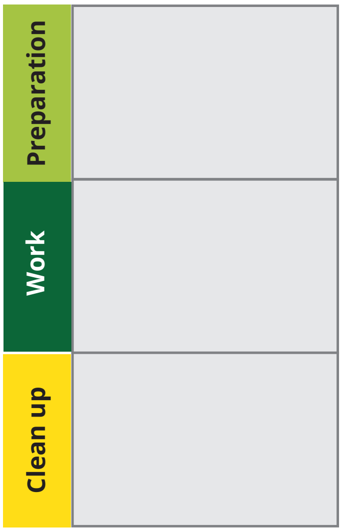
Image 49. Customer journey

The journey of the guest is analysed further on potential touch points where a product could be introduce, which can be found below in image 50. To get a better idea of how likely a product is to succeed, its competition and effect on the emotional state are also described. The last column indicates whether such a touch point could provide an exclusive experience, which could potentially increase the value of the solution.

	Emotional state	Guest	Potential touch points	In competition with	Effect	Ex-clusive?
Arrival		Arrive	Located in restaurant	Furniture and space		N
		Get seated	On table	Table contents; salt, candle, cutlery, etc.		Y/N
Settling		Receive menu and order drink	Special menu	Dishes and/or menus		N
		Receive drink	Sample in or with drink	Drinks and/or snacks		Y/N
Acquisition		Order meal	Hand picked from	Specialities; wine, lobster, dried meats		Y
		Wait	Receive prior to eating	Meal experiences; stoves, pans, plates		Y/N
		Receive meal	Receive as part of dish	Meal experiences and other ingredients		Y/N
Eat		Eat	Hand pick from cart or serving tray	Condiments; sauces, spices, ingredients		Y
Leaving		Pay bill	Sample with bill	Sweets; mints, hard candies, cookies		N
		Leave table	Take home	Food at home		Y/N
		Leave restaurant	Part of tour	Building aspects; wine cellar, scenic view, architecture		Y

Image 50. Guest journey

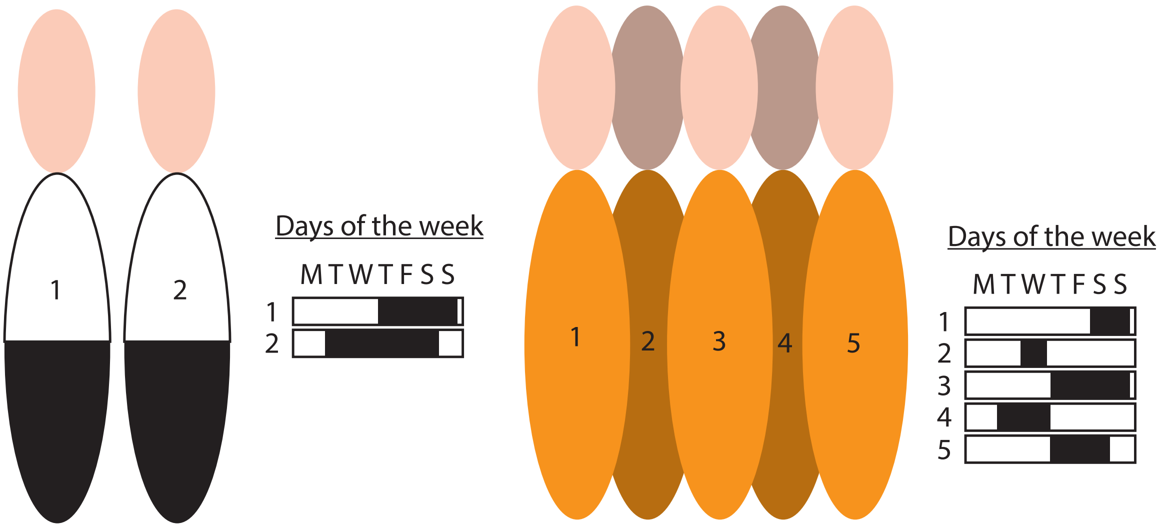
Competition also exists when it comes to time and availability of staff. Below, each phase is briefly summarized to take into consideration when deciding which idea to pursue.



Restaurant staff has time to prepare and maintain if necessary. Time can be increased because the starting time is fluid depending on occupation and tasks. During this time, they can prepare, be educated and trained if necessary.

Staff performs their main activities. Any tasks added during this period will add to their existing workflow, which is constrained by the guests' waiting time and the staff's workload and experience.

Staff has time to clean up and prepare for the next working day. Depending on the length of the workday time and effort available from the staff can vary, but will be much lower than during preparation.



The presence of waiters and chefs will likely vary considering their need and availability. It is assumed that chefs will be more permanently employed and present almost full-time considering their skills are at the core of the restaurant. Waiting staff, however, will likely vary more in presence according to the amount of guests that attend each night and their type of employment (full time or part time).

A SWOT matrix is generated to analyse and conclude the customer journey. The contents of the matrix serve as input for the ideation and are described below in image 51.

Image 51. SWOT Matrix of customer journey

Strengths

Relatively novel concept

Novelties like exclusive wines and dried meats are a known phenomenon in restaurants, indoor farming is relatively new and has an advantage because of this.

Interesting for image

Novelties like the aforementioned exlusive wines and dried meats are consumable and doesn’t necessarily reflect how a restaurant’s kitchen works. An indoor farming experience says something about a restaurant’s ingredient use.

Large choice of possibilities

An experience can be realistically introduced at every phase of the dining journey

Weaknesses

Competes for attention at every step during the dining journey

When introducing an indoor farming experience during the dining journey this will likely not be the center piece of the restaurant, nor the main reason for visiting. The solution will compete with other exclusive elements, like wine and dried meats, for instance.

The longer the wait, the more competing elements that are introduced

As dinner progresses there are more moments in which other experiences and novelties can be introduced. This potentially decreases the “wow factor” and creates situations in which an experience could become excessive.

Differing impacts on the workflow of a restaurant

Both the waiting and kitchen staff will have to change something to their workflow to enable the experience to take place for the guest. This differs per phase and makes it difficult to apply one solution to every phase of the restaurant visit.

The more exclusive, the more it becomes an effort on itself

To make an experience more exclusive in a restaurant, less guests will have to receive it and the experience itself has to be somewhat impressive. This will remove it from their standard workflow and require more effort to train staff.

Diminished effect after eating

The dishes and meals a restaurant serves are often a reason to go there. If the experience were to be introduced after eating, it is assumed that it has much less effect because a guest’s emotional peak has been reached.

Not enough plant capacity for all experiences

Realistically, Microfarm cannot produce enough fresh greens for all experiences, nor solutions which involve supplying every table, every day.

Hygiene

If a solution were to be placed on a table, the plants that are contained could only be used by those guests. Once touched, they cannot be served to other guests due to hygiene issues.

Opportunities

Work with flow between waiting and kitchen staff

The success of implementation will largely depend on how well it fits into the current workflow of the kitchen and waiting staff. A solution that can be easily used by a chef and effortlessly transferred to the waiting staff will increase the chances of success.

Increase emotional state during peaks of restaurant visit

The peaks of the restaurant visit will likely be better remembered than the dull moments. To make these moments and the restaurant even more memorable, these peaks could be increased by introducing an experience.

Less competition during dips in emotional state

Although peaks can be increased, these are also moments at which other competing elements like special dishes and drinks can be introduced. However, this is less of the case during the dips in the customer journey and are interesting moments to introduce experiences that raise the emotional state of the guest.

Serving the guest something exclusive without straining resources

The best solutions involve serving the guest an experience that doesn't require human or food resources to be strained.

Threats

Limited gain not worth the impact on staff, restaurant, and resources

Perhaps the largest threat of the concept as a whole. The relatively small amount of fresh produce that can be gained from Microfarm could simply not be worth the effort for a restaurant to go through. It requires a disproportionate amount of effort compared to other dishes and the monetary benefit will be limited by what guests want to pay and how much a restaurant invests.

Differences in restaurant (staff) operations

Restaurant staff (kitchen, waiting, bartender, etc.) is known to be flexible when it comes to working days and hours. To convey an indoor farming experience properly, it is expected that this staff knows what to do and how to convey it to the guest. This requires extra communication from the restaurant to its staff and could be unrealistic given the amount of staff and the scale of the experience that has to be conveyed.

Exclusive elements supplied by a restaurant

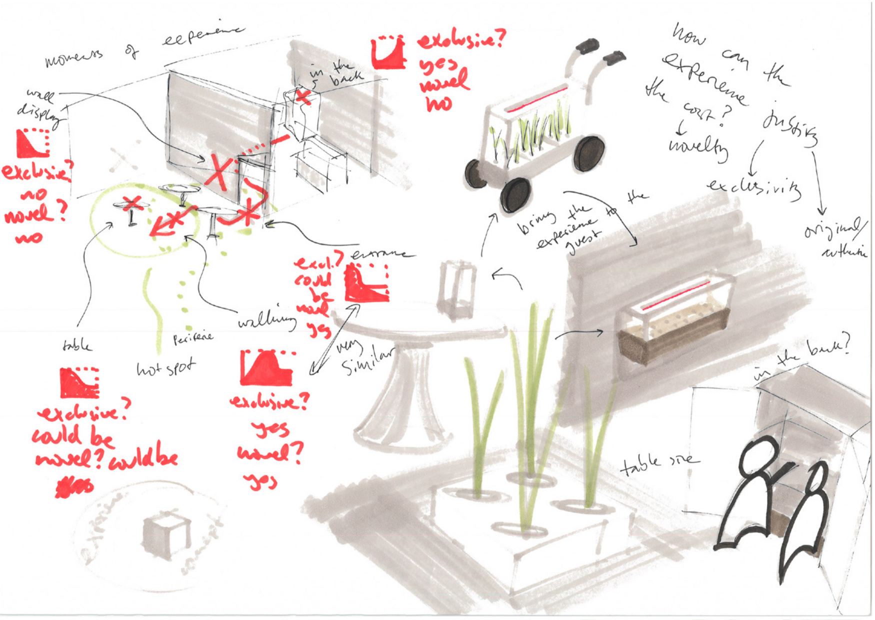
If the restaurant already supplies something exclusive, an indoor farming experience will be less attractive.

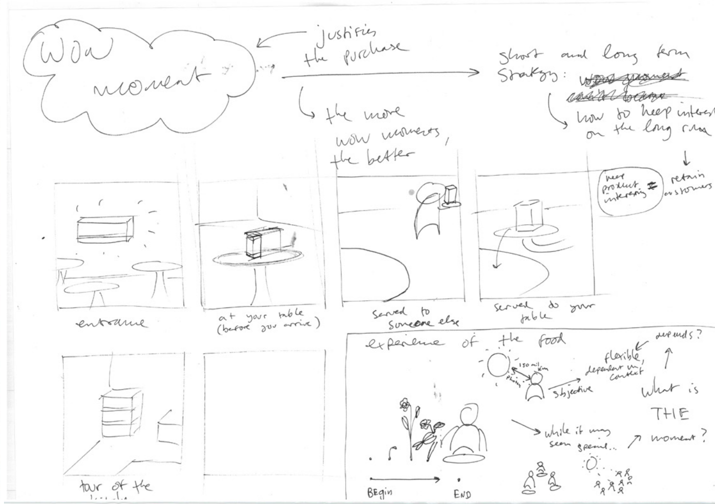
4.9 IDEATION

Adapting Microfarm to the customer journey described in the previous chapter requires a new ideation session.

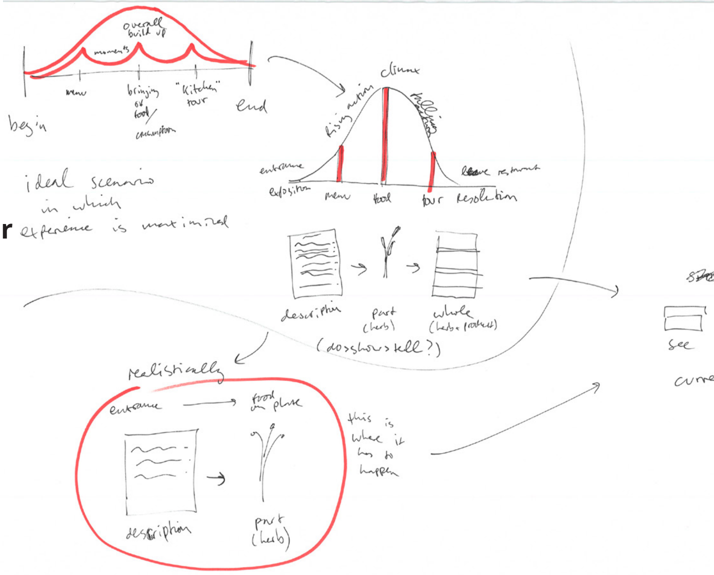
From the moments of experience, several ideas were sketched out that could fulfill a role at each step in the customer journey, these can be found on the next two pages, 136 and 137. To enable the whole journey to be covered, two categories were determined for Microfarm, growing and showing units.

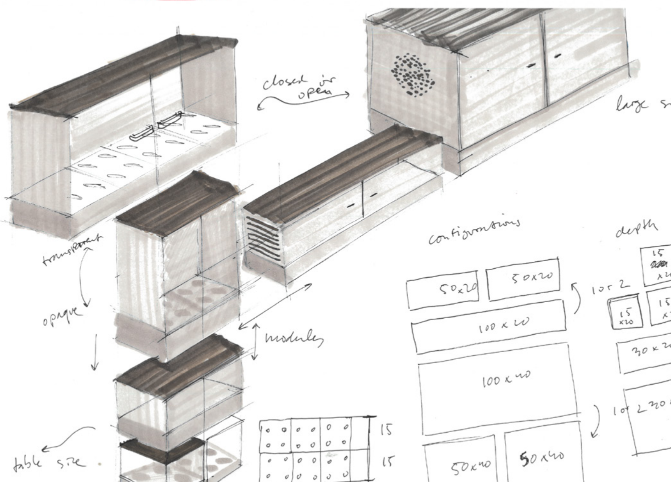
The growing units refer to the products that will help growing the produce, like Microfarm in iteration 1, whereas showing units will enable the restaurant to bring the experience of Microfarm to a table by providing much simpler solutions.



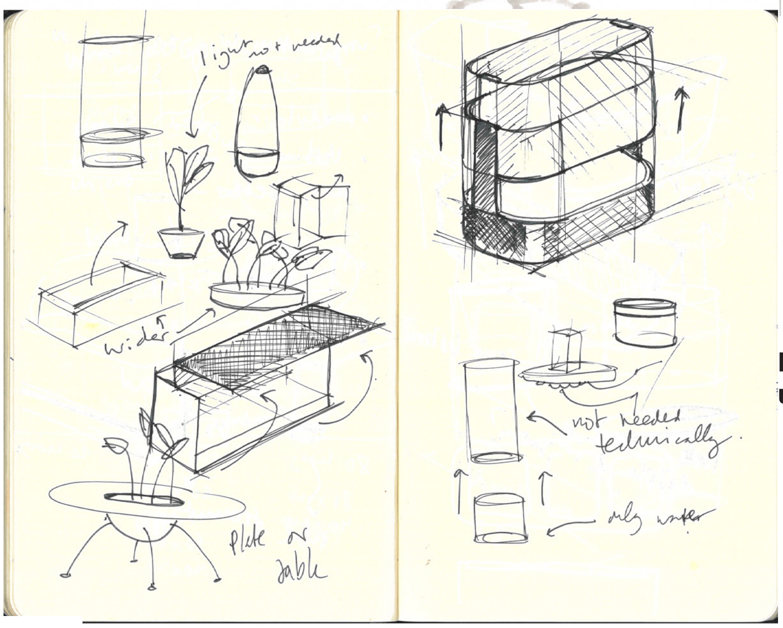


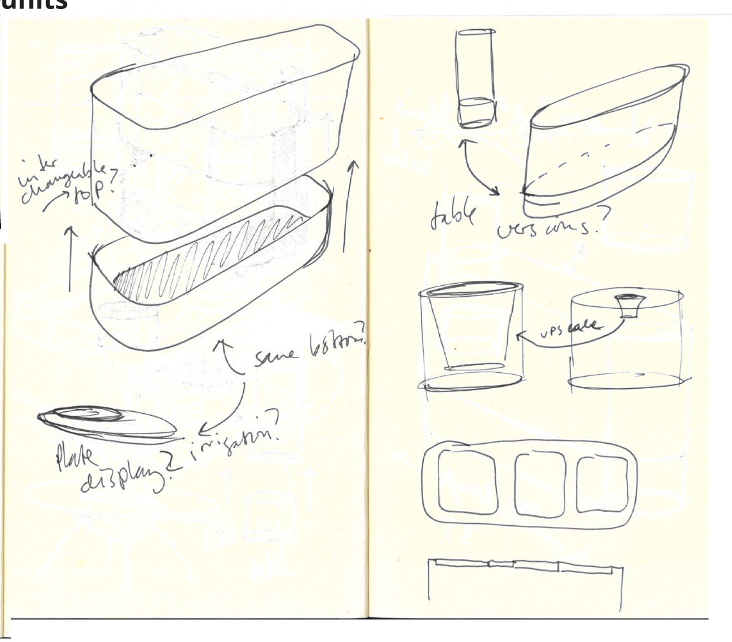
Ideating on moments of interactions and customer journey

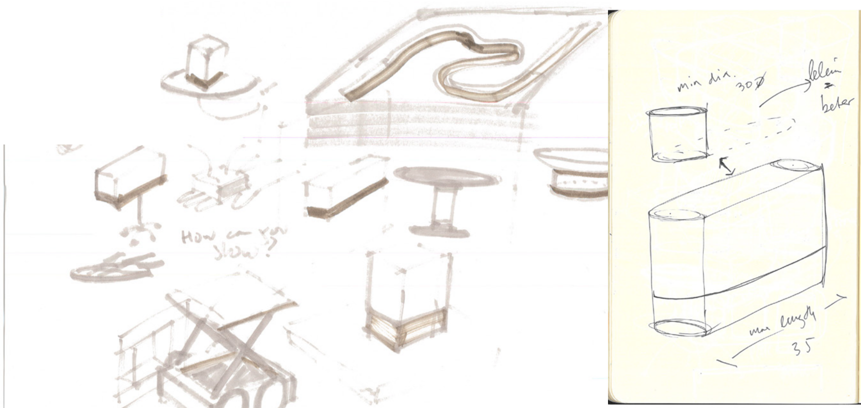


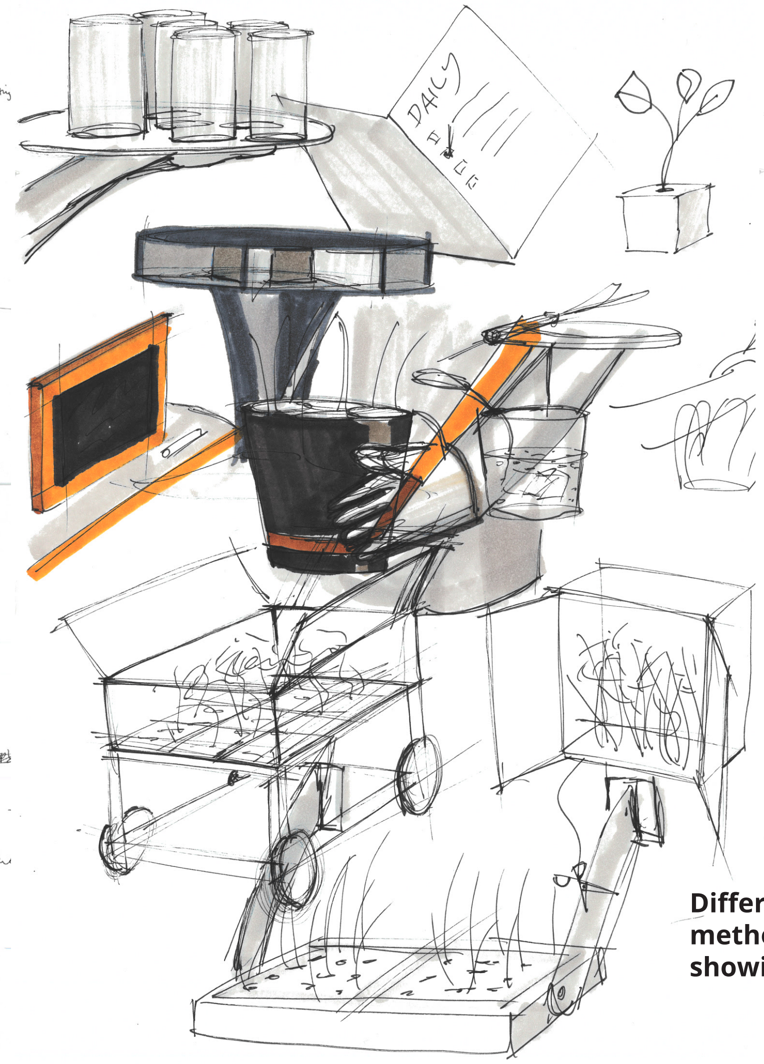


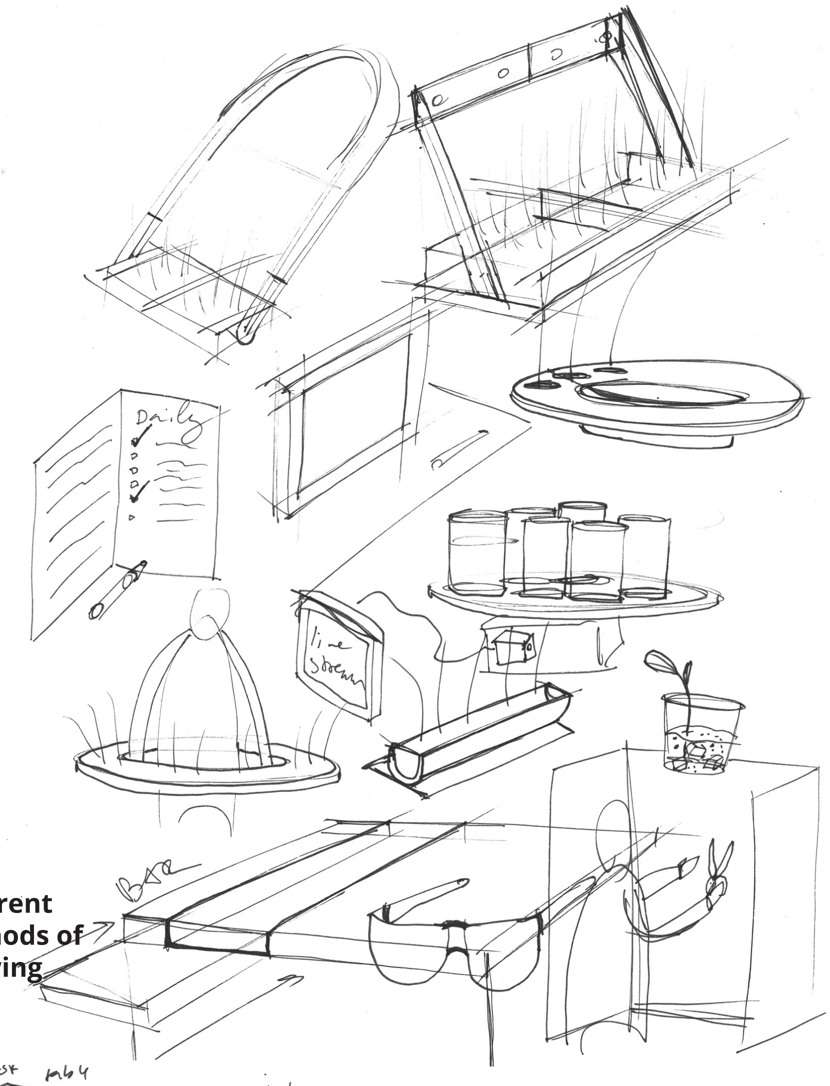
Modular grow units



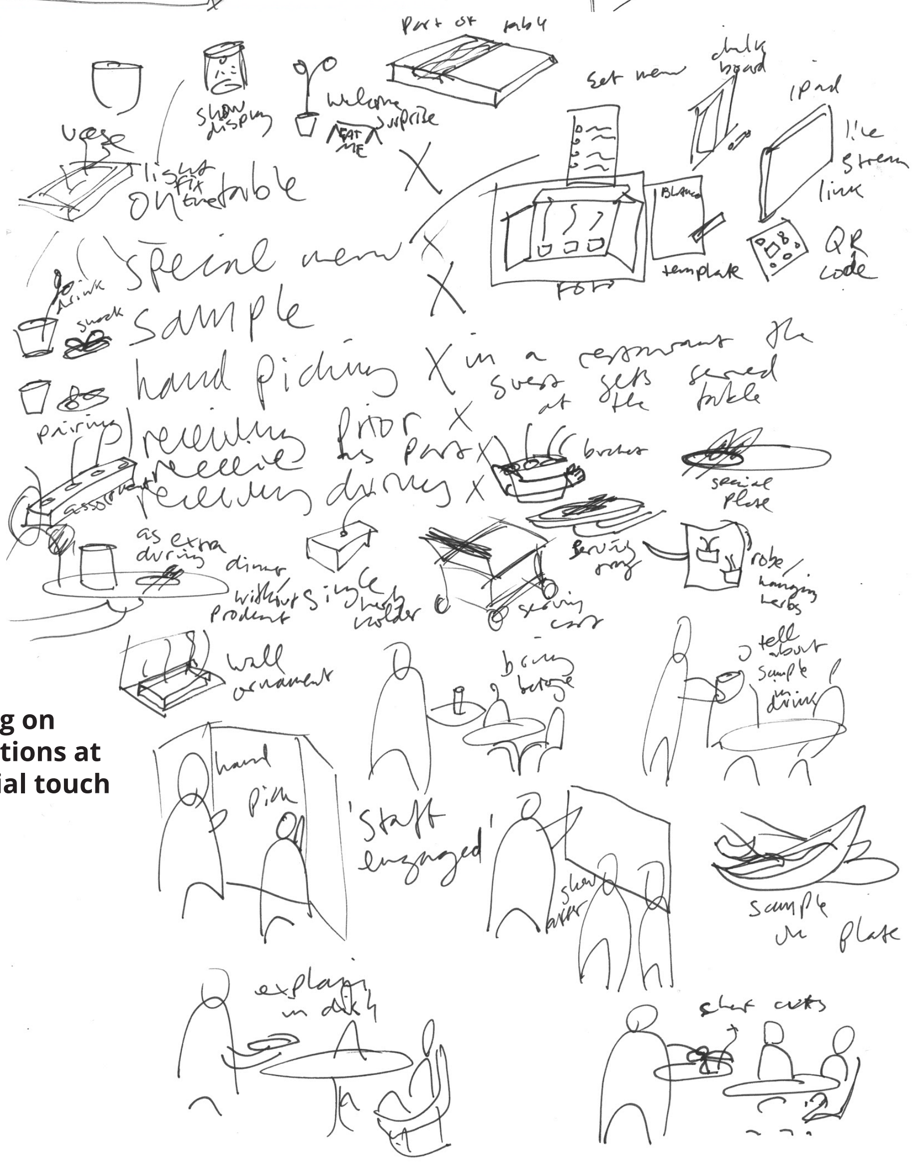








Different methods of showing

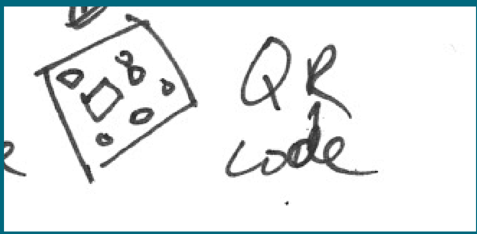


Ideating on interactions at potential touch points

4.10 SHOW UNITS

For every potential touch point ideas were generated. The most interesting ideas are situated between getting seated and eating the meal, with the arrival more likely a domain for a grow unit and anything after eating not being worth the effort (from the SWOT matrix). Below, a select few ideas are presented, elaborated on, and judged according to different criteria. Based on the result, one is chosen for further development.

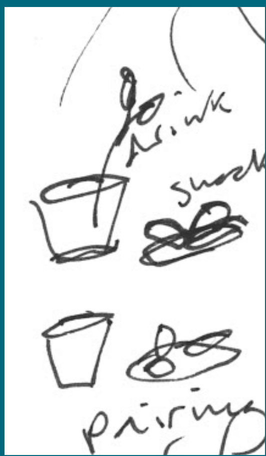
QR code



A menu is one of the first points of interaction between a guest and the food served by a restaurant, and will inform a guest on which dishes are being made and what ingredients are contained. Menus often contain descriptions regarding the origin of the ingredients or specialties and is a low threshold method of intriguing the guest with a restaurant's selection.

Physical menus are the logical choice for dishes served during the season and are mostly made of laminated paper. Microfarm, however, will likely yield different amounts and batches and requires a restaurant to update their menu more often if it were to be included. Based on the effort of producing new menus and the difficulties of communicating such rapid changes to guests, a QR code is proposed that can be pasted in a menu. This requires only digital updating and even allows guests to see the fresh produce selection before they even visit the restaurants as it will be online.

Pairing



Many ingredients and drinks can be paired to create unique taste sensations. An example of this are mixed drinks, like gin and tonic, where specific gins and tonics are used that are garnished with a range of fruits and vegetables to create a more unique drink, but is also possible with wine and ingredients like cheese and herbs.

Pairings require interaction between the kitchen and bar staff, the food aspect will likely be provided by the kitchen whereas the drinks are made by a bartender. Proposed is a vessel that makes it easy for the kitchen staff to place the ingredients in and transport.The bartender is able to easily see how many ingredients are contained and is able to communicate with the kitchen staff in terms of quanitities required.

Table piece

The most intimate interaction between guest and freshly grown ingredient would take place at the table. Here the guest has time to use all their senses in exploring the ingredient and could serve as a conversation piece between dinner companions.

Providing a guest with a table piece requires a chef to prepare the piece and for the waiting staff to bring it. This could easily be done by laying the ingredient on a plate and leaving it at that, but unless it is explicitly communicated the guest will not understand its origin. Proposed is a vessel that holds a small plant or selection, which has a small reservoir at the bottom and a tiny light integrated to reiterate the freshness of the ingredient and to create the idea that the ingredient is specially provided for the guest.

Flower basket

Condiments are often served during dinner to enhance certain dishes, examples of these are mostly sauces, but this could also be done with herbs. Such a serving style provides guests with a nice suprise after receiving dinner and can also evoke a feeling of exclusiveness if applied to a specific dish.

As with the table piece, it would be prepared by the kitchen staff and be served by the waiting staff during dinner service. This will allow the restaurant to control how much is used per day and for which dishes it is used. Proposed is a vessel that enables the kitchen staff to take the growing trays out of Microfarm for use in the kitchen but also directly allows the waiting staff to take it out into the dining room. Such a solution would provide functonality in both the kitchen and dining room and requires no extra preperation besides the initial setup. While serving, waiting staff could explain the origins of the ingredients and speak on behalf of the chef.

Evaluation

To make a decision regarding the ideas proposed, criteria that are influenced by the context and customer journey are created to elaborate on how the ideas perform. They are as following:

Flow friendly

From user research and SWOT: how much effort does it require a restaurant to use and maintain?

Wow factor

From customer journey : how impressive is the solution for a guest?

Visibility

From customer journey: how well does the solution speak for indoor farming?

Exclusivity

From the value proposition: how exclusive is the solution?

Quantity required

From a practical viewpoint: how much does it require and is it realistic?

On the next page each criteria is evaluated per idea.

QR Code

Flow friendly: Although much less than making a new physical menu, it requires kitchen staff to update the menu online and on a regular basis to keep it up to date.
Wow factor: A guest would have to put effort into figuring it out by themselves, which takes away from the surprise, and it is quite static.
Visibility: Very visibile or not at all, a webpage could allow more information to be conveyed, including elaborate descriptions and images of the growing process. However, using a mobile phone for extended periods during dinner is considered to be rude and if the code isn't scanned no one would know.
Exclusivity: Everyone can access it, which takes away from the exclusivity
Quantity required: A restaurant can control what is put on the menu, but it could potentially backfire if the quantities can't be delivered.

Pairing

Flow friendly: If the same ingredients are used it would become part of the workflow, however, if the ingredients keep changing both the recipes and menus would have to adjust accordingly. Requires some interaction between bar and kitchen.
Wow factor: Pairing of fresh grown herbs with drinks and foods is not usually done, so some wow factor is expected.
Visibility: Not very visible, would have to be communicated explicitly on the menu or by the person serving (waiter/bartender)
Exclusivity: Realistically not, it would be part of a menu and thus available to everyone**.**
Quanitity required: A restaurant can control what is part of the pairing and how it is communicated (special menu, QR, etc.) but it could potentially backfire if the quantities can't be delivered or if the specific

Table piece

Flow friendly: Regardless of whether everyone receives it or a select few kitchen staff would have to prepare each individual unit and the waiters would have to serve and retrieve, ensuring they are cleaned and made ready for re-use.
Wow factor: Potential for a wow factor as it is something that isn't currently supplied by a restaurant and a potential conversation starter, but dependent on whether it is part of a dish or applied to every table.
Visibility: The solution would bring the grown produce to the individual and set itself apart from other specialities. It would require some explanation, though.
Exclusivity: Depending on if every guest receives it or not.
Quantity required: Not realistic for every table, has the possibility of backfiring if supply runs out.

Flower basket

Flow friendly: The solution is used in the kitchen and can be transfered easily to the dining room, reducing the effort to a minimum.
Wow factor: The element of surprise and selection can be used as a wow factor as bringing condiments itself isn't necessary novel.
Visibility: As with the table piece, the solution would bring the grown produce to the individual and set itself apart from other specialities. It would require some explanation, though.
Exclusivity: Depending on if its part of a dish or if everyone receives it. The former would be much more exclusive than the latter.
Quantity required: A restaurant can control the amount of produce used, but it could backfire if it were to be expected for every dish, every day.

By looking back at the SWOT matrix, a general conclusion is drawn per idea.

QR code: Relatively novel application and requires little effort once configured, but it competes for visibility with other menu items and there are concerns such a web-based solution would be too much effort for the relatively little amount of harvested produce.

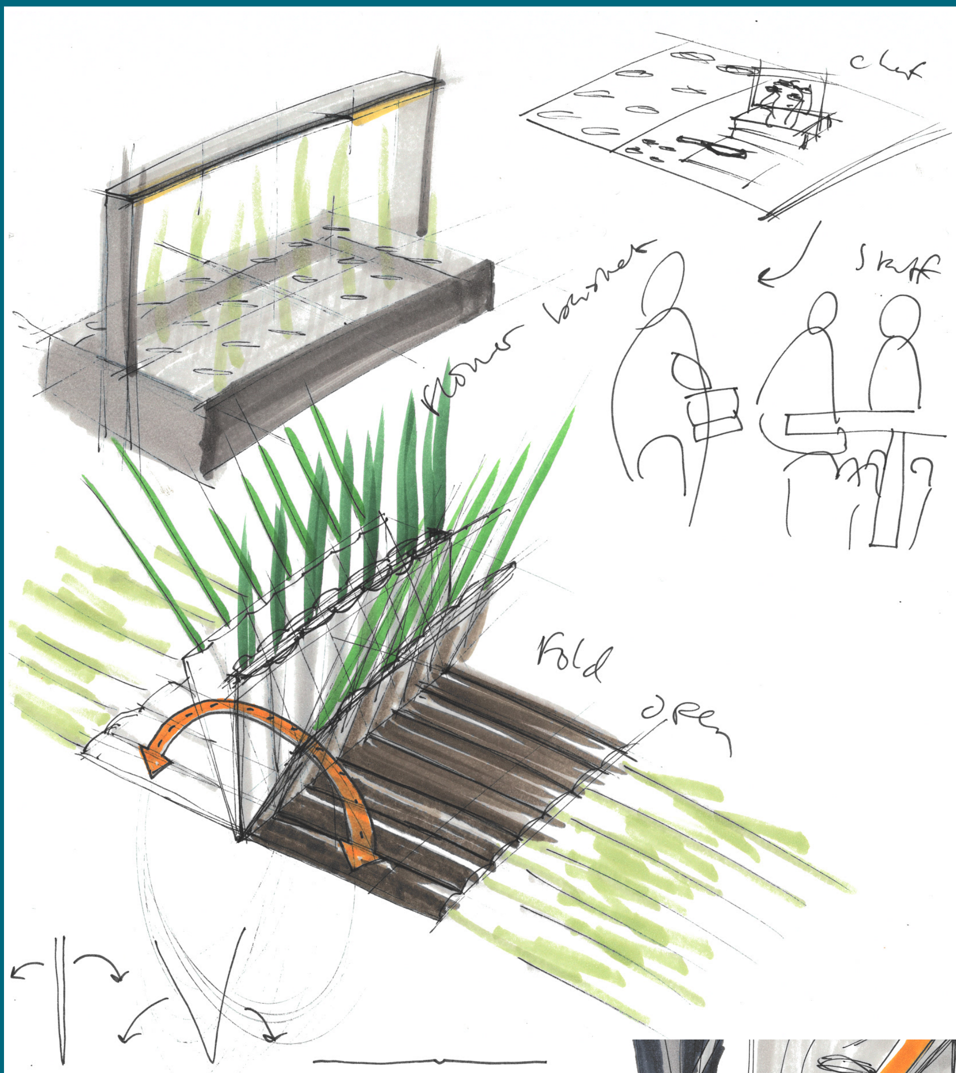
Pairing: Unique for pairings, such a solution has the potential to easily flow between the kitchen and bar, and can be introduced as a starter as opposed to the main course. However, this solution competes with starter items and likely has limited impact to justify the the application (buying Microfarm to only supply a starter item).

Table piece: Very visible and likely increases the emotional state for an extended period, but there are concerns that such a solution can only be supplied in limited amounts and thus requires extra effort in both training and handling by kitchen, waiting, and potentially cleaning staff.

Flower basket: Interesting to show as a restaurant, it brings the kitchen into the restaurant, and works very well with the flow between kitchen and waiting staff because it has little to no extra handling. There are concerns that it has to compete with other novelties served during dinner and that the amount of harvested produce might not justify the use of such solution.

Conclusion show units

From evaluating the four ideas, it is decided that the flower basket idea will be worked out further. This idea seems to fit best in the flow between kitchen and waiting staff, and allows a restaurant to keep a grip on the amount of freshly grown produce served to guests.



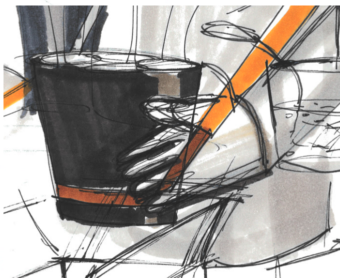
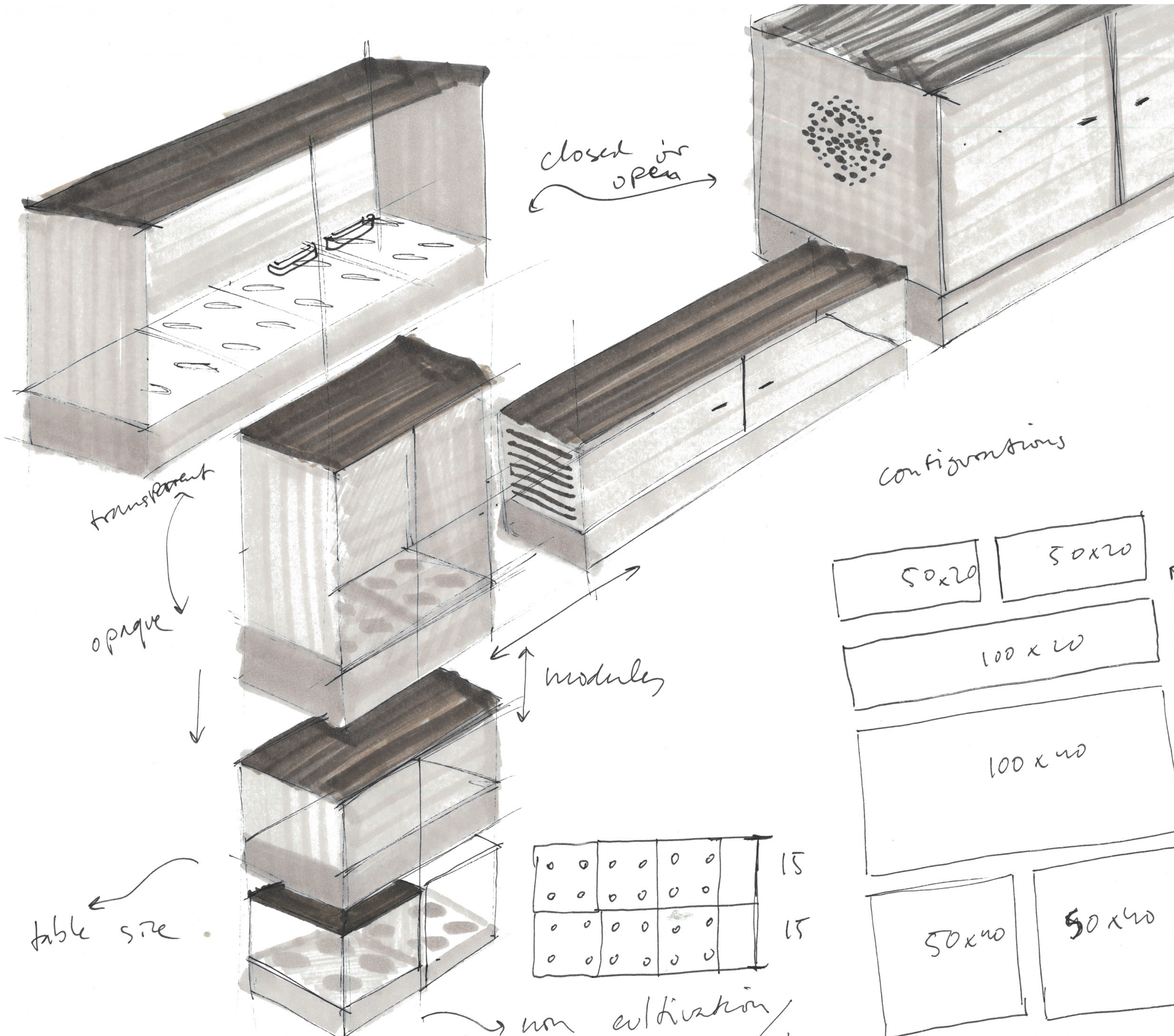


Image 52. Further flower basket ideation

4.11 GROW UNITS

Ideating further on growing units yielded the idea of a more modular Microfarm, where user receives single levels as opposed to a whole shelf/ closet. Splitting Microfarm into single levels with differing formats answer many of the concerns found during validation of the first iteration, such as the high unit cost, the size of the product, and the type of plant that can effectively be grown in it. Overall, such a move would increase the flexibility and scalability of the product, which would realisically translate into a higher value for the user. On the right page in image 53, a 3D model is made of what this could potentially look like, but the styling will have to be refined, which will be done in the next section.



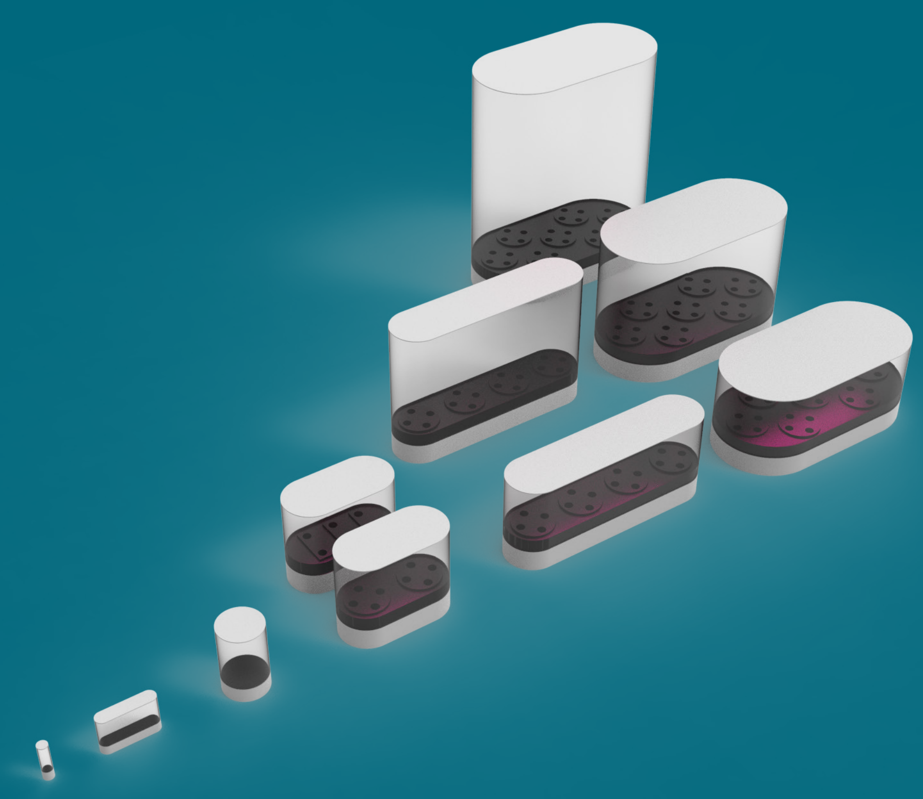


Image 53. 3D model of grow units

4.12 FORM & DETAILS

To give the grow and show units an aesthetically pleasing look, some ideas have to be developed about the form and details of the final concept. From the restaurant styling section it was concluded that there are many differences in restaurant styling and not one single solution. It was found that restaurants make use of repetition, something the grow units will enable, and that round elements are not uncommon. By looking at plant containers, displayed on the page to the right in image 55, these round elements can also be found.

The space in which plants are grown, though, is preferably as rectangular as possible because it ensures the space is being used most efficiently. Although Microfarm is not meant for high yields, this form-follows-function principle is useful for making the product fit in the restaurant in an efficient manner. During conceptualization it was found that while a circular shape could be efficient for plant growth, the actual space needed was much larger because accessibility from all sides has to be taken into account.

Because this does not necessarily produce a very exciting or outspoken shape, unless really forced to as shown in image 54, it was decided that the focus should be on details such as color and composition of the product.

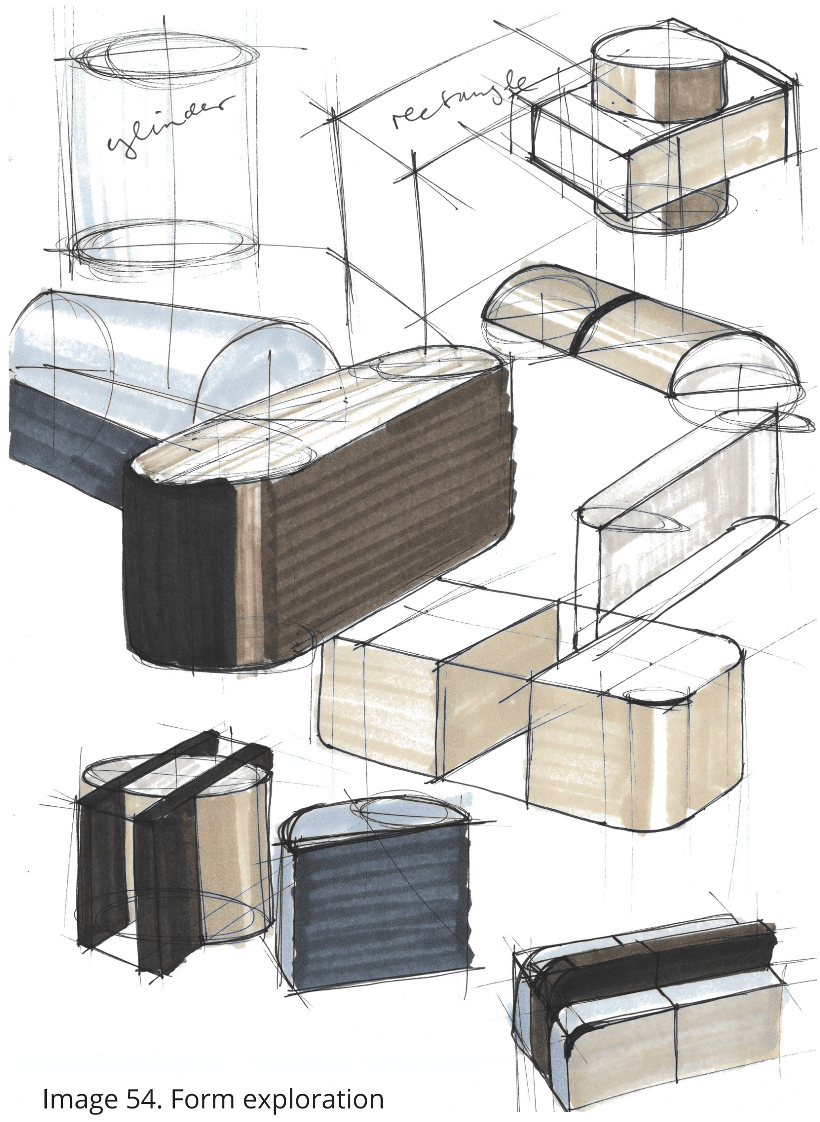


Image 54. Form exploration

To the right:
Image 55. Flower container collage


stekkie
PIKAPLANT

5

Final Design

In this chapter the final design of Microfarm, Nanofarm, and the germination box are presented. Besides these designs, Priva Portal is presented and the business model and implementation plan are described.

5.1 MICROFARM

This section describes the final design of Microfarm, the main result of this graduation project. Microfarm consists of stackable cultivation units which can be placed inside the dining room of restaurants. The three variations allow different types of crops to be grown and the styling of the product can be altered to complement the interior of a

The main value of Microfarm is enabling restaurants to grow their own plants using techniques from indoor farming. At the center stage are the seeds and growing trays that are placed inside Microfarm.

The seeds, obtained by using Priva Portal, are contained within a growing medium known as a Quick Plug. Before being placed in Microfarm, these plugs are placed in the growing trays and germinated in the germination box, which is described further on in this chapter on page FIX ME. In image FIX ME on page FIX ME, a method of identifying the plants being grown is displayed.

Once the seeds are germinated, the growing trays are taken from the germination box and directly placed in Microfarm. From here on the user only has to refill the water reservoir, adding nutrients in the process, and wait till their plants reach maturity.

To use the freshly grown produce, the growing trays are simply taken out and its contents can be removed or trimmed. The growing trays can be placed back instantly or placed in Nanofarm, which enables chef's to keep the fresh produce alive for extended periods during the work day. This product is described in further detail on page FIX ME.

Small

Microgreen and small leafy vegetables

Medium

Herbs and leafy vegetables

Large

Large herbs and edible flowers

Image 56. Different unit sizes of Microfarm

Microfarm comes in three different sizes to accommodate the crop that is being grown. Above in image 56 each size is displayed and includes a description of what it is used for. Each Microfarm is nearly identical in its build up, only the size of the frame and top cover differs per model. On page 159, Microfarm's components and sizes can be found. Due to the varying heights, restaurants can customize the size and types of crops grown in their Microfarm. An example of this can be found below in image 57.

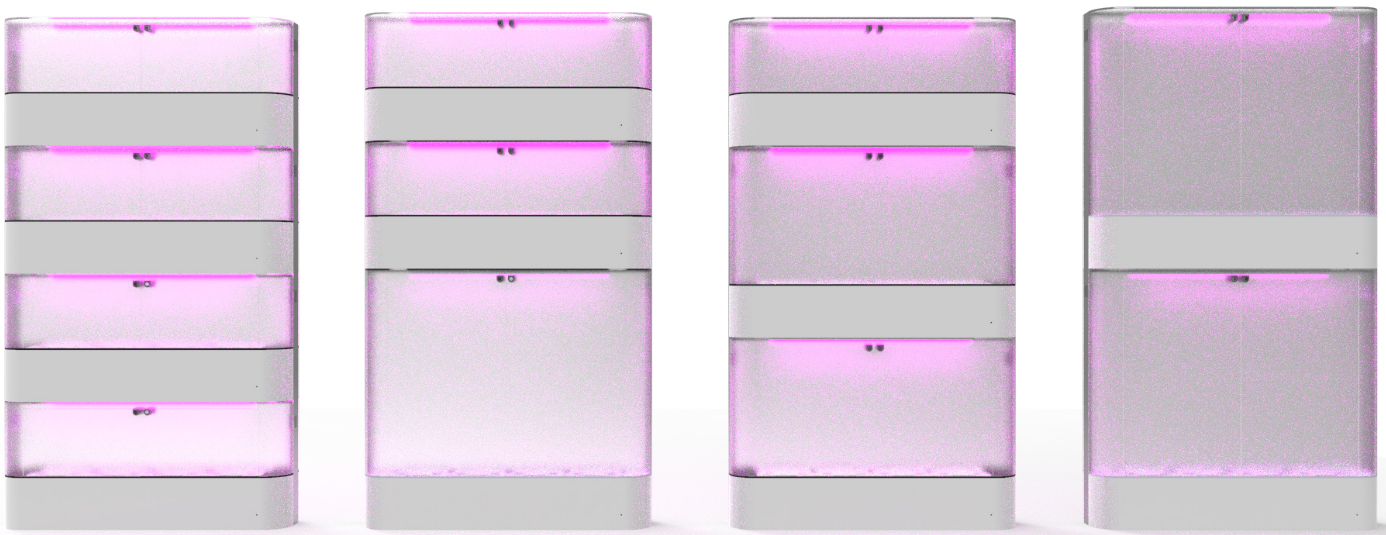


Image 57. Potential configurations Microfarm

The material color of the bottom housing, top cover, and frame can be easily be customized to make Microfarm fit in any restaurant. An example can be seen on the page to the left.

The aluminium frame can be anodized in different colors, as seen below in image 58. Here the options for black and natural are displayed. The polycarbonate top cover and bottom housing can individually be customized to match the restaurant's color palette, of which a select few options are shown in image 59. The top cover can be changed in terms of opacity depending on how much a restaurant can and wants to show, as seen in image 60.

Image 58. Black or natural frame color

Image 59.
Selection of top cover and bottom housing colors

Image 60. Top cover going from fully see-through to closed

Image 61. Shot of three different size

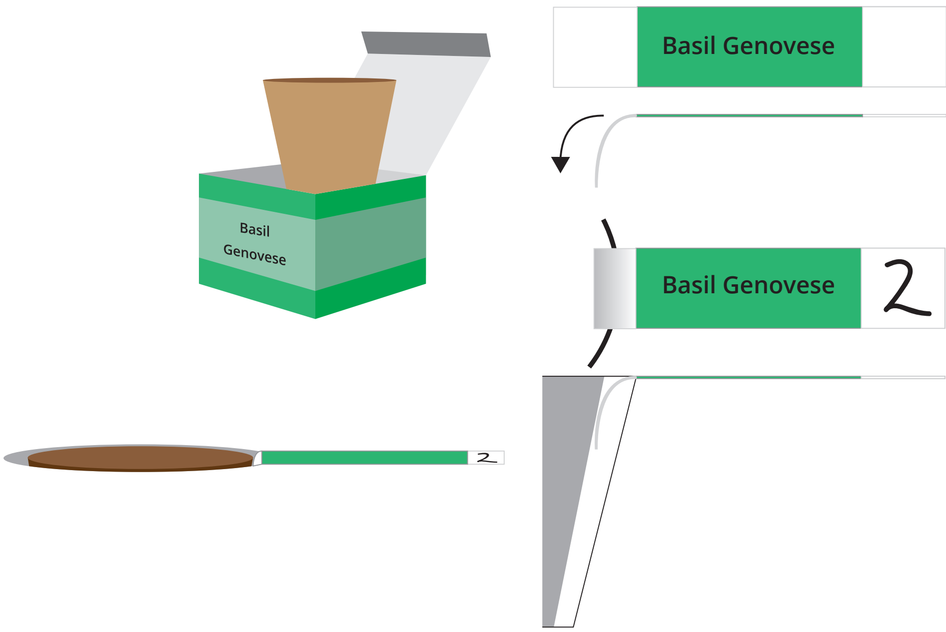
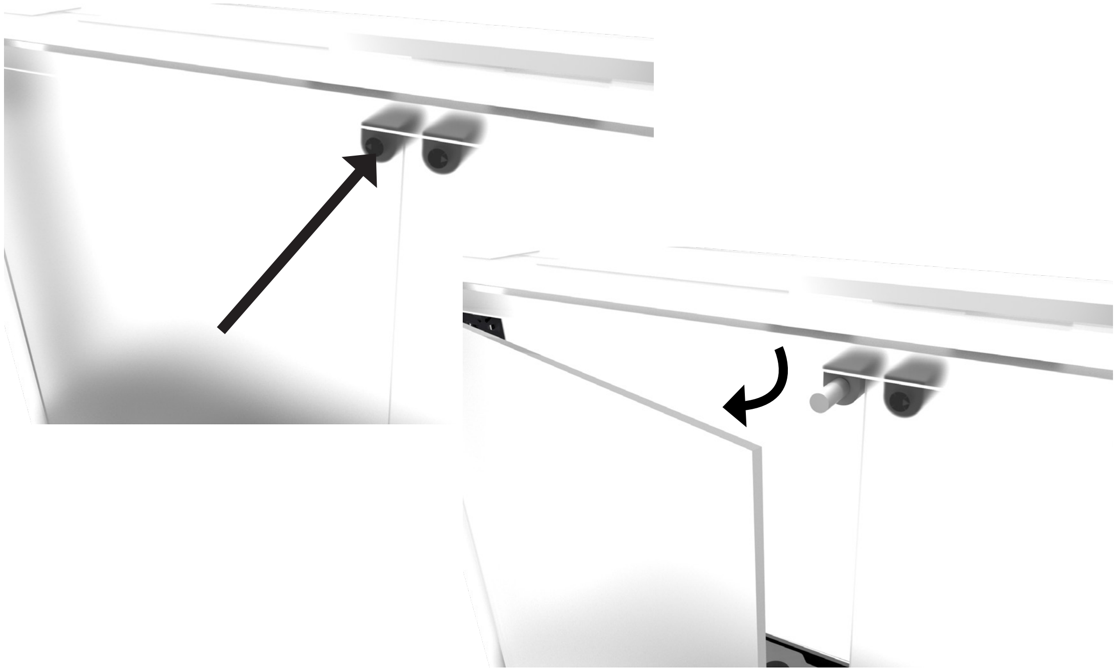


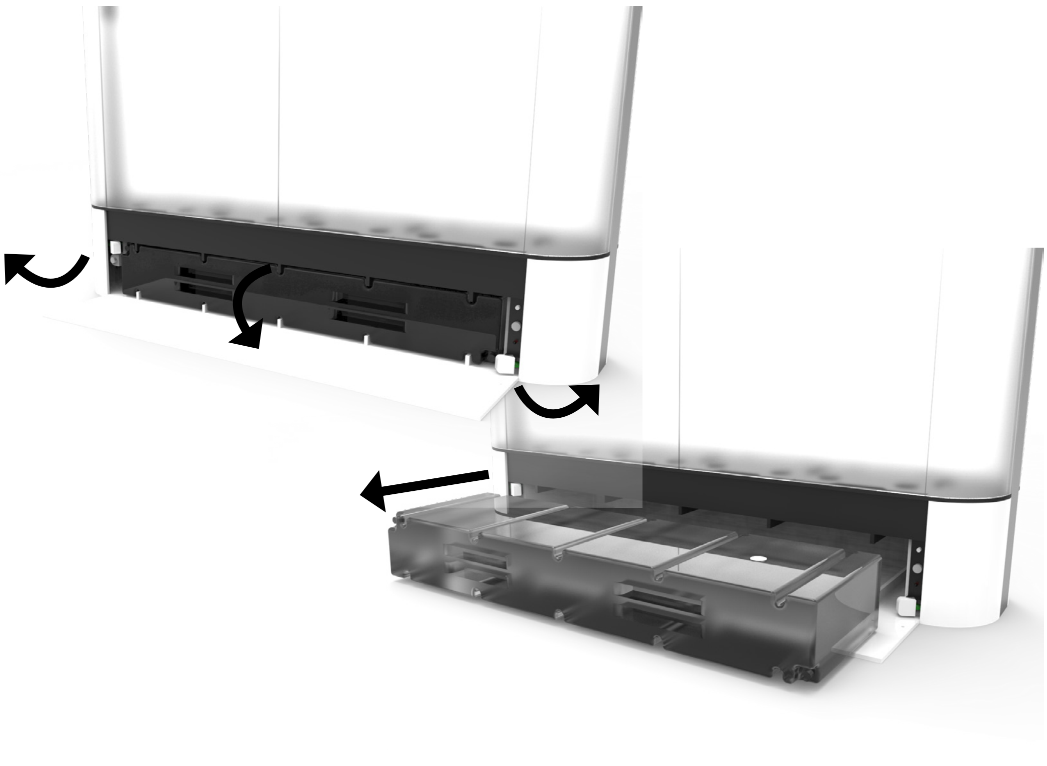
Image 62. Identification of plants

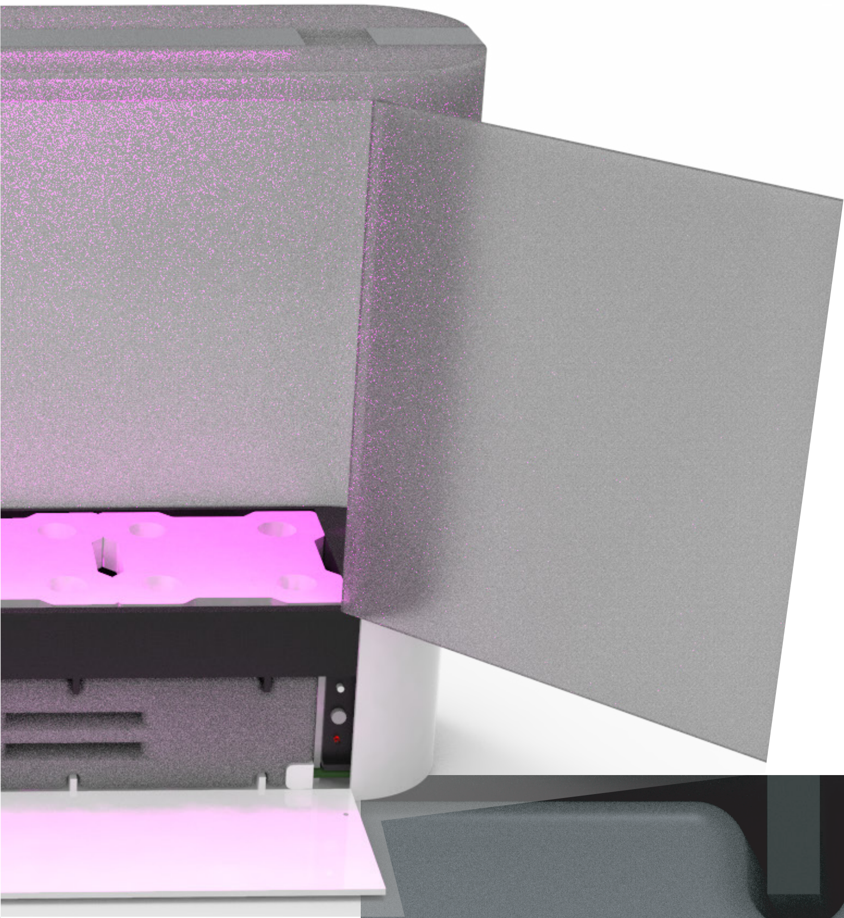
To open both the two main doors and the utility door at the botom, a so-called “push to open” mechanism is used. This requires a gentle push after which the pin will extend and move the door far enough to open further by hand. This keeps Microfarm clean of any door handles.



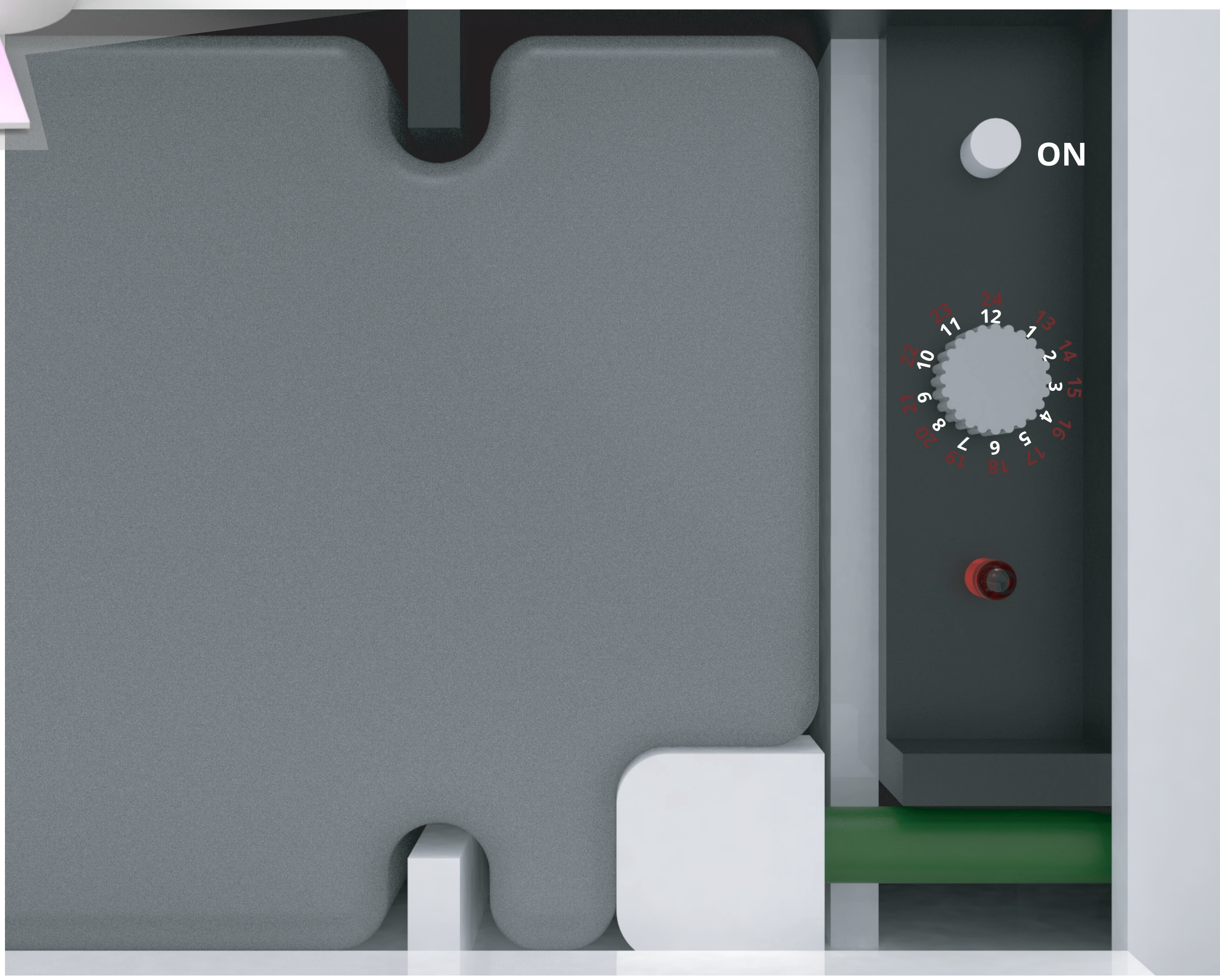
The water tank is located at the bottom of the product and has a capacity of roughly 10 liters. Depending on the phase of plant growth, it has to be refilled every one to two weeks. Like the control panel, it is accessed through the utility door at the bottom.

To take it out, the user has to disconnect the irrigation system by removing the two plugs at the bottom right and top left. The tank can then be brought to a sink for filling. After filling it can be placed back, and the two irrigation plugs have to be connected.





Microfarm’s control panel is accessed by opening the utility door at the bottom. On the bottom right, the control panel is kept as simple as possible by only requiring the user to turn it on and set the time at which the growing cycle of 16 hours starts. Below that indicates two buttons is an LED that will flash once the water level has reached a minimum, but it can also be used to indicate the starting time of the light cycle.



1. Top cover
- **a. Main doors**
- **b. Front**
- **c. Back**

2. Aluminium frame

3. Bottom housing
- **a. Utility door**

4. Growing trays

5. Irrigation reservoir

6. Fans

7. Control panel

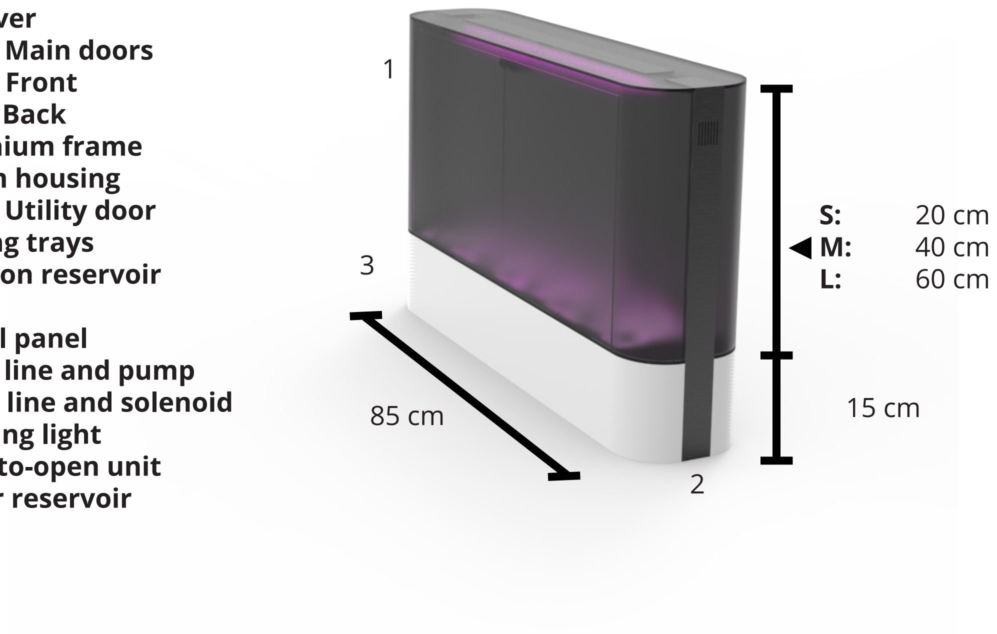
8. Supply line and pump

9. Return line and solenoid

10. Growing light

11. Push-to-open unit

12. Water reservoir



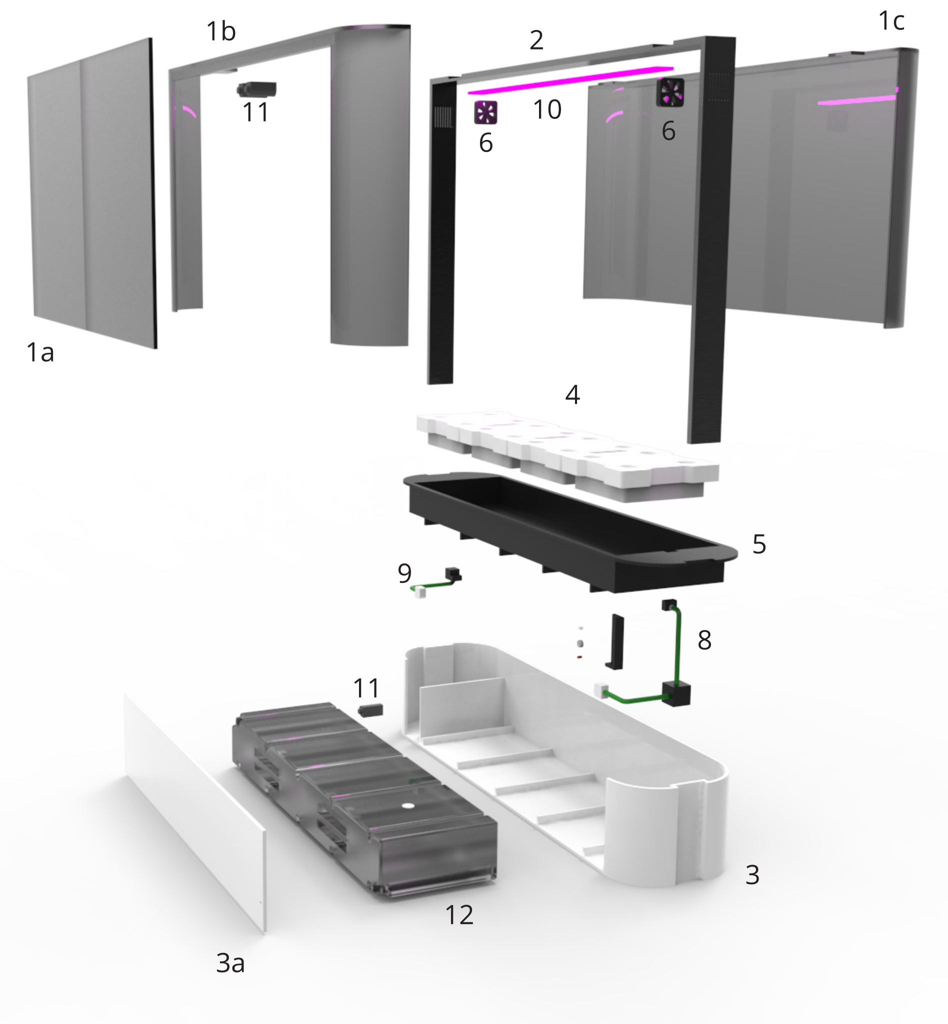


Image 63. Exploded view

Technical components

Microfarm's technical components can be split up in three groups: lighting, irrigation, and ventilation

Lighting

An LED module provides plants with ample light for optimal growth. This light has a pink look because plants mainly require red and blue wavelengths for photosynthesis. It is possible, though, to switch this out with a white light LED module, which has the same light intensity but is slightly less effective due to other, less useful wavelengths being present.

Irrigation

Microfarm's irrigation usse a single pump to guide the water into the growing reservoir at five set intervals during the day. Once the water level reaches a set height of two centimeters, a magnetic switch known as a solenoid opens at the bottom of the reservoir and fully drains into the water tank placed in the bottom of Microfarm.

When the water tank is empty, a red LED will start flashing indicating a refill. Although not elaborated upon, a water measuring sensor is required to do so. Because plants start require more water as they mature, an estimated guideline can be followed for how long a water tank lasts:

Small: ~14 days
Medium: ~10 days
Large: ~7 days

Ventilation

The two fans placed in the frame at the top have two functons; providing fresh air and removing heat from the product. The fans will run continuously while the light is on and regulates the temperature and moisture level inside of Microfarm.


Drain:
Solenoid
Supply:
Pump

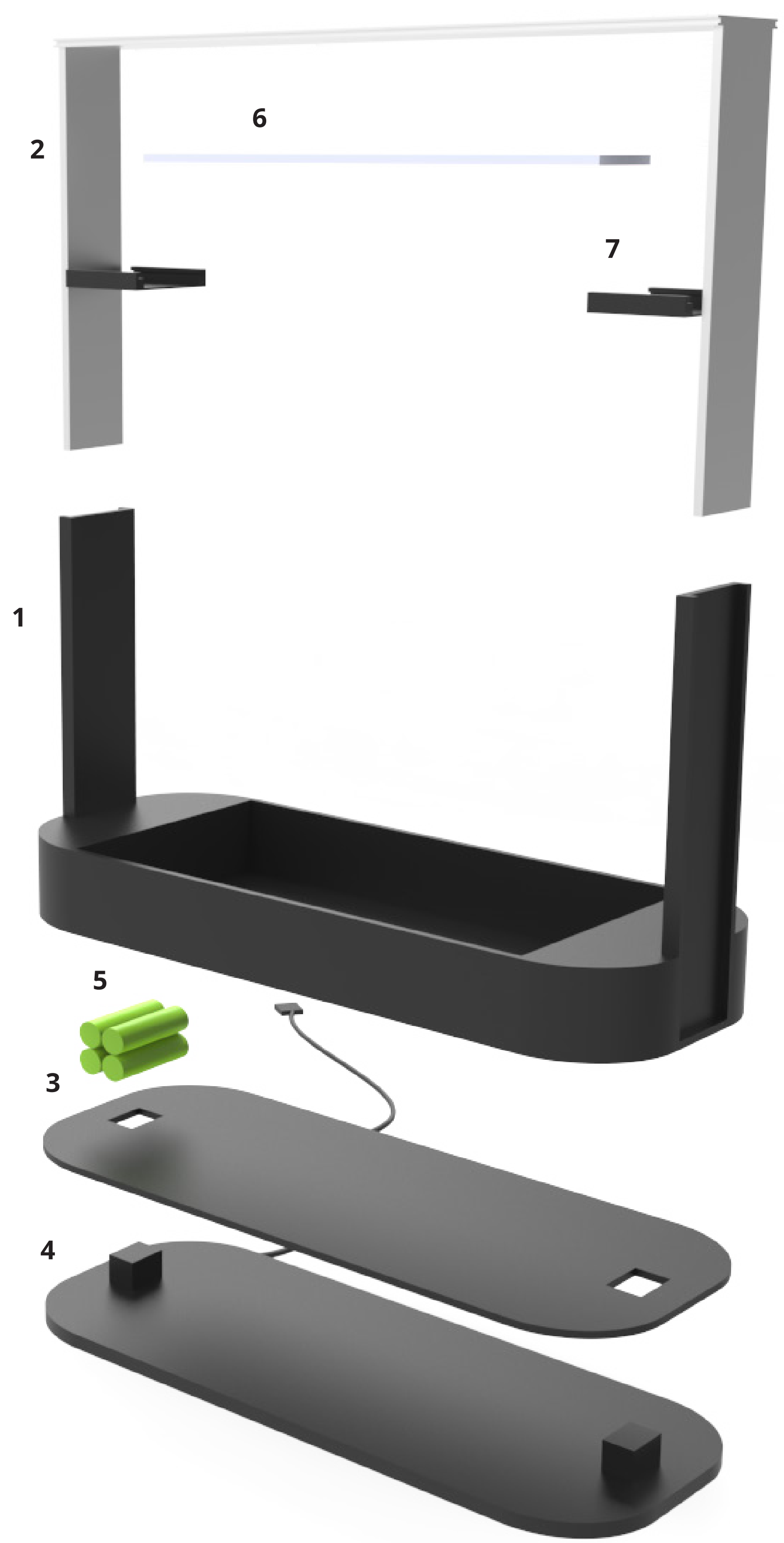
5.2 NANOFARM

This section describes the final design of Nanofarm, a fresh produce condiment basket and plant storage device used by the kitchen staff. Nanofarm can be used by chefs to hold produce from Microfarm and keep it alive for the duration of the working day, but Nanofarm can also be used by the waiting staff to bring the indoor farming experience to the table. This dual function enables the restaurant to create such an experience for guests while minimizing the extra preperation and effort required for them to do so.

Due to its shape, Nanofarm can be easily picked up and carried through a restaurant. A maximum of two growing trays from Microfarm can be placed in Nanofarm and depending on the plant height, it can be adjusted to accommodate taller plants.

Integrated into Nanofarm is a small LED light for keeping plants alive while outside of Microfarm. A battery allows it to remain functional for a limited time when removed from its power supply, which allows it to travel through the restaurant. As mentioned in the introduction, this allows a restaurant staff to bring indoor farming to the guest in situations where the static nature of Microfarm doesn't allow this to happen.

1. Body
2. Aluminium frame
3. Bottom part
4. Charging plate
5. Battery
6. Light
7. Holders

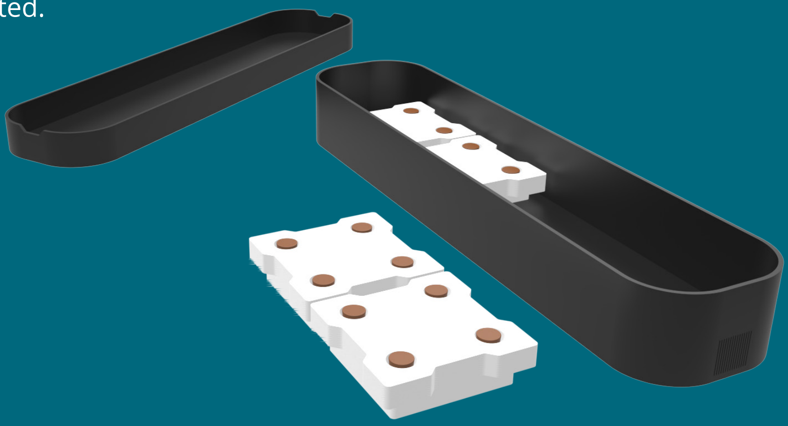


5.3 GERMINATION BOX

Delivered with Microfarm is a germination box that enables the user to start the growing process. Germination is the first step of plant growth and important for sprouting seeds into tiny plants that can be placed in Microfarm.

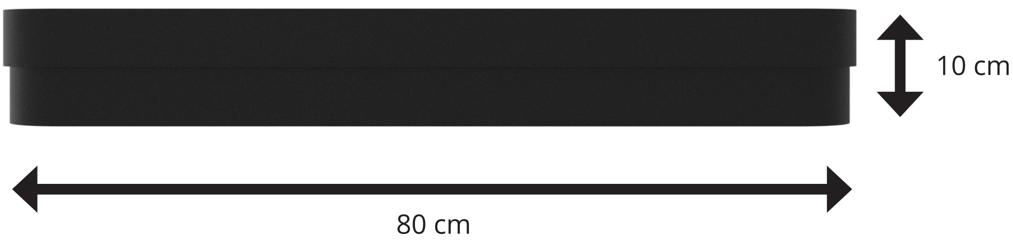
The box consists of a top and bottom part that slide into each other, it is dimensioned in such a way that four growing trays can be placed inside.

The top part is taken off and prepared growing trays are placed inside and given water until the plugs are saturated.



Once closed and stored for five days, the seeds will have germinated and are ready to be placed in Microfarm.


BREAD


10 cm
80 cm

5.4 PRIVA PORTAL

In the scenario, a service that allows the user to order and re-order the supplies needed to grow in the Microfarm is proposed. This platform will act as a central platform where the user can order new supplies such as seeds and fertilizer mixes, learn about how to use the Microfarm, and get in contact with Priva on one platform. In this section, Priva Portal is worked out as a result of the ideation phase and each element of it is explained.

Starting at image 64, on the page to the right, relevant information about the Microfarm should be accessible via, in this case, the homepage of Priva. This is the first interaction the user will likely have with both the product and the company. First impressions last, and its key that potential users aren't scared away by an unattractive website or incomplete information.

The product itself is not the only aspect of the Microfarm that adds value for the user. The website should clearly tell the user what the ordering process looks like and show previews of the other aspects of the Priva Portal, as can be seen in image 65 on the right. This includes the ordering form of the product ("order"), the seeds ("shop") and the tutorial aspect of the portal ("learn"). Receive is not worked out as this is not a very relevant aspect of the portal, but the user should be assured that their order arrives in one piece, in a reasonable time.

Image 64. Microfarm page on Priva's website

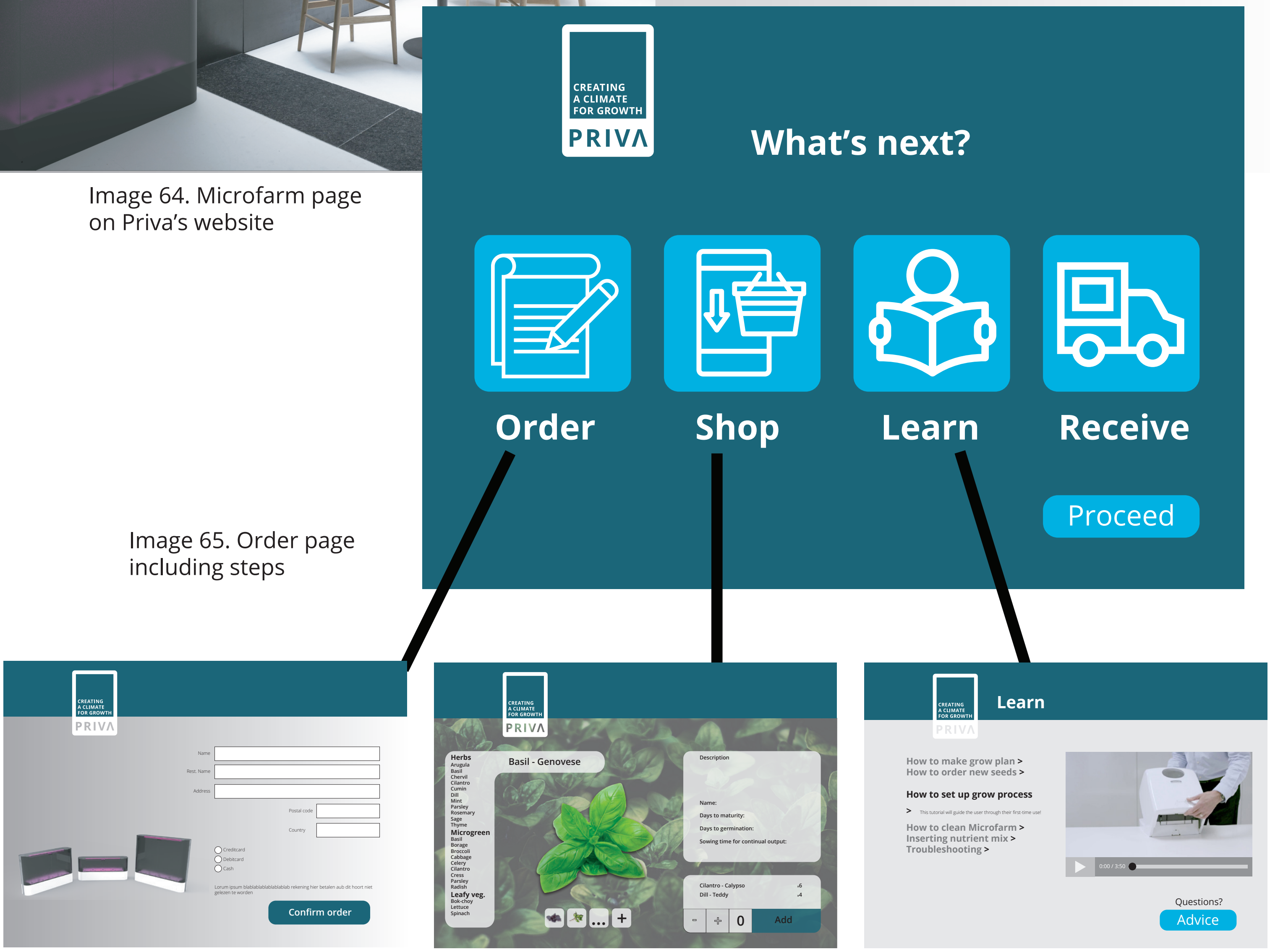


Image 65. Order page including steps

This effect could potentially be achieved by hovering over the icons or clicking on them and having the information appear.

Main page

Once the ordering process is complete, the page in image 66 on the page to the right will become available for the user to access all of the features of the Priva Portal. The remainder of this section will explain important aspects of the portal.

Order page

An important added value of the Priva Portal is the ability for the user to order seeds and nutrients. The order page will display the different types of seeds available for ordering, as can be seen in image 67 on the bottom right page. Included are descriptions of the different elements on the page. Established users can access this page at any time, while new users could see this page first before being led to the main menu if needed.

From appendix I, it was concluded that the Microfarm could work on a single concentrated nutrient solution, which makes it unnecessary to include the option for ordering these seperate. Instead, the user should automatically receive enough to grow for a set period of time, such as 3 months to a half year, with each order assuming full time operation in that period. If it were necessary, image 67 can serve as inspiration, here the crops could be replaced with different nutrient solutions.

Image 66. Priva Portal homepage

Image 67. Order page

Grow plan page

To keep track of when and how long plants have to start growing in the Microfarm, the Priva Portal should be able to generate growing schedules named“Grow plan”. The added value for the user is that they don’t have to spend much time on creating a plan themselves and helps in keeping track of time for them later on in the growing process. When a plant is almost done with growing, the user could see that the following crop has to be germinated. Because not every restaurant will want to, it will not be mandatory for them to make these plans. Two reasons for this could be: they keep track of it themselves, or their plants don’t have to be harvested at a specific time which defeats the purpose of such a plan.

In image 68, on the page to right, the growing plan page is displayed. The contents of the growing plans should be automatically filled in using the ordering information from the order page. The user might order more than can fit at that moment or have multiple farms, which could mean more growing plans are possible. This can be seen on the top left in image 68. On the bottom of image 68 an example of what a specific growing plan could look like can be seen. The three different strokes inside of the growing plan containing plant names could be a solution for a product that has multiple levels, or to replace the page at the top left of image 68.

Learn page

To teach the user how to use their Microfarm, the Priva Portal should include a “learn” page as seen in image FIX ME on the bottom of the right page. As mentioned in the ideal scenario, Priva Academy can be used for educating users of their products. This does not necessarily require them to visit De Lier in person; it is also possible to receive online tutorials. For professionals in the horticultural industry, Priva’s technologies can have a big impact on their daily operations to justify such a trip, while the user of the Microfarm is not impacted significantly enough to justify such a trip. It is more logical that training how to use the Microfarm is done online using tutorials made by Priva Academy, which lowers the threshold and takes away the issue of geography and distance. One of the major added values of the Microfarm concept is that it is both easy to use and time efficient, which makes it more likely that an online tutorial is a sufficient training.

Advice page

There are likely situations in which the user has questions that are not answered by the learn page, issues with their product, or simply in need of advice. When this happens, the user should be able to contact a specialist at Priva that can help with resolving these issues. In the worst case, the malfunctioning of a Microfarm could ruin whatever is growing inside and have a negative impact on the user.

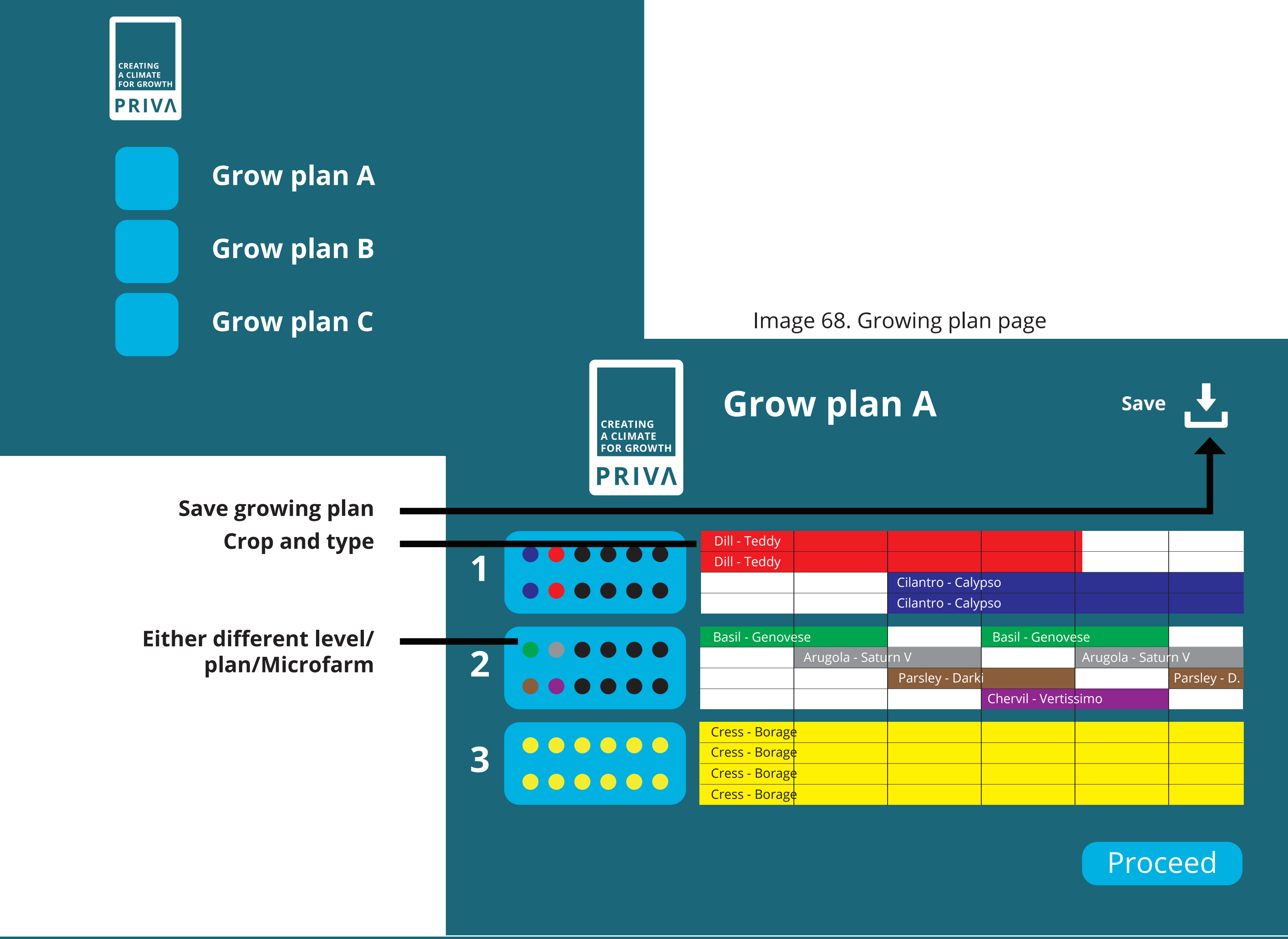


Image 68. Growing plan page

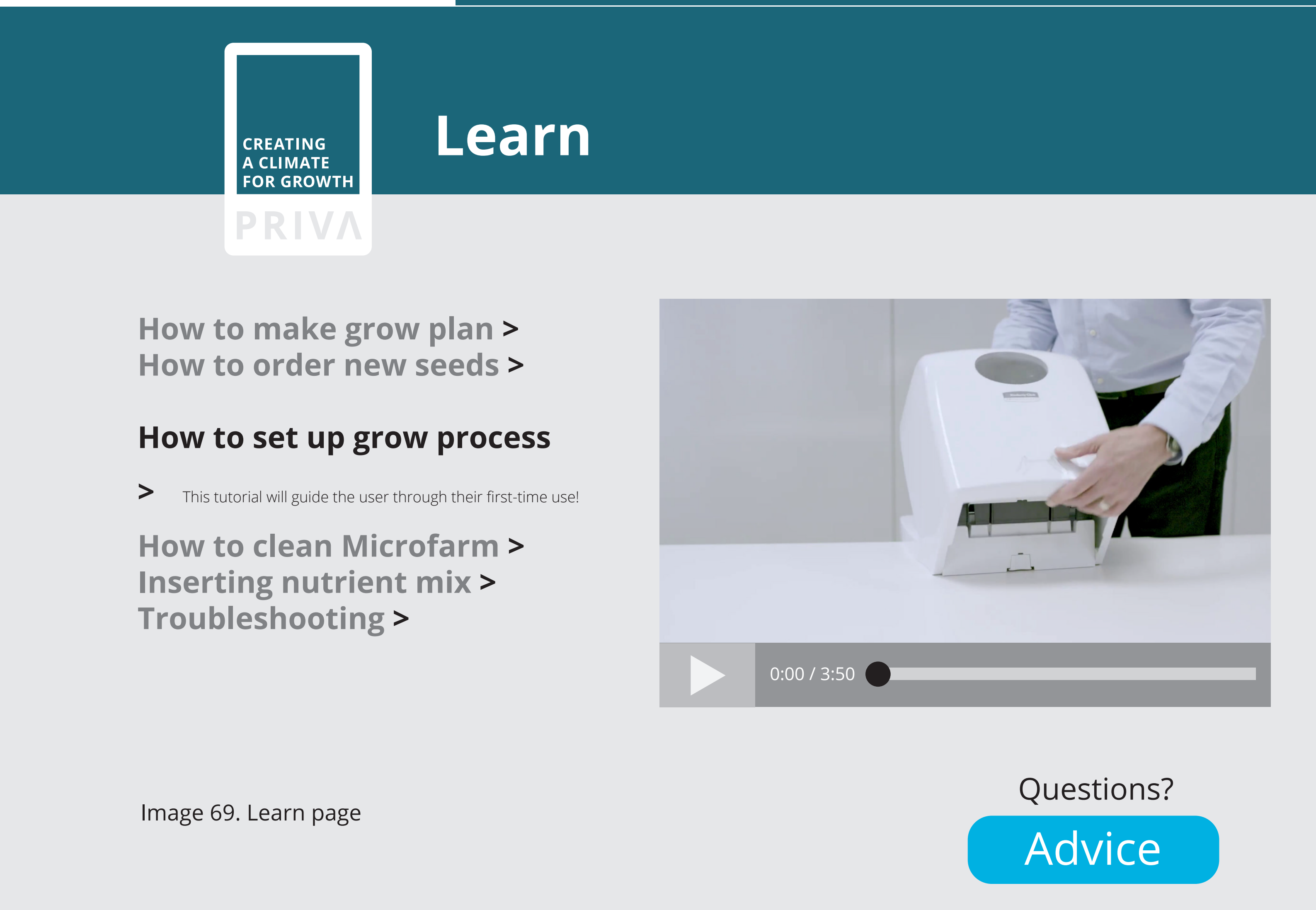


Image 69. Learn page

Delivery

As the last step of the service provided through Priva Portal, the Microfarm and its contents have to be delivered to the user.

Consumables

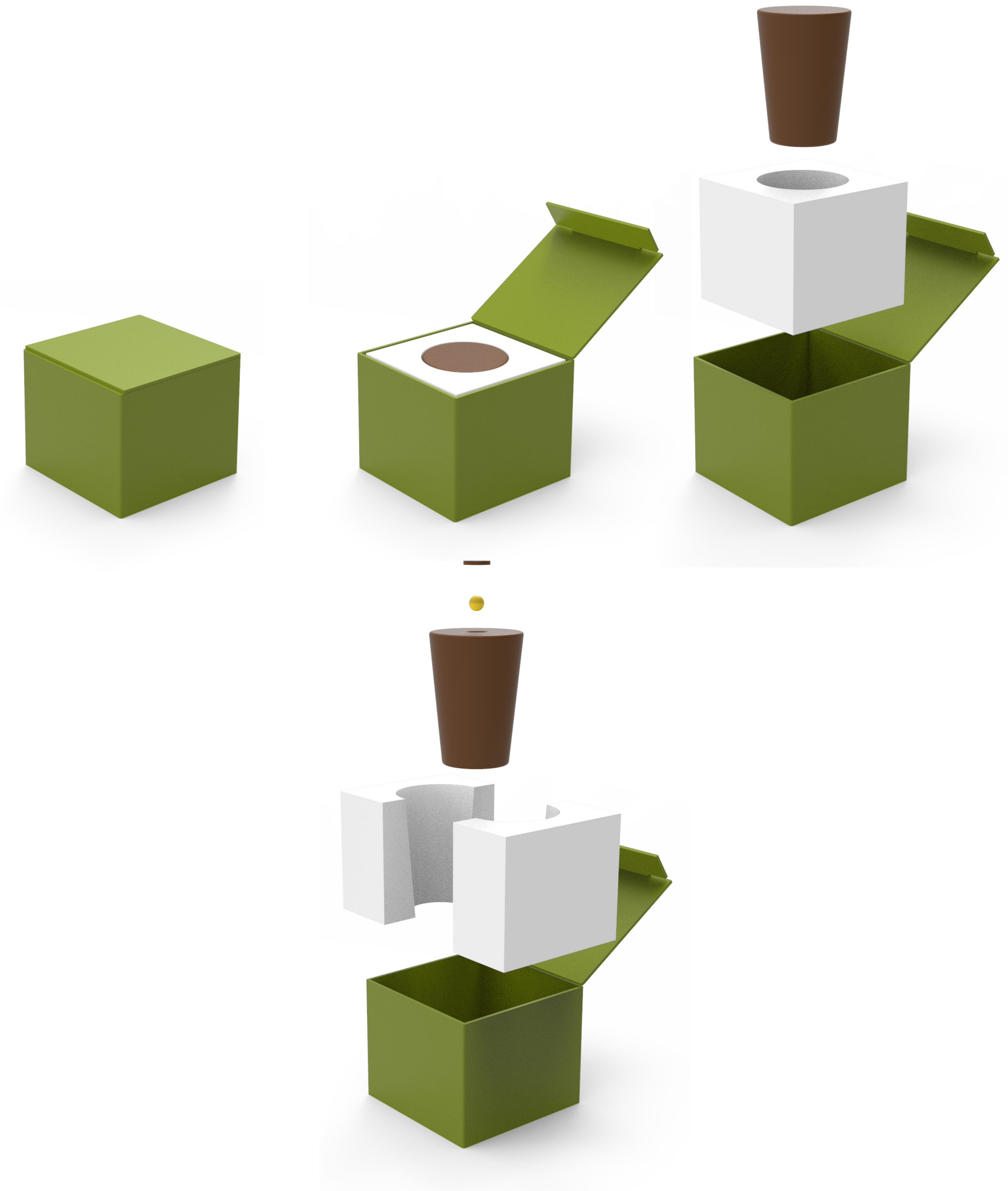
Normally seeds and plugs are bought in larger quantities, hundreds at a time for both, due to the amount of volumes that are involved in the horticultural industry. Concentrated nutrient mixes are mostly bought as dry minerals and mixed afterwards, which saves costs on shipping due to the lower mass. For the future user of the Microfarm, these quantities are unrealistic and their normal method of delivery requires time to be invested into preparation for use.

Nutrients are available in liquid forms and in small quantities, this aspect will not be covered any further as this seems to work already. However, for the plugs and seeds, a solution was generated that can be on page FIX ME to the right. To deliver these two components in a convenient way, the plug and seed are combined and can be placed in the product as is. The seed/ plug combination removes the need for the user to separately acquire seed and plug, and takes away the user step of having to manually combine them. Instead, they are delivered together in a box, which is designed in such a way that the user recognizes which type of seed is contained inside. Important in the design of this box is that the contained plug cannot be damaged through transport, which will cause it to likely fall apart, or water is introduced which would start germination before being placed in the product. In this case,

Product itself

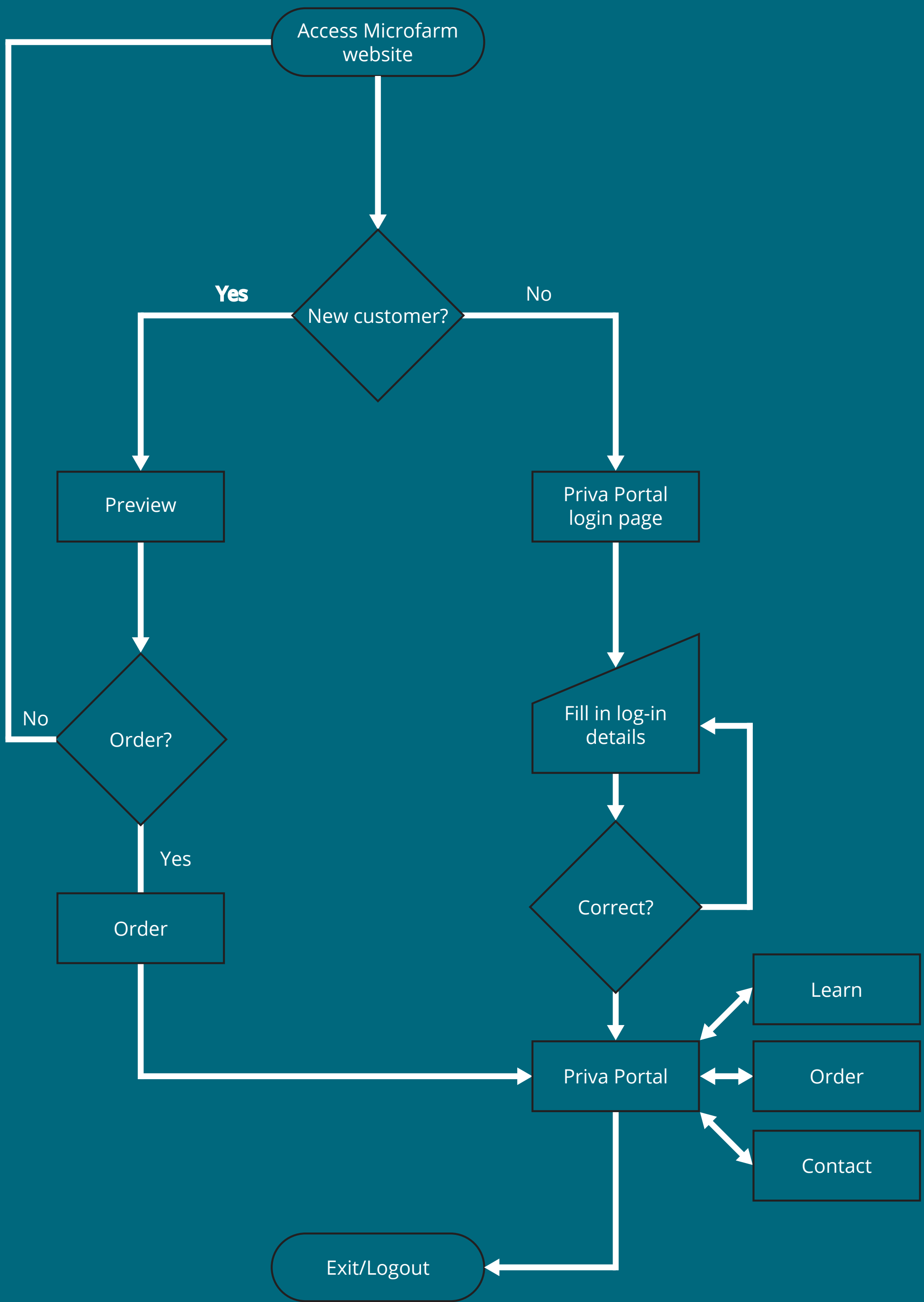
For delivery of Microfarm, it is recommended that Priva create this service themselves. Although it is possible to send as a large package via the postal system, a more personal approach by having it delivered by Priva is consistent with the little input, high service idea and fits the leasing business model described in the chapter FIX ME. Providing such service ensures Priva can provide their service without relying on other parties and keeps the lines between the parties short. Such service is also convenient for other Priva Portal related aspects, such as the delivery of the above mentioned seed and plug combination, the maintenance of a user's Microfarm, or to provide personal assistance with any of the aspects of use.

To the right: Image 70. Seed and plug combination in its package



Flowchart

The flowchart below in figure 71 illustrates how new and established users of the Priva Portal go through the process of using this service. It aims to clarify the different paths a new and established user goes through by withholding most of the Portal's functionality for users that have not purchased the Microfarm yet. This keeps competitors and non-customers from benefiting of the Portal's functionality.



To the right: Image 71. Priva Portal flowchart

5.5 BUSINESS MODEL

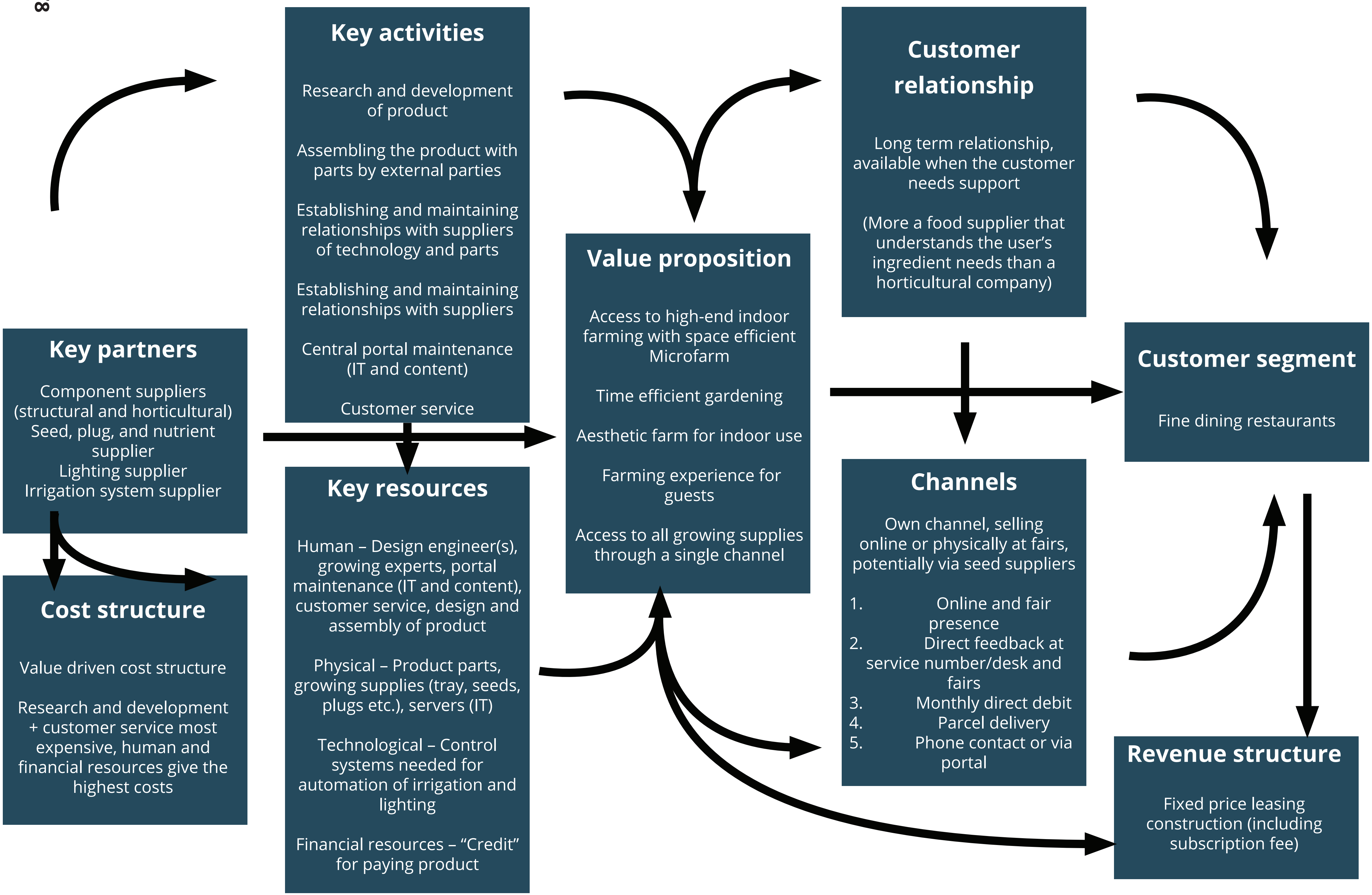
To the page on the right, the Business Model Canvas is filled in incorporating the aspects found above. The most important block of the model is undoubtedly the so-called value proposition, which reflects the relevance of the Microfarm as a product for the user as well as addressing the needs they have when using this product. From the value proposition, the rest of the canvas can be placed in perspective.

Cost price

In iteration 1 it was estimated that the total cost price of the product would be around €10.000 to €12.000, based on the price of a competitor and input from Matthias van de Berg. For the final design it is difficult to determine this price because the materials and sizes have changed, which makes it difficult to estimate what the cost price of the components it. Choosing plastic as the dominant material means that more money has to be invested in injection molds and that the investment that has to be earned back is higher in the beginning. What effect this would have on a leasing price is unclear.-

Implications and conclusion

Although the Business Model Canvas mainly serves as a communication and support tool for the business model of the Microfarm, formulating the value proposition and the underlying mechanism helps in painting a realistic picute of how the Microfarm will have to generate value for the user and revenue for Priva. Determining that the product is strongly value driven reemphasizes the need for maximizing user value, much of which has been covered in the previous sections as well.


Key partners
Component suppliers (structural and horticultural)
Seed, plug, and nutrient supplier
Lighting supplier
Irrigation system supplier
Key activities
Research and development of product
Assembling the product with parts by external parties
Establishing and maintaining relationships with suppliers of technology and parts
Establishing and maintaining relationships with suppliers
Central portal maintenance (IT and content)
Customer service
Key resources
Human – Design engineer(s), growing experts, portal maintenance (IT and content), customer service, design and assembly of product
Physical – Product parts, growing supplies (tray, seeds, plugs etc.), servers (IT)
Technological – Control systems needed for automation of irrigation and lighting
Financial resources – "Credit" for paying product
Cost structure
Value driven cost structure
Research and development + customer service most expensive, human and financial resources give the highest costs
Value proposition
Access to high-end indoor farming with space efficient Microfarm
Time efficient gardening
Aesthetic farm for indoor use
Farming experience for guests
Access to all growing supplies through a single channel
Customer relationship
Long term relationship, available when the customer needs support
(More a food supplier that understands the user's ingredient needs than a horticultural company)
Channels
Own channel, selling online or physically at fairs, potentially via seed suppliers
1. Online and fair presence
2. Direct feedback at service number/desk and fairs
3. Monthly direct debit
4. Parcel delivery
5. Phone contact or via portal
Customer segment
Fine dining restaurants
Revenue structure
Fixed price leasing construction (including subscription fee)

Implementation plan

The Business Model Canvas describe the who, what, and why's, however, how will Priva introduce the Microfarm and how will they validate whether it is a success? The following section describes the implementation plan of the business model from the lef, and is split up in several phases.

Phase 0 (1 year)

The first phase is conducted before the Microfarm is introduced to the market, and has the aim of validating whether the product and business model are fit to the user. Specifically, the value proposition, cost stream, and revenue stream are interesting at this point because the question whether the user will want to pay for the value that is provided is most important for determining the success of the product (plus service) as a whole. Through this process, the customer segment and the relationship between them and Priva are also validated more precisely. The end of this phase is marked by a go/no go decision that decides whether the development will continue or be ceased. To make conclusions on the short term regarding these topics, an iterative approach has to be taken that determines which aspects of the design provide value, require adjustment, or have to be removed.

The Lean startup method by Eric Ries is well suited to this phase; the Microfarm contains aspects that cannot be tested within the scope of this project but that are important to validate and improve the design and business model. Important aspects include: use on the long term, cost price, interaction and experience with the Priva Portal service, and user satisfaction with the quality and yield of the produce grown inside of the Microfarm. The Lean startup method aims at validating the Business Model Canvas through the use of a MVP (Minimum Viable Product), which is described by Ries as a "version of a new product which allows a team to collect the maximum amount of validated learning about customers with the least effort". Through development of these MVPs, the value that customers are willing to pay for and how it manifests itself in the design are understood and worked out.

Potential users working close to Priva, like the participants in the research on page FIX ME, are ideal participants for this phase because the short distances allow Priva to build up a network and keep close contact. The distance between Priva and user is also best suited for testing the delivery and service aspects, such as Priva Portal, because this service will require a somewhat close proximity between the user and the location from which it is provided.

At the end of this phase, a go/no go decision is made to continue development of the Microfarm or not. Although unfortunate, it is possible that a decision is made to not continue the project as is, however, this will have helped Priva in two ways: saving them money or creating new product/service ideas (known as a pivot). It is recommended for Priva to generate knowledge about the methodology to be able to effectively initiate the process themselves.

Phase 1 (1 year)

Granted that the Microfarm makes it past phase 0, the Microfarm and Priva Portal are ready to be developed and produced into a full fledged product and service. Because phase 0 mainly aims at quick iterative steps, where change is always possible if it adds value, it would not have been wise to embody the design aspects in this phase as it could end up being a waste of time and resources. However, in phase 1, the so-called key activities, key partners, and key resources will become important in making all aspects of the embodiment come together properly.

The design resulting from phase 0 will force the development team to make an inventory of what activities are responsible to deliver its value proposition, what kind of partners are required and which resources are available for development of the product. Resulting from this process, the parts required for the product are obtained and assembled into its final form. The aim of this activity is to create partnerships that ensure the right quantity can be delivered for the right price (thus beneficial to the cost structure), and includes suppliers of lighting and irrigation equipment, for instance. However, this is not only done for the physical product, but also the digital component known as Priva Portal, where partnerships have to be created with companies that can provide the platform (IT), seeds, and concentrated nutrient mixes that are required for the product. These partnerships will be important to satisfy the user's demands, for instance when they want to start growing more than is available at that moment, or want other functionality from the platform over time. Because Priva has experience with manufacturing, assembly, and implementation of such projects, this process should not be too difficult.

The end of phase 1 should yield a design that is production ready and in accordance with the business model that is envisioned at the end of phase 0. Again, this product should be tested before being released into the market with similar users as phase 0. The go/no-go moment at the end of this phase has to do with its accordance to the business model; although key resources, partners, and activities can change, they cannot have too negative of an effect on the balance between the cost structure and the value proposition. Examples of these are the product or certains parts being too expensive to justify the value proposition or removing important value based on the costs of individual components. In a no-go scenario, phase 1 should be continued till satisfactory results are yielded, but care should be taken to understand how the value proposition and cost structure interact with each other to prevent the development team from creating tunnel vision and getting stuck in this phase.

Phase 2

The only unmentioned block left from the Business Model Canvas is concerned with the channels through which service is given to the user and where the product will be marketed, sold, delivered, and paid. This also includes the overall marketing and communication strategy behind the product. Although placed after phase 1, it has to be initiated somewhere during phase 1 to ensure that once the product is ready for production, it is also ready to be delivered to the customers.

First it is important to establish a strong brand identity that customers and users will recognize the product with. It is realistic to consider whether the Microfarm should be sold under a different name and company; Priva's large-scale horticulture market is much different than the restaurant market of the Microfarm. Priva's name is not known in the restaurant market and a new company would enable more freedom to establish a brand identity that operates independently from Priva and is observed by the customer as such.

In this phase, the following channels will have to be created in order for the purchase and post-service to take place:

Service channel

The location on the web where the Priva Portal will be found and which will enable the user to use the service

Showroom channel

Where the future user can "see" the product. Online is a given, but a physical presence should also be created through so-called horeca fairs, where the restaurant industry comes to discover new trends and solutions.

Sell channel

Where the user will buy the product, this is likely done online and requires Priva to partner up with a so-called payment service provider to ensure users can purchase online, and service fees are withdrawn monthly through direct debit.

Delivery channel

The delivery of the Microfarm and its consumables through one dedicated party, whether this be Priva or a partner.

Important in setting up these channels is to keep it simple for the user, which reflects the little input, high service principle of the Microfarm. Intrinsic of the fixed price leasing construction is that the user is given the impression that they are always working with one company/channel, which makes it straightforward for them to know who to contact and where to do so.

The end of phase 2 should coincide with the end of phase 1, and the implementation plan should be concluded with market introduction of the Microfarm.

5.6 RECOMMENDATIONS

Pilot testing

If Microfarm were to be developed it is recommended, as described in the implementation plan, that a pilot test is held and a network is created with restaurants that would want to participate. This would increase the word of mouth between restaurants and would provide priceless information for iterating the design/

Use of plastic over time

For now polycarbonate is chosen for the plastic parts of Microfarm (besides the growing tray), because of its excellent optical properties and high operating standards. However, it is not sure how the combination of light, heat, and moisture will affect the plastic over a long time. It is recommended to research what happens over time and if this is acceptable for the overall aesthetics of the product.

Germination unit

Not much time was left after the last iteration, the germination unit proposed is likely not the best solution and can be improved. In previous versions of Microfarm this germination space was placed in the product, but was taken out as it was deemed that this would be inefficient to do for every unit. Unless every plant were to be harvested and replanted at the exact same moment, much less germination room would be needed. A major problem with the current design would be that it is prone to temperature changes and that requires a decent amount of storage space.

Water reservoir

The water reservoir is now presented in a way that is feasible, but ideally this mechanism would be worked out in a way that it doesn't require the user to reconnect the hoses themselves. A coffee machine water tank is one of the first ideas that jumps to mind, but a hose connection was not considered at any point although this could also be a feasible solution.

Plant space

In the last iteration, the plants are perhaps a bit too close to the top cover on the sides and might be impeded at later stages of growth. There is also a risk that the top covers will become dirty due to plants rubbing against them. It is recommended that this be solved by either slightly increasing the thickness, minding that doing so will make it portrude more into the restaurant, or changing the type of growing tray.

Nanofarm

At this moment Nanofarm is still relatively complex. If this design is considered for further development it would be interesting to either research whether this adds value in a restaurant to justify the cost, or to see if a more low tech solution without any light would also be sufficient in conveying the indoor farming experience.

Business model

In the current context Microfarm would preferably be leased as this fits well with the little input high service for restaurants. However, the final design is much smaller and perhaps also interesting for home users as the investment cost would be much lower if most components were made of plastic (but initially higher on Priva's side due to investments in injection molds). It is assumed that the skill level of restaurant users is quite similar to that of home users, and it would be interesting to research whether this is an interesting market.

5.7 CONCLUSION

Indoor farming and vertical farming are up and coming technologies, yet there are little to no solutions that are provided on a small, individual consumer sized scale. In this graduation project, it is concluded that such a solution is feasible on a small scale and that restaurants are an interesting user group for indoor farming because it can provide benefits besides food production. Also, the hydroponic method of cultivation has many elements that lend itself to user friendly handling.

There are, however, concerns that Microfarm in its current state will not provide enough value to outweigh effort a restaurant will have to invest both in terms of money and staff. The realistic yield versus how much a restaurant would want to use is also very critical as this dictates how well a restaurant could use it in their day-to-day operations. The last point, freshness of food would be one of the major selling points, but here in The Netherlands there is a unique situation where high quality food is grown very efficiently and for a low price, right around the corner. The fear is that if there are cheaper alternatives that can be marketed to guests as being “fresh” Microfarm would not be needed for to drive home this point.

5.8 PROCESS EVALUATION

Looking back at the personal project brief and planning it can be concluded that most of the actions that were planned were also performed. This shows that the overall process that was envisioned was realistic and feasible within the time given for the project. However, the project did last a bit longer and that has to do with specific choices made in certain sections that forced more time to be taken.

The analysis phase saw no issues and the result was both useful on the short term - determining a suitable user group- and longer term - having a solid basis for the physical product and understanding of the indoor farming context. In the user research phase the largest issue was recruiting potential participants and it was found that the interview style, an emotional collage exercise, was a lot to ask from restaurants to participate in due to the amount of time this would require them to invest. This was a blessing in disguise, though, because it taught a lot about how a restaurant works (they have no time) and after two restaurants there was realistically enough information about the context to ask more specific questions about the future use, something that wouldn't have happened the way it did if they all had participated. Going into ideation, the mistake was made to fixate on a certain type of design (closet size), which yielded concepts that weren't necessarily to different from each other. At this time, the type of climate and irrigation system were also determined, which was not a problem considering these technical solutions were not novel nor would it affect the design too much. Next, developing a business model and creating the prototype was an eye opener and brought to light that the design was not well suited to the context that was found in the user research, because the focus was still on efficiency, although the value of the product was in the experience. This also raised questions about effectively communicating this experience to guests, which is difficult to do if Microfarm is just is one place. Taking into consideration this idea, the final design of Microfarm and Nanofarm were realized.

5.9 REFLECTION

When I first started out with this graduation project I hadn't imagined the result being anywhere near what it turned out to be! This project wasn't an existing design brief set up by Priva or by the supervisory staff, but rather my very own graduation project. Overall I am very satisfied with the result, although the process of getting to this result was sometimes a bit bumpy.

Most of the challenges in this project had to do with me creating my own project, because this effectively meant that there wasn't a red line that I could somewhat follow. This gave me a lot of freedom to make my own choices and learn about the topic of indoor farming, which is something I really wanted to get out of the project, but this freedom also made me crash into myself at points.

My chair and mentor have other academic backgrounds within industrial design than I do, which is one of the reasons I chose them, but this meant that there were moments they had different expectations of the project than I did. I personally didn't see this as an issue because I recognized the value in their feedback and was aware that it would bring the design to a next level, but because of a combination of my IPD background, personality, and ownership of the project I found it difficult to flip that switch immediately.

I find it difficult to flip that switch because in that situation I am often stuck in my own train of thought and prioritize the wrong things because of this. From this I learned that I need to communicate more often with the people I work with and that I shouldn't allow myself to work for extended periods of time without communicating. Another thing I realized through this, and I basically already knew from spending long times alone, is that I really do not enjoy working by myself. Motivating myself to go on became more difficult as the project and the complexity progressed, which not only resulted in some of the issues described above, but also in general apathy. Of course this partly has to do with the reality that my project was performed during the summer, but this has made me realize that in my future as industrial designer, I would very much like to work in a team on a project basis, like a design bureau, because I feel that this type of setting works well with my personality and way of working.

On the bright side, I have gained a lot of confidence doing this project by myself and recognize that once I do know where to go I can deliver high quality work. I think that, although it still has to cultivated much more, I have a wide skillset and have shown that I am able to deal with complexity.

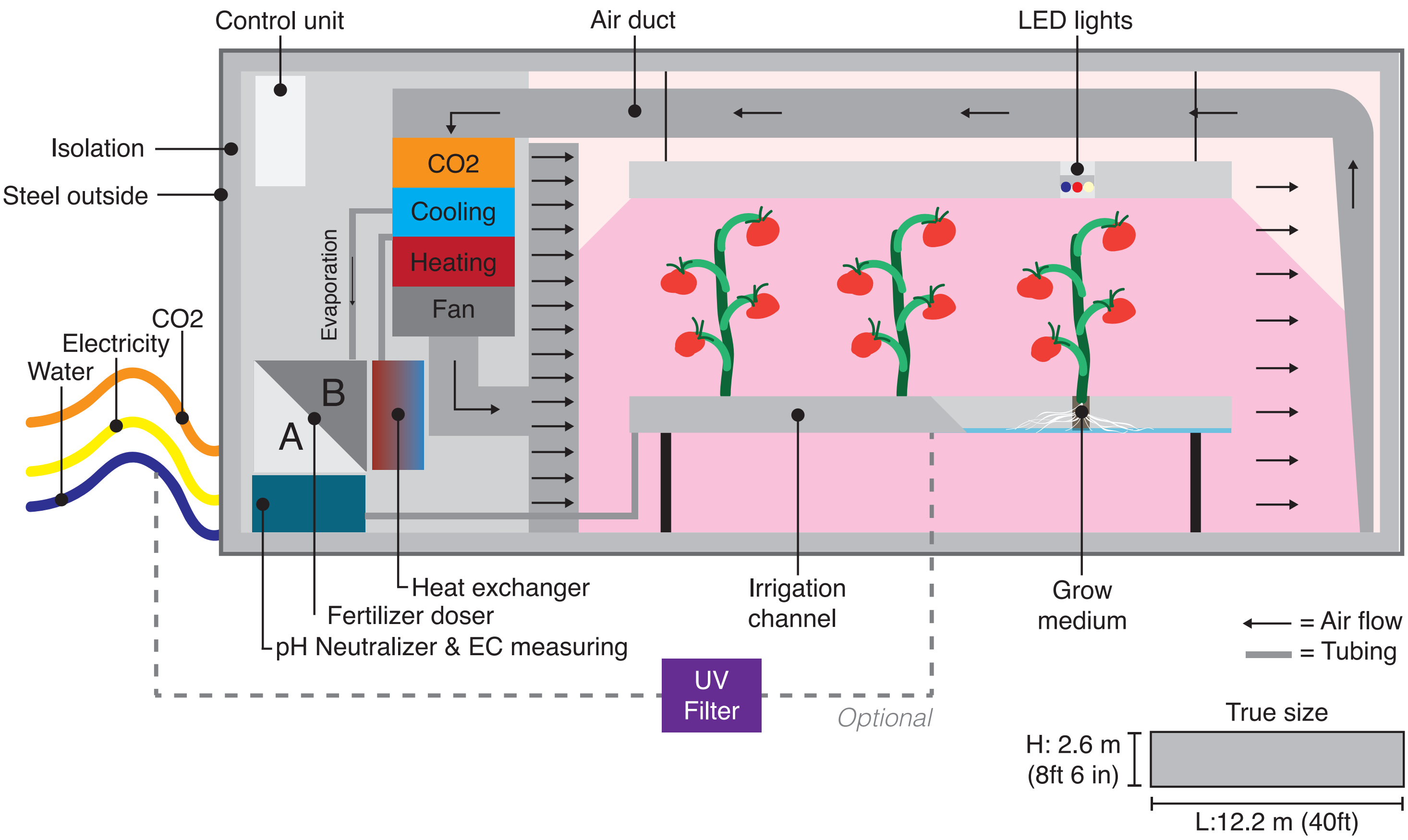
REFERENCES

[1] Roozenburg, N.F.M., Eekels, J. (2011) Productontwerpen, structuur, en methoden 2nd edition
[2] Retrieved April 19, 2019, from https://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond
[3] Kotler, P., & Armstrong, G. (2018). Principles of Marketing. Harlow: Pearson Education Limited.
[4] Sanders, E.B.N., Stappers, P.J., (2012) Convivial Toolbox
[5] Alberts B, Johnson A, Lewis J, et al. (2002) Molecular Biology of the Cell. 4th edition Retrieved April 2, 2019
[6] Photosynthesis. (n.d.). Retrieved April 26, 2019, from https://www.rsc.org/Education/Teachers/Resources/cfb/Photosynthesis.htm
[7] May, P. (n.d.). Chlorophyll. Retrieved April 26, 2018, from http://www.chm.bris.ac.uk/motm/chlorophyll/chlorophyll_h.htm
[8] Paris, Q. (1992). The von Liebig hypothesis. American Journal of Agricultural Economics, 74(4), 1019-1028.
[9] Sze, H. (2008, November 13). Plant Growth & Development. Lecture presented in University of Maryland, College Park. Retrieved April 2, 2019, from https://www.life.umd.edu/classroom/BSCI442/Lec17_Reprod_DevF08.pdf
[10] Wickers, D. (1978). Indoor farming. London: J. Friedmann
[11] Despommier, D. (2010) The Vertical Farm. Martin's Press
[12] Kozai, T., Niu, G., & Takagaki, M. (2016). Plant factory an indoor vertical farming system for efficient quality food production. Amsterdam: Academic Press.
[13] Despommier, D. (2013). Farming up the city: the rise of urban vertical farms. Trends in biotechnology, 31(7), 388-389.
[14] Despommier, D. (2011). The vertical farm: controlled environment agriculture carried out in tall buildings would create greater food safety and security for large urban populations. Journal für Verbraucherschutz und Lebensmittelsicherheit, 6(2), 233-236.
[15] Pirog, R. S., & Benjamin, A. (2003). Checking the food odometer: Comparing food miles for local versus conventional produce sales to Iowa institutions.
[16] Menezes, M. C., Costa, B. V. L., Oliveira, C. D. L., & Lopes, A. C. S. (2017). Local food environment and fruit and vegetable consumption: An ecological study. Preventive medicine reports, 5, 13-20.
[17] See 16
[18] Läubli, D., & Ottink, N. (2018, April). In fresh-food retailing, quality matters more than price. Retrieved from https://www.mckinsey.com/industries/retail/our-insights/in-fresh-food-retailing-quality-matters-more-than-price
[19] See 12
[20] Hershey, D. R. (1994). Solution culture hydroponics: history & inexpensive equipment. The American Biology Teacher, 56(2), 111-118.
[21] Nath, A. (2016). Post harvest management and production of important horticultural crops. Jodhpur: Scientific.
[22] lights
[23] Retrieved October 16, 2019, from https://www.vernier.com/news/2018/09/04/what-are-the-best-light-sources-for-photosynthesis/

[24] Retrieved April 19, 2019, from https://www.wur.nl/en/newsarticle/LED-lighting-in-greenhouse-horticulture.htm
[25] An Overview of Hydroponic Nutrient Management for Every Grower. (2019, January 10). Retrieved from https://university.upstartfarmers.com/blog/overview-hydroponic-nutrient-management
[26] See 25
[27] See 12
[28] Retrieved October 16, 2019, from https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide
[29] Retrieved April 19, 2019, from https://www.farmshelf.com
[30] Ohr, T. (2018, February 5). Infarm raises €20 million to strengthen its position as Europe's urban farming leader. Retrieved April 19, 2019, from https://infarm.com https://www.eu-startups.com/2018/02/infarm-raises-e20-million-to-strengthen-its-position-as-europes-urban-farming-leader/
[31] Grove. (n.d.). Grove Ecosystem - Grow Fresh Food In Your Home. Retrieved April 19, 2019, from https://www.kickstarter.com/projects/grove-ecosystem/grove-ecosystem-grow-fresh-food-in-your-home
[32] Retrieved April 19, 2019, from https://replantable.com
[33] Retrieved April 19, 2019, from https://www.growx.co/our-greens
[34] Retrieved April 19, 2019, from https://supercloset.com**]**
[35] Retrieved April 19, 2019, from https://eu.clickandgrow.com/collections/products
[36] Retrieved April 23, 2019, from https://www.foodlog.nl/artikel/we-eten-minder-groente-en-fruit-behalve-in-restaurants/
[37] Retrieved April 23, 2019, form https://www.khn.nl/website/inspiratie/trends/puur-gasten-willen-het-pure-spul
[38] Retrieved April 23, 2019, from https://www.transparencymarketresearch.com/smart-indoor-gardening-market.html
[39] Retrieved April 23, 2019, from https://www.insideoutcayman.com/2018/05/23/the-growing-trend-of-indoor-plants/
[40] Retrieved April 23, 2019, from https://www.agritecture.com/blog/2018/11/26/indoor-farmers-romaine-calm-after-e-coli-outbreak
[41] Retrieved October 15, 2019 https://wetten.overheid.nl/BWBR0011700/2016-07-01
[42] Retrieved October 15, 2019 https://www.engineeringtoolbox.com/relative-humidity-d_895.html
[43] Esmeijer, M. (1999). CO2 in greenhouse horticulture. Aalsmeer/Naaldwijk: Applied Plant Reseach.
[44] Retrieved October 15, 2019, from https://www.health.harvard.edu/staying-healthy/blue-light-has-a-dark-side
[45] Retrieved October 15, 2019, from http://businessmodelalchemist.com/blog/2005/11/what-is-business-model.html

APPENDIX

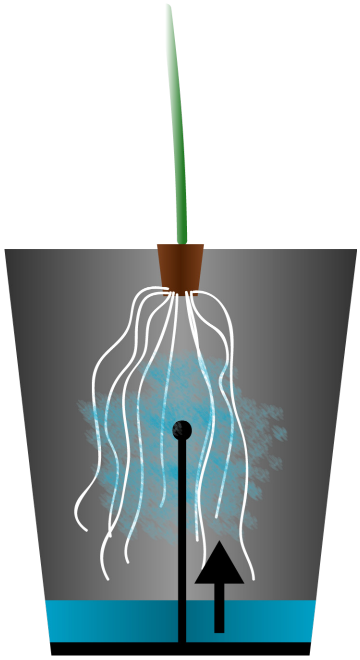
B. GROWING CONTAINER DESCRIPTION



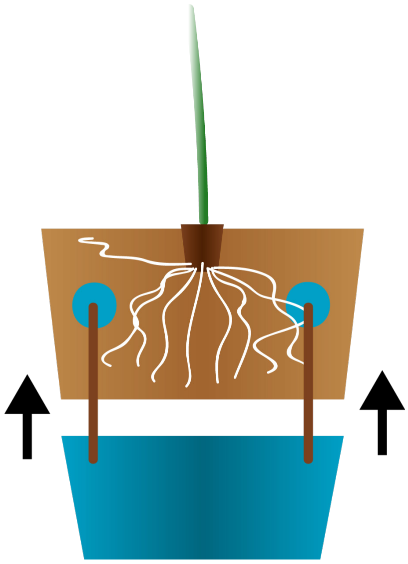
Control unit
The brain of the Grow Module, it runs and regulates all systems needed.
Fan
Airflow in container is created using a fan. This airflow ensures an even spread of CO_2 levels, the temperature, and relative humidity.
Air duct
The air duct is responsible for transporting the air back once it has entered the growing chamber.
LED Lights
LED lights create artificial lighting that plants need in order to perform photosynthesis.
CO2 regulator
When the air comes back from the growing chamber, the CO_2 content is lower than when it entered because plants use CO_2 for photosynthesis. This device, connected to a tank, adjusts CO_2 back to an optimum level.
Heat exchanger
To keep the heating and cooling coils at the right temperature, a heat exchanger is used. This process is similar to the cooling of a refrigerator.
Cooling coil
The air being returned through the air duct contains moisture released by plants, this moisture can be reclaimed by cooling the air below the optimum temperature, which creates condensation (like an air conditioning). This condensation can then be reintroduced into the irrigation system for watering plants.
Heating coil
After the air is cooled for moisture removal, the temperature is lower than the optimum temperature for growing. This means that the air has to be warmed up before it is used again.
Irrigation channel
This channel carries the nutrient-rich water to the growing trays, which will transport it to the roots of the plants.
Growing trays
The growing trays contain the growing medium and plants. The tray is hollow and fills up with nutrient rich water that comes in contact with the plant roots extending from the growing medium.
Grow medium
The choice in medium can vary and has effect on how plants receive nutrients. This medium can be seen as an insert containing the seed of the plant being grown. In the Grow Module's hydroponic system it can be done with Rockwool inserts that fit into the irrigation channel.
Isolation
To ensure that the temperature stays stable inside of the growing chamber, isolation is used to shield it from outside environmental conditions.
Steel outside
The outside of the Grow Module is a shipping container made of steel.
UV Filter
In some applications, a UV filter can be used to clean bacteria from excess water drained from the irrigation channel for reuse.
Fertilizer doser
Two nutrient tanks supply nutrients to a mixing chamber before being sent to the irrigation channel. It contains two tanks, because certain minerals will precipitate when in contact.

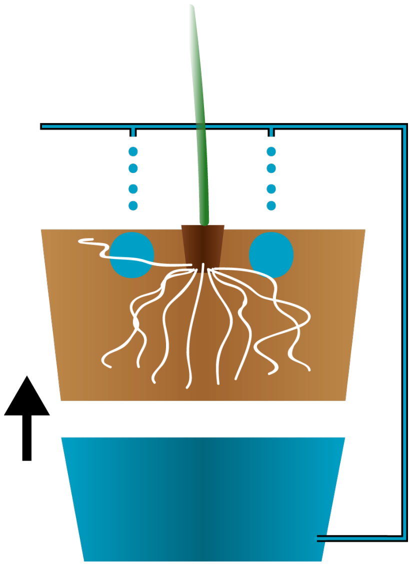
Aeroponics

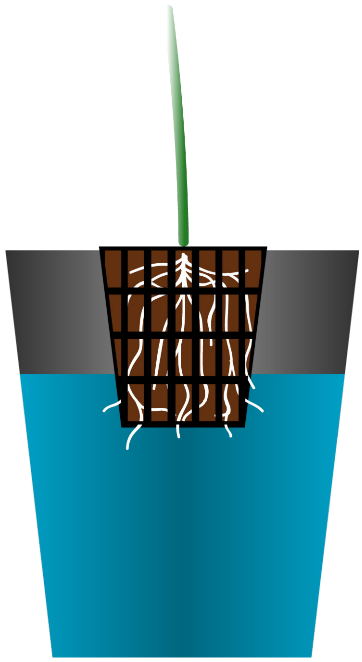
Instead of constantly being in contact with the nutrient/ water solution, the roots are periodically saturated with a fine nutrient solution in form of a mist. This ensures proper aeration and is proven to be effective at smaller scales.



C. COMMON HYDROPONIC SETUPS







Passive sub irrigation

Water and nutrients are absorbed from a lower situated reservoir into the growing medium through a principle called capillary action. This can be achieved by using a wick or capillary mat.

Top irrigation

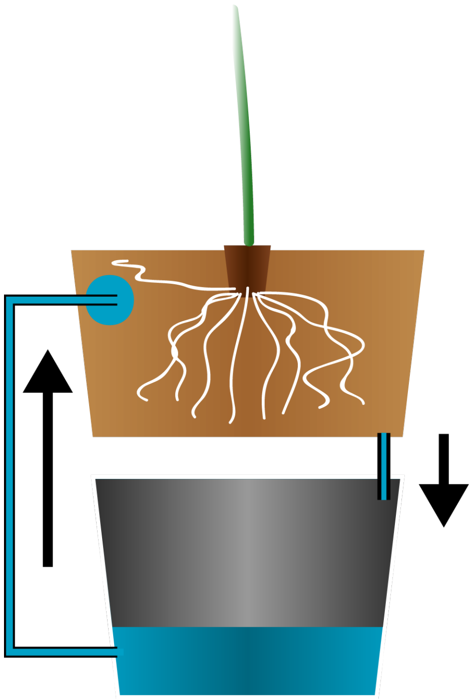
The nutrient solution is pumped up and fed from above. Providing a stream right above the medium can do this, but it using a probe is also not uncommon, as can be seen in the field test in the first chapter. The drain water can be fed back to the solution tank.

Deepwater culture (DWC)

Similar to static solution culture, the difference is that DWC uses a mesh pot filled with a medium that holds the roots and allows oxygen to reach these . The roots then grow out of this medium into a solution. Using a pump similar to that in an aquarium, oxygen can be supplied to the roots. This is quite critical because the submerged roots also require oxygen.

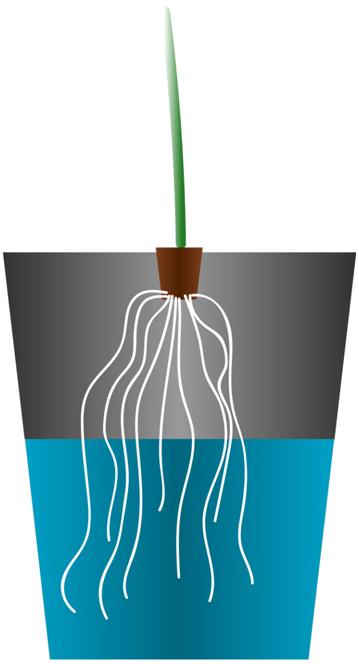
Flood and drain

Also known as ebb and flood systems, this setup fills the tray containing the medium or reservoir with the water and nutrient solution using a pump. The solution then slowly drains back into the reservoir, at which point the process can start over again. The advantage is that the medium gets regularly flushed with water and nutrients . This working principle is being used in Priva's growing container, which can be seen in on page X.



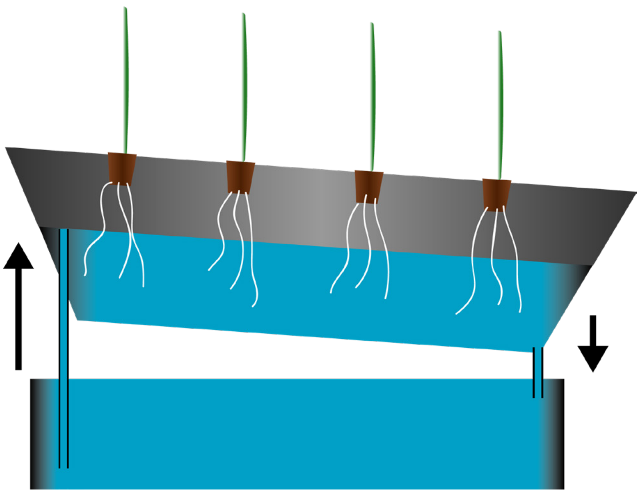
Static solution culture

The simplest of hydroponic techniques, it requires a container that holds the nutrients and water. This solution will be in contact with the roots and is either changed regularly or when the level reaches below a certain amount.



Continuous flow solution

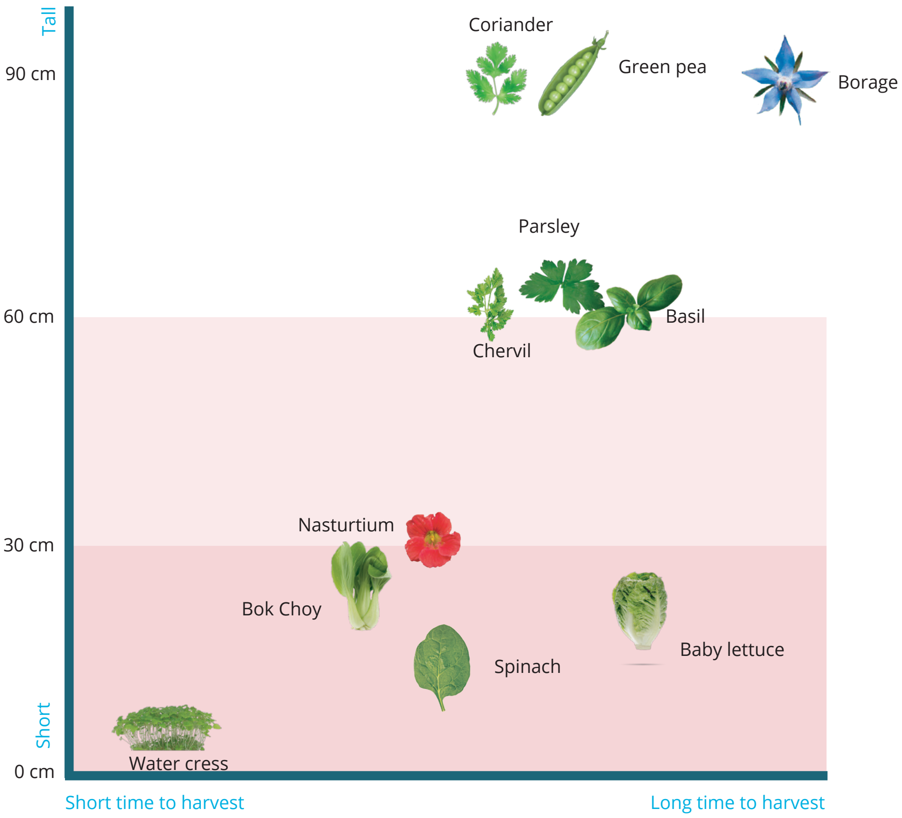
The nutrient solution will, as the name suggests, flow past the roots continuously to ensure they absorb the nutrient solution. A well-known practical application of the principle is the nutrient film technique (NFT), which uses channels at a slope of roughly 2.5% to supply a shallow stream that flows due to gravity. This doesn't only ensure the roots are continuously in contact with the solution, but also supplies oxygen to the roots by doing so. A pump is required that recirculates the solution at 1 liter per minute, per meter. This method is well suited for leafy vegetables but gives a lower fruit and vegetable yield.



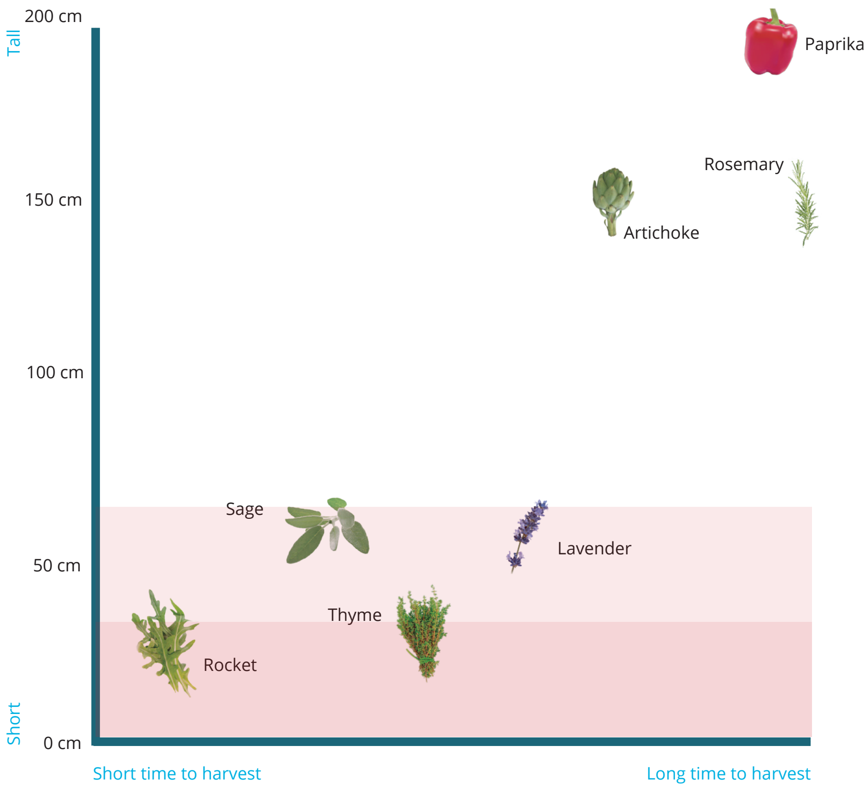
D. FUNCTIONAL ANALYSIS

Use process	Specific procedure	System response	Growing Process	Component response	Inputs	Implications
Open struture	Grab handle	Door open				The product requires a user to be able to open it
Introduce seedling	Place seed(ling) in medium					
	Place medium in system					The product has to hold the medium
Close structure	Push handle	Door closes				The product requires a user to be able to close it
Turn on device	Plug in the device					The product requires a power source
	Press on button	Interface turns on				The product requires a user interface
Set program	Select grown crops	Recall growing program				The product requires a database of growing programs
Start program	Press start	Change illumination	Start light cycle	Turn on light	Electricity to light	The product requires an adjustable lighting system
			End lighting cycle	Turn off light		
		Prepare nutrient solution	Mix solution	Add water	Extract water from source	The product requires a water source
				Add nutrients	Extract nutrients from source	The product requires a nutrient storage
			Regulate EC	Raise EC	Extract water from source	The product requires a device that monitors EC
				Lower EC	Extract nutrients from source	
				EC good	None	
			Regulate pH	Increase acidity	Extract acid from source	The product requires a source of acid
				Decrease acidity	Extract water from source	The product requires a device that checks pH
		Enable flow of solution	Pump solution to irrigation channel	Turn on pump	Nutrient solution	The product requires a water pump
				Turn off pump		
			Recycle nutrient solution			The product requires a water pump for extraction
		Enable ventilation of growing area	Move air to plant	Turn on fan	Electricity to fan	The product requires an adjustable fan
			Extract used air	Keep fan running	Used air	The product requires a ventilation system
			Regulate CO2 content	Increase content	Extract CO2 from source	The product requires a source of CO2
				Decrease content	None	
				CO2 good	None	
			Regulate relative humidity	Decrease moisture	Extract cold from heat exchanger	The product requires a cooling coil in the ventilation
				Increase moisture	None	The product requires a water pump to recycle the water
			Regulate air temperature	Reduce air temperature	Extract cold from heat exchanger	The product requires a heat exchanger
				Increase air temperature	Extract heat from heat exchanger	The product requires heating coils
Harvest produce	Grab handle	Door opens				
	Remove produce					
	Remove medium					
	Push handle	Door closes				
Stop program	Press program end	Terminate program				
	Unplug device	Turn off device				
Clean system	Grab handle	Door opens				
	Remove tray	Tray comes out of the device				

E. YIELD VS LENGTH



Graph 5. Harvest time vs length for annual plants



Graph 6. Harvest time vs length for perennial plants

F. PERSONA

Having mapped the research in chapter 2.2, a persona can be constructed to represent the user of the product that is being designed, what their values are, and what their wishes are regarding the use of the microfarm. Although slightly redundant, the persona helps in summarizing the ideal user of the product. While it is customary to construct multiple personas, only one is made to represent the end user; although slight variations in wishes and demands were found between the different chefs at restaurants, there were not enough participants to truly be able to differentiate between the different types of chefs.

Gilbert Mansveld
41 years old
Head chef at restaurant OM
Center of Den Haag

Important values:

Freshness and quality of ingredients are of high priority
Guests have to be served a unique experience
Use of ingredients that guests don't normally encounter

Main goal of using farming product: Continuously growing many small batches of herbs, microgreens, and small leafy vegetables.

Main purpose for guests: Showing a selection of the ingredients the restaurant is working with and adding to the overall dining experience.

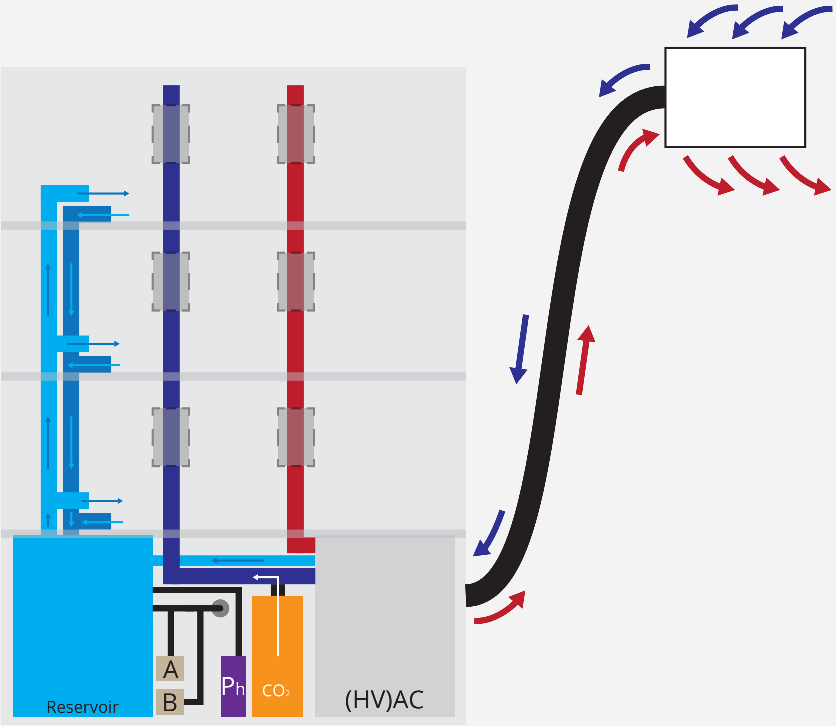
Type of design: Functional design, with aesthetics fit for the dining room of a modern fine dining establishment.

Location: Against the wall inside the dining room, in proximity of the kitchen.

Size: Undeep design, taking roughly the width of a 4 person table,

G. CLIMATE SYSTEM CONCEPTS

Climate Concept 1 - HVAC + Added CO2



Why a HVAC + additional CO2?

All-in-one heating, ventilation, and air conditioning solution
Closed system
Most stable environment = highest yield
Transpired water can be reused
Consumed CO2 always replenished

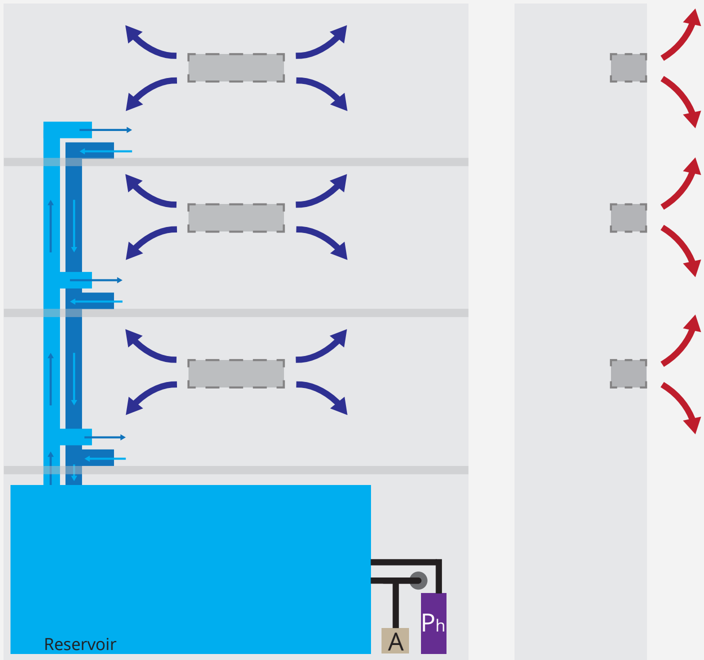
The HVAC (heating, ventilation, and air conditioning) system, as the name suggests, is an all-in-one solution catered towards climate control in the growing container. This makes it a closed system and water that is transpired by plants can be reused through the use of its heat exchanger. This system can be adjusted to the needs of specific plants and gives them the most stable environment to grow in, which in turn provides the highest yields.

Why not?

Technology not optimized for smaller scales
Bulky
Expensive both in terms of investment and electricity costs
Outside venting required
Restaurant conditions are already comfortable for humans, therefor also plants, and raised CO2 levels are available in the dining room
High doses of CO2 fatal to humans

HVAC systems are generally bulky and are meant for creating a pleasant environment on larger scales (houses and offices), which means that it isn’t optimized for the scale envisioned in this project. These solutions are generally expensive, and require large amounts of electricity. Outside venting is required for acquiring fresh air and getting rid of the used air, which might not be realistic for a restaurant. The last critique is also the most crucial; the product will be placed inside, which already provides a stable climate for plant growth.

Climate Concept 2 - AC



Why AC?

Smaller solutions available
Retain closed system
No outside venting is required depending on type
Cheaper than HVAC and less electricity consumption
Cleans the air; CO2 acquired from inside the restaurant converted to O2

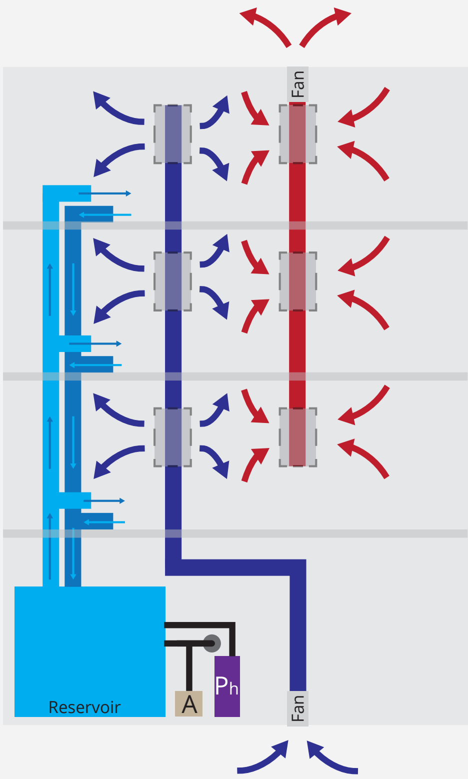
A system with just an AC would likely provide most of the same functionality as the HVAC, however, the heating aspect is excluded, which is not necessary considering that the product is standing inside and the lamps provide heating.

Why not?

Systems not optimized for reuse of water, requires adjustments
Vented air hot and humid
Bulky solutions for the size required
Consumes a large amount of electricity
Restaurants conditions are comfortable for humans, therefor also plants
Costly (although less than HVAC)

Not all AC systems provide a method of effectively reusing the condense water and a system will have to be chosen that vents hot air and humidity directly into the restaurant. As with the HVAC system, the solutions are still bulky and expensive for the small scale of the product, and consume a large amount of electricity.

Climate Concept 3 - Ventilation



Why ventilation?

Fans available in a large range of sizes
Compact
Low energy consumption
Most simple solution
Cleans the air; CO2 acquired from inside the restaurant converted to O2 by plants
Restaurant environment already comfortable for humans, therefor also for plants. Only the heat of the lamps and humidity has to be removed by the ventilation.

A ventilation system would refresh the air, ensuring the heat and moisture is removed from the growing chamber and replenished with new “fresh” air without many of the investments mentioned in the previous two concepts. It is the most environmentally friendly of the three and its context doesn't require much more than refreshing the air.

Why not?

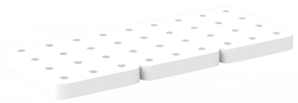
Not a closed system; least stable environment and highly dependent on outside
No reuse of transpired water
Vented air hot and humid

While it is the easiest technical solution and most environmentally friendly based on electricity consumption, the lack of a closed system means that 90% of the water used cannot be reclaimed. Also, the product is highly dependent on the temperatures in the

H. DETAILED INNER EMBODIMENT ITERATION 1

Growing trays

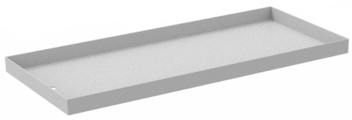
The growing tray holds the plug and seed combination in the Microfarm. Similar trays are made of PE (polyethylene) that are blow molded into shape, however, they are also commonly made of PS (polystyrene/styrofoam) to lower the costs. It would be recommended to explore whether it is possible to use a bio-based foam to lower both the cost and environmental impact. A potential issue is that foam materials could fall apart if handled too much, which both ruins the tray and clogs up the irrigation system, and it will not be as easy to clean.



Dimensions: 300 mm x 400 mm x 50 mm
Hole diameter: 30 mm
Material: PE (polyethylene)
Production method: Blow molding
Recommendations: Exploring bio based foam as feasible alternative

Irrigation tray

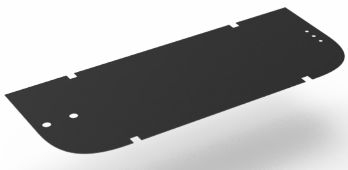
The irrigation tray holds the growing trays and should be similar to a Danish tray, as described in chapter 3.5. These have ridges in the bottom that allow the water to completely drain from the tray and is manufactured by thermoforming polystyrene sheets. Although many standard sizes are available, it is recommended to customise it to the given dimensions below to ensure the product does not become too thin or thick.



Dimensions: 1050 mm x 450 mm x 50 mm
Material: PS (polystyrene)
Production method: Thermoforming
Recommendations: Customize shape

Seperator sheet

The seperator sheet divides the growing room from the so-called utility space containing the irrigation system and reservoirs. Although not a crucial component, it prevents any sort of plant waste from falling into hard to reaches places inside of the utility space. PMMA (perspex) is chosen because it is not a structural element and likely not very visible. The material can be relatively cheap and easy to manufacture through laser cutting, but it is recommended to calculate which exact thickness is needed to prevent cracking on impact, if the growing lights don't directly heat up the sheet, and if it's perhaps wiser to laser cut aluminium sheets.

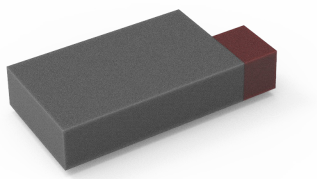


Dimensions:
Material: PMMA (perspex)
Production method: Laser cutting
Recommendations: Determine thickness for impact, deformation of sheet through heat of lamp, and potential for aluminium alternative

Frame

The frame is the main structure of the Microfarm, and acts as a skeleton upon which all the parts are assembled. Aluminium that is cut and welded is chosen as the material because it is both light weight and strong, however, a bit more expensive than using steel (because steel is cheaper and easier to process). Steel would have to be galvanized to prevent iron oxide (rust) from forming and makes the product much heavier, which makes it more difficult to transport. It is recommended that a comparison should be made between the pros and cons of using aluminium versus steel in terms of price and weight.

Dimensions: 1800 mm x 1100 mm x 500 mm
Material: Aluminium
Production method: Cutting and welding
Recommendations: Compare cost and weight of steel and aluminium



Reservoirs

The reservoirs holds the water needed for irrigation and include a drain tank. Most standard water tanks are made of HDPE (high-density polyethylene) and manufactured through blow molding. HDPE ensures no chemicals leach into the water and are used, for example, in plastic milk packaging. This reservoir requires some post production in form of cutting to ensure the right fittings can be installed for the irrigation system. Making a custom tank allows for both the dimension and outlets and inlets to be properly adjusted [3], and it is recommended to explore whether this a feasible solution.

Dimensions:
Material: HDPE (high density polyethylene)
Production method: Blow molding
Recommendations: Compare customization versus post processing

Growing light

The growing lights are the most important piece of equipment inside of the Microfarm; they enable the plants to undergo photosynthesis. These lights will be bought from the manufacturer as the number of suppliers is limited and customization is not needed. The "Horticulture Linear" by Samsung is chosen, because its dimensions are small enough to fit into the Microfarm. Using an online calculator to determine PPFD from a lamp's specifications, it is found that four lamps are needed per growing room to reach the same light intensity (~250 umol/s/m2) when assuming that at least 50% of the light reaches the target. However, this light can't be installed right away because it doesn't contain a heat sink to get rid of excess heat, and as a recommendation a heat sink has to be found that allows it to do so, without containing too much thickness. The height of the growing rooms likely have to be changed to keep the 400 mm distance between light and growing tray.

Dimensions: 281 mm x 41 mm x 5 mm
Type: Horticulture Linear
Manufacturer: Samsung
Recommendations: Determine type of heat sink and change in height

Tubing

The tubing ensures that the irrigation is transported both up to the irrigation tray and down back to the mixing tank when it is used. The material commonly used for this purposes is PVC (polyvinyl chloride), which is first cut and then glued and sealed together, ensuring no leaks are created at the seams. Some sources report health and safety issues are related to the use of PVC, but still acknowledge its wide spread use.As a recommendation, PE should be explored as an alternative.

Dimensions:
Material: PVC
Production method: Extrusion and cutting
Recommendations: Exploring PE as an alternative to PVC

I. IRRIGATION SYSTEM

Volume requirements for irrigation reservoir

In a hydroponic system water is mostly lost by transpiration of the plants. About 97% to 99.5% of the water taken up by a plant is transpired [X3], and the water supplied through the irrigation system is used by the plants to replenish the transpired water. It can therefor be assumed that the water required by the system is equal to the water transpired by the plants. For the Microfarm, its water consumption would ideally be calculated by physically measuring the environmental conditions inside of the product and modifying known meteorological equations accordingly, or measuring the difference between the supplied and drained water over time. However, due to time and resource constraints, this is not possible and will have to be calculated by using available methods that rely on generalized assumptions. These methods can be found in appendix J, and result in the following values:

Blaney-Criddle method: 5.625 liter per day
Rule of thumb: 3.76 liter to 5 liter per day
Penman equation: 7.122 liter per day

All values are per square meter [m^2]

To briefly summarize appendix J, the Blaney-Criddle equation's flaw is that it is based purely on average annual daylight time and the average temperature, while the rule of thumb simply states a range of 0.3 - 0.4 gal per sq. ft. for a greenhouse at the peak of the summer. Both equations consider sunlight and neglect that the light intensity of the growing lights in the Microfarm will be far less than that of the sun. The more intense the light, the more a plant transpires, which requires a conversion that introduces new uncertainty. A rough conversion factor from sunlight to light in the growing room was determined to be about 3.22. The Penman equation is the most accurate and considered to be theoretically sound, as it allows light intensity, temperature, relative humidity, and airspeed to be filled in, but has the flaw of introducing uncertainties when estimating certain values. Given the limitations, the Penman equation will do.

Scenario

The amount of water required per day for 1 m2 is known and determined to be roughly 7 liter, which is a major step towards determining how large the water reservoir has to be at a minimum and whether this actually fits inside of the Microfarm in its current shape. To determine this, a scenario has to be assumed that incorporates both the amount of times per day irrigation is conducted, how many days the Microfarm should work without having to be refilled, and the current state of the design; they are defined as following:

Cycles per day: 4
Minimum time of functioning without input: 8 days
Growing area: 1.08 m2
Volume available under the Microfarm: 94.5 liter

Result

Total volume required in system for single level filling: 73.23 liter
Absolute minimum at which irrigation is possible: 11.23 liter

Total volume required in system for simultaneous three level filling: 90.35 liter
Absolute minimum at which irrigation is possible: 30.27 liter

How these amounts are calculated can be found in appendix FIX ME. These values will be used later on in determining what type of system is most appropriate.

Water supply to irrigation reservoir

The water needed for irrigation, which has to come out of the restaurant itself, can be supplied in two ways; either manually or through a mechanism connected by a water hose.

<u>Manually</u>

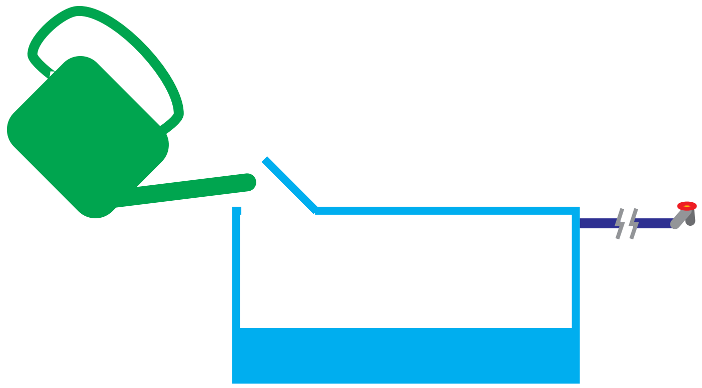
Adding water by hand would require either the water to come to the reservoir or vice versa. A watering can would have to be supplied with the Microfarm that preferably holds around 10 - 15 liter of water, requiring somewhere between 5 to 7 refills depending on the size of the can and how far it is filled up. This is less convenient than being able to fill the reservoir all at once by removing it, but the user has to carry 75+ kilograms if the reservoir is removable, which would even be less convenient (let alone impossible for nearly every user).

<u>Automatically</u>

Automatic water supply requires the water reservoir to contain a switching mechanism that can measure when the water level has reached below the 11.23 liter mark. This takes away effort from the user, but raises the question of when the nutrients have to be added.

<u>Implications</u>

Both methods are viable solutions, and it is likely that some restaurants will prefer one or the other. A water hose might be impossible to connect at certain locations due to distance and/or unattractive looks of the hose itself, while a watering can requires more effort. Giving this as an option would be a possibility, products like a coffee machines also come in versions that do both.



Water supply to irrigation tray

Once the water/nutrient mix is in the Microfarm, it can be pumped up to the irrigation trays. From the volume requirements, it was found that there are two different methods that will each bring different requirements regarding the size of the irrigation reservoir under the product.

Simultaneous

As the name suggests, the three levels currently present in the Microfarm would be refilled at the same time, as seen on the next page. According to Infinite Acres irrigation engineer Guus Sprenger, this is best done by using one pump and tweaking every output to fill each irrigation trays at the same rate. This is necessary because the output at the top is lower than at the bottom due to the pressure difference resulting of these heights._Including three pumps instead of one is also possible, but would likely defeat the purpose because tweaking is still necessary to ensure uniform output.

From the calculations in the previous part of this section, it was found that this type of system requires an irrigation reservoir that is at the very maximum of the size possible under the Microfarm in its current state.

Single

Filling each level seperately from another is also a viable option, which results in a lower amount of volume required for the irrigation reservoir(s). Instead of having three outputs, there is only one output and each irrigation tray drains its water/nutrient mix to the one below.

Although less volume is taken by the system, irrigation engineer Guus Sprenger noted that this type of solution is a bit more difficult to realize. The rate of supply has to roughly equal that of the drainage to prevent the irrigation trays from going above the 2 cm mark and in an extreme situation, risk over overflowing.

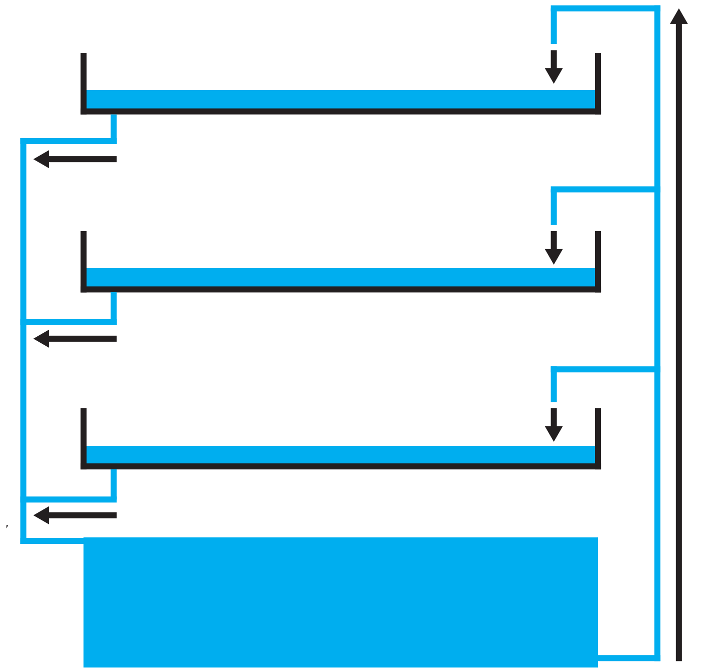


Figure. Simultaneous reservoir irrigation

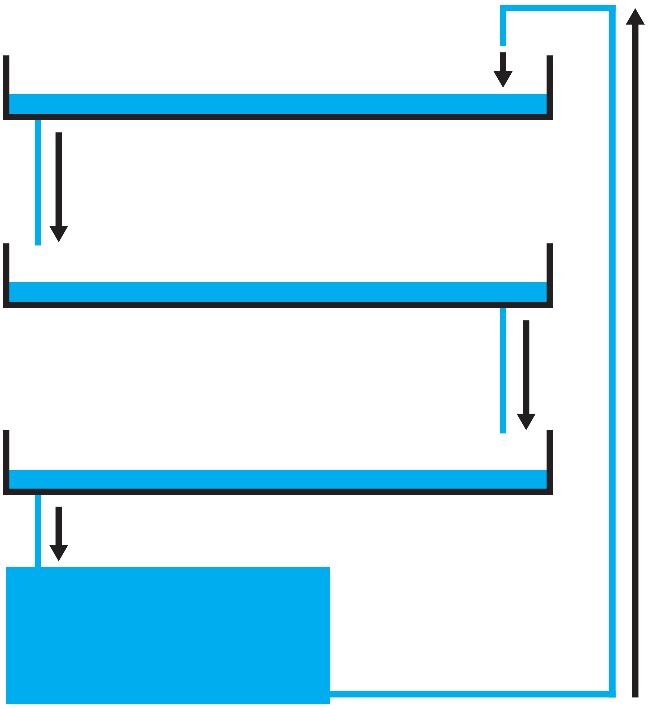


Figure. Single reservoir irrigation

Dosing of nutrients

Introducing nutrients into the system can be done before or after refilling the reservoir under the Microfarm.

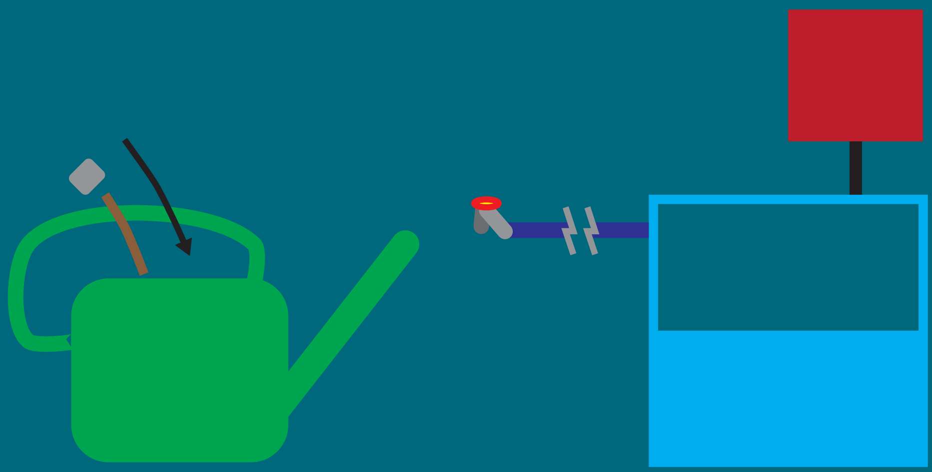
Before

If the water is supplied manually, nutrients could be added before it is introduced to the Microfarm, which is performed by the user themselves. According to the mix ratio for the concentrated nutrient solution used, the user adds this amount to a watering can after which it can be supplied. It is less technically complex, but requires more effort.

After

Adding nutrients is still possible if the water is supplied manually and would have to be added in a similar way as the water. If the water is supplied automatically the reservoir would either need an opening to add the nutrients or require are an additional reservoir from which it is added (like the container).

It will be assumed that the nutrients are added before to keep the technical principle of the concept straightforward and simple. Working out the technical details behind a concept with two different systems seems rather specific and is not necessarily interesting for the final concept. Though if Priva were to develop Microfarm, it would be an interesting point to research.



Maintaining pH and EC levels in the water/nutrient solution

As mentioned in chapter FIX ME, section FIX ME, pH is important for the uptake of nutrients by plants and EC describes the concentration of nutrients in the water/nutrient mix (but not their amounts), and have an effect on the water uptake of plants . Ebb and flood systems can generate issues regarding pH and EC levels, because drain water is introduced back into the mix reservoir after irrigation. The nutrients contained inside of the drain water will accumulate and cause the nutrient ratio, and the EC and pH, to change.

While there are methods of controlling the pH and EC of a water/nutrient solution through technology, it is very likely that these systems require investments that influence the cost and resources required for it to work negatively. A low-tech solution that requires the user to check and influence these values would cost very little in terms of investment, but is an added step for the user and requires them understand and perform the task accordingly. To lower the amount of effort the user has to put into maintaining the irrigation system, the regulation by either technology or hand is completely removed. Proposed by irrigation engineer Guus Sprenger, a semi-closed system is chosen to be able to reset the pH and EC at a given moment, which means that all of the water/nutrient mix left in the mixing reservoir is drained into a different container that will be disposed of. Please refer to appendix FIX ME for a more elaborate explanation on the considerations made.

Implications

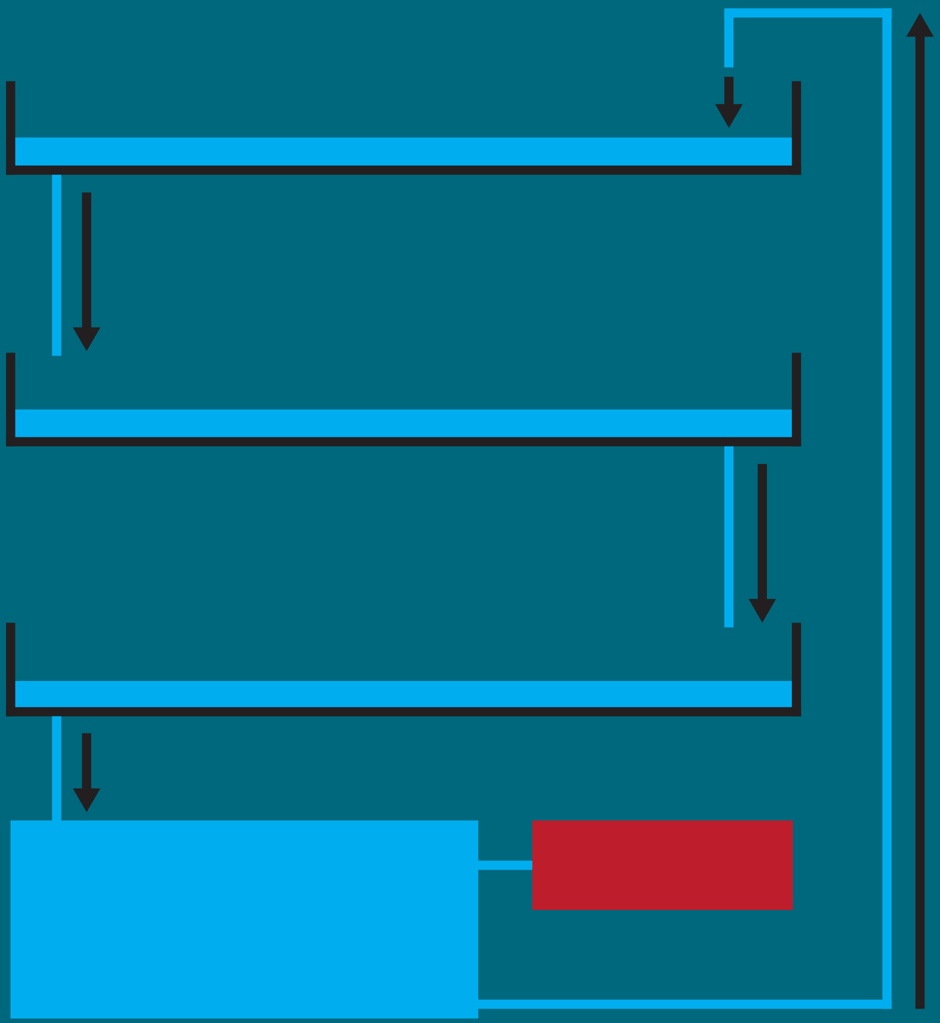
Introducing a drain reservoir in the irrigation system will require the contents of this reservoir to be emptied accordingly. In the Netherlands the contents of this reservoir would be labeled as *kunstmest,* literaly translated as artificial manure, which cannot be emptied into the sewage system because it is labeled as chemical waste. This requires this waste to either be disposed by the user or to be picked up by an external party, the former being unrealistic in terms of the amount of effort that it requires from the user and the latter possible by making it part of the service that comes with the Microfarm.

Disposing of user water/nutrient mix

The semi-closed system proposed introduces the need for discarding of the used water/nutrient mix. As mentioned before, it is considered to be chemical waste and has to be brought to the proper facilities to for processing. Because it is unrealistic to expect the user to drive up to this facility on a week- or monthly basis, this waste would have to be collected. This could be done by a company specialized in doing so or by Priva themselves; the former being an existing service, and the latter having to be developed by Priva. Although the existing service would be easier from Priva's viewpoint, having Priva pick it up would be more logical for the user as an external service because Priva would cease to be a single point of contact. Having this service combined with the delivery of new seeds and nutrients would be a logical combination.

Envisioned system

Now all the important aspects of the irrigation system have been discussed, it is possible to generate the irrigation system. Displayed to page FIX ME on the right in image FIX ME is the system envisioned for Microfarm. It was a logical choice to opt for a single reservoir irrigation system because it requires less water to be held, but also generates less drain water that needs to be emptied each week (30 liter compared to 11 liter). The drain water is emptied into the red reservoir seen in image FIX ME and it is recommended that this reservoir be emptied every week.



J. IRRIGATION SYSTEM CALCULATIONS

This appendix describes the equations used in chapter FIX ME, regarding the irrigation system of the Microfarm.

Volume requirements for irrigation

Blaney-Criddle: The Blaney Criddle equation is a simple method for measuring evapotranspiration in a crop based on the average temperature and amount of daily sunlight available. This method, however, should be applied for periods longer than a month, and is known to be not very accurate, which is increased in extreme situations. One major problem with the calculation is that it assumes the growing lights have the strength of the sun, which is nowhere near the case in the Microfarm. Another shortcoming of the method is that it considers evapotranspiration, which is not the case in the Microfarm as the evaporation of the medium itself is negligible. This means that results should be considered as a rough estimate on the high side, although for the other calculations considering transpiration without data this also likely the case. The equation goes as follows:

ETo = p * (0.457 * Tmean + 8.128)

Where:

ETo = Reference crop (grass) evapotranspiration for 1m2
p = Mean daily percentage of annual daylight hours, where p is assumed to equal 1as there are no clouds to obstruct the light from reaching the plant
Tmean = Average temperature of one month, where Tmean should equal the temperature inside of the restaurant, estimated to be 22c

Thus:

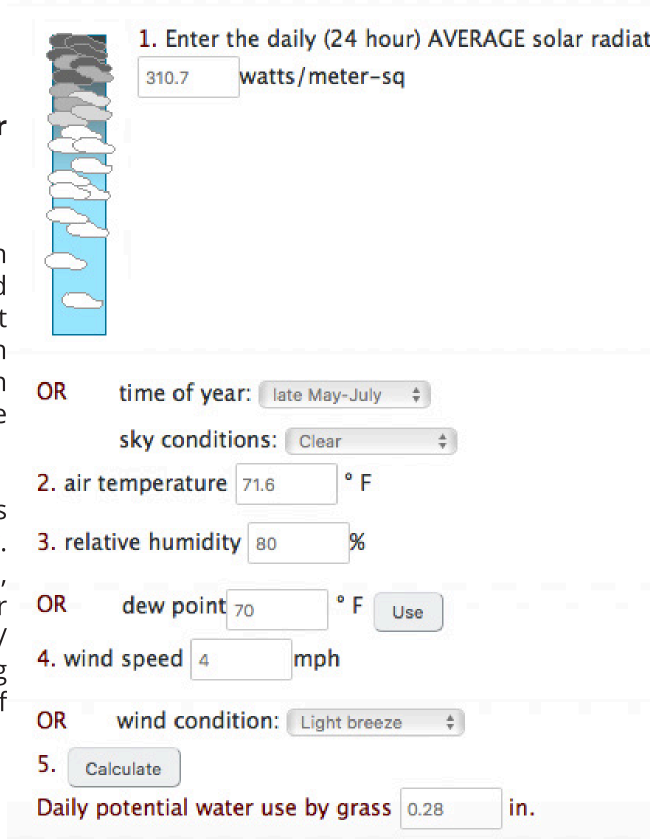
ETo = 1 * (0.457 * 22 + 8.128) = **18.128 L/day**

Rule of thumb method: This method is a rule of thumb describing that a greenhouse requires 0.3 to 0.4 gallon per square foot, per day, at the peak moment of the year when the sun is at its strongest. As with the Blaney-Criddle equation, it is assumed that the growing light has the strength of the sun. This rule of thumb is a gross simplification of what is actually going on and should be considered as such.

1 gallon = 3.75 L, 0.3 gal, 0.4 gal = 1.125L, 1.5L
1 ft2 = 0.093 m2, 1m2 = 10.76 ft2
thus

10.76(1.125, 1.5) = **between 12.105 L and 16.14 L per day**

Online Penman equation: The Penman equation considers more variables in its calculation and should give a more accurate results. To the right, a screenshot can be found of a calculator that allows one to do so. In this calculation, it is assumed that each growing room has two lamps (from section FIX ME), equal to an average "solar radiation" of 310.7 W/m2.



As a result, the daily potential water use by grass is calculated to be 0.28 in, which converts to 7.112L per day. This is much smaller than the previously found numbers, which can be explained by looking at the average solar radiation of the sun. This is estimated to be 1000 W/m2, which is 3.22 times stronger than the growing lights currently used [X7]. One of the shortcomings of this method is that the equation is originally meant to calculate open water evaporation and that the reference crop is grass, not a crop that will be grown in the Microfarm. [X8]

With this knowledge, the previous to amounts are also converted according to the logic that the sun is 3.22 times as strong as the growing lights used. In reality, this conversion is likely larger because at the given strength of 103.4W per growing chamber the lamps would have to work at full capacity, which at 100% efficiency - all the light emitted being received by plants - would likely cause damage to the plant due to the high intensity. This gives the following equations:

Blaney-Criddle: 18.128L day-1/3.22 = **5.625L per day**
Rule of Thumb: (12.105L day-1, 16.14L day-1)/3.22 = **3.76L to 5 L per day**
Online Penman (reference): 7.122L per day

By converting the Blaney-Criddle equation and the rule of thumb to an equivalent of the growing lights used, the range of actual water used is drastically decreased from 11L to 3.362L. This shows that there is still uncertainty as to what is actually the right answer, but gives a ballpark figure of what to expect.

Conclusion

For now, it will be assumed that the water use is 7L per day because it is a safe bet. If it turns out that the amount is lower, thus the system oversized, the user would have to refill the product less often, which would not be a problem. Choosing the lowest amount could potentially result in the system being undersized and requiring more refilling.

Scenario calculations

The amount of water required per day for 1 m2 is known and determined to be roughly 7 liter, which is a major step towards determining how large the water reservoir has to be at a minimum and whether this actually fits inside of the Microfarm in its current shape. To determine this, a scenario has to be assumed that incorporates both the amount of times per day irrigation is conducted and how many days the Microfarm should work without having to be refilled; they are defined as following:

Cycles per day: 4 (material of plug = coconut coir, requires irrigation 3-5 times per day)
Minimum time of functioning without input: 8 days (week + 1 day buffer)

Next to the scenario, there are more factors that determine the amount of volume that is actually needed and are given below:

Growing area: 9 trays of 300 mm by 400 mm = 1.08 m2
Volume available under the Microfarm (1050 mm x 450 mm x 200 mm): 94.5 liter
Volume required for 20 mm submersion in one (1050 mm x 450 mm) irrigation tray: 9.45 liter
Amount of irrigation trays used at the same time: All 3

This scenario results in the following volumes:

Water required for compensating 8 days of transpiration (8 days times 7.122 liter times 1.08 m2) : 62 liter
Minimum volume for filling three irrigation reservoirs: 28.35 liter
Minimum volume for filling three irrigation reservoirs + last irrigation: 28.35 + (1.08 m2 * 7.122/4 liter) = 30.27 liter

Total: 90.35 liter needed for 8 days of supply with 3 simultaneously filled irrigation reservoirs

If the three irrigation trays were to be filled simultaneously, a minimum of 28.35 liter is required to fill them up to a height of 20 mm. It excludes any irrigation of the plants itself; if the 8 day buffer were to be added, the total volume that would have to be taken up by the water and mix reservoir is 90.35 liter, which leaves little to no space for other components like pumps and potential additional reservoirs.

This requires the irrigation system to be approached differently; instead of irrigating each reservoir at the same time, only one reservoir will be irrigated with the water/nutrient mix. Allowing the used water/nutrient mix to be drained to the other two levels instead of directly into the mix reservoir makes this possible and results in a much less complex system from a technological viewpoint.

<u>Implications</u>

Minimum volume for one reservoir + last irrigation: 11.23 liter

This is the minimum volume below which the mix reservoir will have to be refilled to ensure 20 mm of water height in the lowest irrigation reservoir at the end of irrigation. This amount symbolizes the very minimum size of this reservoir.

Total volume required in system (62 liter + 11.23 liter): 73.23 liter

This is the total volume of water that is required to be held between the water and mix reservoir to ensure enough water is present for 8 days of irrigating single level. Because it is a very specific amount, it will be rounded up to 75 liter.

Maintaining pH and EC levels in the water/nutrient solution

pH

A favorable level of pH is around 5.5, although the norm for drinking water actually ranges between 7.0 and 9.5. The most simple approach would require the user themselves to measure the pH and EC, In larger growing operations, like the growing container, these levels are monitored and adjusted through an interplay between sensors and the addition of water and/or acid. This type of technology is not favorable to use in the Microfarm, though, because the sensors that are required are a considerable investment, need calibration by someone with the knowledge of how to do so , and make the overall irrigation system more complex. What also makes it less favorable is that there aren't any irrigation systems with pH and EC control available for the scale envisioned. This poses two challenges: how to lower the pH of the water/nutrient mix and how to keep the pH of the water/nutrient mix at 5.5.

How to lower the pH

In the growing container the pH is adjusted by adding an acid to the water/nutrient mix, such as citric, phosphoric, nitric, or sulfuric acid . The Microfarm would preferably not include an additional mechanism for dosing this acidic solution, because this would add a new layer of complexity to the irrigation system and user handling. Guus Sprenger, irrigation engineer at Priva/Infinite Acres, noted that when using Quickplugs a method of regulating pH is imperative because the material of the plug itself has no capability of maintaining a steady pH (known as buffering). It reinforces the need to, regardless of it being a mechanism or not, adjust the pH of the water/nutrient mix. This leaves one option left, and that is manual addition by the user. Given that the water supply needs to be replaced by the user every 7 days, it is assumed to be reasonable that the user needs to add this to the water themselves when the water tank has to be refilled. There are two options here, either supplying the user with a bottle through Priva Portal or making them use something out of their own kitchen. Adding vinegar (acetic acid) is a known method for lower the pH of a solution and is assumed to be present in the restaurants the Microfarm will be placed.

How to maintain pH

The capacity of the water/nutrient solution to hold a certain pH is known as buffering. Drinking water has a buffer to ensure that any fluctuation in pH is kept to a minimum, and this buffer should be thought of as a sponge that absorbs acids. At some point this buffering capacity diminishes as it is used up, but this is largely dependent on the hardness of the water used. To aid this process, concentrated nutrient solutions should be chosen that are buffered. These are available and allow the water/nutrient mix to maintain a pH of 5.5 after water, with a small amount of acid, is added.

EC

Ideally, the level of EC is kept between 1-3 dS m-1. It can be checked with an EC meter (which sometimes contains a pH meter as well) , or automated with sensors and interpreted afterwards on a larger scale. In closed hydroponic systems where the same solution is continuously recirculated, nutrients are being depleted as time progresses as well as not every nutrient being depleted equally (which affects the pH). Irrigation expert Guus Sprenger noted that in an ideal situation where the pH and EC are not regulated through the user or technology, the solution left over in the tank is switched out every time the water reservoir is refilled. This is based on the fact that after the tank is refilled, it can't be guaranteed that the EC is ideal nor if the composition of the nutrients are ideal when the contents are not removed. Another option given by Guus was switching from hydroponic to soil based growing which would allow both of the pH and EC to become less crucial because the medium has much more storing capacity.