Liveable Integrated Farming in healing Environments

Polle Taminiau
4056507
TU Delft
Faculty of Architecture
Architectural Engineering

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Introduction:

Our environment is changing rapidly due to climate change, global warming effects, diminishing lack of vegetable resources, deforestation and a growing world population. The continuous discussion on changing the environment is a challenge which needs to be addressed from an interdisciplinary framework. Vegetation on roofs, green walls, producing organic food in a hydroponic is one of the most innovative and rapidly developing fields in the worlds of ecology, technology, horticulture and the built environment to date. However, urban areas buildings and green environment are still structured and organized in separate ways, instead of combining best of both. For example, the expo in Milan 2015 dedicates a series of architectural design to a fully fledged and functional vertical farm producing organic food and vegetables. Instead of separate use of space and environment the building incorporates both functions.

Due to the multifunctional dimensions of vertical farming and "green buildings", this research explores the link between architecture, vertical farming and the impact on people, more specific, a healing environment for people in mental healthcare facilities. This interest became more focused when I discussed my interest with a board member of the Parnassia Groep, an umbrella body of 660 (mental) healthcare facilities in the Netherlands and in Europe. Creating a healing environment is the outmost priority of Parnassia. The Parnassia group is currently in the process of innovation to make their facilities, buildings and space more sustainable. The facilities need to change accordingly to meet the demands of its clients and its infrastructure from a sustainable perspective. In short, adding green facilities and methods into a health care facility is regarded as a contribution to a better climate and healing environment but also a contribution for therapeutically involvement of the patients and their needs.

Problem statement

Triggered by the concept of vertical farming I widened my scope by focusing on the impact and benefits of spatial and green use for people, planet and profit. What kind of environment is considered a healing environment? In what way architectural concepts and values contribute to this notion of healing environment? Why is it so trendy to create roof terraces that not only contribute to pleasure and space us but moreover to production use related to urban agriculture? Why is vertical farming growing in attention? Does vertical farming contribute to an added value for current and new concepts of building? All these thoughts lead to the following research question:

What are the requirements for vertical faming in healthcare facilities from the perspective of people, planet and profit?

The research question is divided in sub-questions:

1. How does green add value to buildings of the health care facilities and its client?
2. What are the existing techniques available for green architecture?
3. Which criteria are necessary for a healing environment from the perspective of people, planet and profit?

These questions will be addressed in the context of an existing healthcare building of the Parnassia Group. Since the Parnassia Group has 660 different locations, the aim of this research is also to create a toolbox that can be implemented on the locations where it is needed. This toolbox will be tested on one or more locations. This toolbox will also help to contribute towards a sustainable world.

This research paper is divided in four parts; the first part investigates the added value of green to the healing environment. The second part is about vertical farming methods. The third part will look at adding green on the exterior of the building and what benefits it has to the buildings and its surroundings. After the reflection in part 5 the conclusion will be presented.

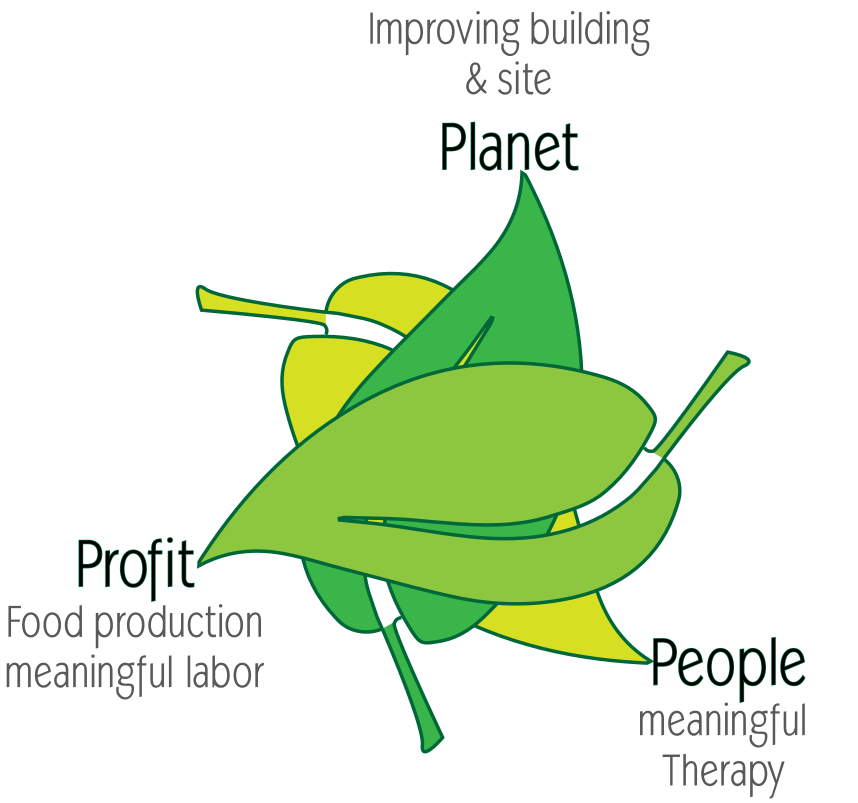
Research methods:

This research has been conducted in an exploratative way, using different sources such as literature studies, research project and interviews. Also the framework of planet, people and profit will be used to investigate the multidimensional effects of green buildings.

Literature studies:
The investigation is focused to understand the basis of green in the build environment. Different growing systems can be analyzed that are used in vertical farming.

Research project:
Parnassia Group has 660 different health care facilities, by visiting them and experience, a building concept can be made about the possible methods and requirements of adding green in a healthcare building.

Interviews:
The selection of interviews are based on the research question and accordingly experts have been selected to discuss their knowledge and experience in vertical farming, health care environments and public-private cooperation in the built environment.



People, Planet, Profit
source: Own image

Framework

The perspective of planet, people and profit is used as a framework to investigate and to define the necessary requirements for vertical farming in a healing environment. In this research, planet, people and profit are understood as follows:

Planet: improvement of the building

Throughout history urban green has been used for multifunctional reasons, from leisure activities to production. In general it can be stated that due to the global warming effects, our cities will be up to 6 degrees hotter as high density developments lead to the so called "urban heat island" effect. This climate change impacts directly the urbanized regions and its buildings. In response greening up buildings can contribute to a sustainable and climate regulation.[1] Greener buildings will maintain competitive advantages in the market place due to the lack of wasting energy and creation of new circuits of energy.

The existing stock of Parnassia has different buildings in different contexts. One of the buildings located on Platinaweg 20, an industrial urban area, has no green at all. This building and its surroundings are in need for improvement both for its social and economic values. This building will be the focus of a researchproject to determine the steps for greening up the building and improving the healing environment.

People:

In short the impact on green on people is tremendous. For the clients of the Parnassia Groep it is essential that they can function in a healing environment. The quality of light in a facility determines the well being of its people and the quality of green enhances the state of mind of the clients. The green concept can help in improvement of the building and also can work therapeutically for the clients.

Profit:

Recently the mandate and budget measures regarding (mental) health care, have been shifted from from an national to a local level[2]. Health care organisations are in the process of adapting those changes in their organisations and budgets, since these have been limited as well. New ways of financing their facilities and services are currently investigated. Sustainable changes are prioritized to reduce energy costs for instance. Innovative and efficient use of their space, climate system and buildings are investigated, such as vertical farming. The reason for the positive approach for the green concept is that the healthcare facilities can produce, sell and profit from the green concept. Furthermore selling regional products in the Netherlands is a niche[3].

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[1] (2011) *Green roof developer's guide.* The Green Roof Centre. p.7

[2] Rijks Overheid(2014): *Geestelijke gezondheidszorg (GGZ)* data retrieved from: http://www.rijksoverheid.nl/onderwerpen/geestelijke-gezondheidszorg on 10th of June 2015

[3] Dirks, B.(2015) Het Central Park van de Randstad. Amsterdam,De Volkskrant 8 juni 2015. p.3

	Urban level	Building level	Spatial level
	location addressing parking street furniture positioning	insolation building depth scale spatial materialization	day light blinds reflection lighting color
	traffic surrounding	facade package	acoustics
		ventilation smell	outdoor space fresh smell
	texture walkability street furniture	climate control cooling insolation texture	climate control blinds thermostat

Senses on different scales
source: edite from: Mens, N., Wagenaar, C. (2009) . p. 9

Added value of green in healthcare facilities:

Light increases the quality of life inside the building. Day light is primal need for human kind: the high intensity, the dynamics and the color spectrum are of huge importance of the quality inside a building. Lack of light on the other hand can lead to depression, insomnia and decrease your learning curve. More natural light increase the mental health of the clients in health care facilities[4].

In the history there was already the belief that contact with shrubs, grasses and flowers fosters psychological wellbeing and reduces the stress of urban living in city. In the Middle Ages nursing homes and monasteries had already built green court yards, so patients would recover more quickly[5]. This belief is confirmed in recent studies the link between contact with vegetation and health benefits. The restorative effect of natural scenery hold the viewers' attention, diverts their awareness away from themselves and form worrisome thoughts and evokes a meditation-like state[6]. Natural setting evokes a wakeful and relaxed characterized by a decreased heart rate and a quicker stress recovery according to Swedish studies[7].

Rooms without windows or no visual access to the outdoors cause stress, especially in the workplace and in health care facilities[8]. In 1982 and 1985 studies were done where prison inmates had a view over farm land or forest and other inmates had a view onto other cells, walls or buildings. The inmates that had the view over the landscape were less likely to report for sickness.

Additionally, there are therapeutic benefits from the act of caring for plants. The Variety of sound, smells, colors and movement provided by plants, can add significantly to human health and well-being[9]. Plants also filter the air borne pollutants and therefore they filter out viruses. Green can have social benefits such as improved aesthetics; health and horticultural therapy; improved safety, and additional recreational opportunities.[10]

Architectural factors for healing facility building

In healing environments are factors that influence the patients' recovery. These factors can be used in the design stage of health care facilities[5].

The factors that influence the healing environment contain the following:

Nature: Having a view on nature reduces stress.

Daylight: Next to nature is daylight important for the recovery process.

Climate: A healthy and comfortable climate contributes to a better healing environment

Organization: The organization in healthcare facilities is of great importance to the clients. They need to find their way through the building by applying landmarks.

Smell: Also scent can reduce stress, mostly this scent coming from plants.

In the recovery process of the mental non-stable clients can be linked towards the senses of the clients. These senses can be applied on three level of scale: the site, the building and the space. In the next scheme notions are added to all sense that can have influence on green.

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4 Van de Beek, A. (2010). *Bouwen met Groen en Glas*. Boxtel. Aeneas Media. p.10
5 Mens, N., Wagenaar, C. (2009) *The healing environment*. Bussum. Uitgeverij THOTH. p. 9
6 Ulrich, R.S. and Parsons, R. (1992). Influences of Passive Experiences with Plants on Individual Well-being and Health. Timber Press Inc., p96
7 Ulrich, R.S. and Parsons, R. (1992). Influences of Passive Experiences with Plants on Individual Well-being and Health. Timber Press Inc., p99
8 Ulrich, R.S. and Parsons, R. (1992). Influences of Passive Experiences with Plants on Individual Well-being and Health. Timber Press Inc., p27

9 Johnston, J. and Newton, J (1996); *Building Green, A Guide for Using Plants on Roofs,* Walls and Pavements; The London Ecology Unit, London, p.48
10 Peck, S.W.(1999) *Greenbacks from green roofs: Forging a new industry in Canada.* Toronto, Canada Mortgage and Housing Corporation. P. 6

Technology: Plants Growth

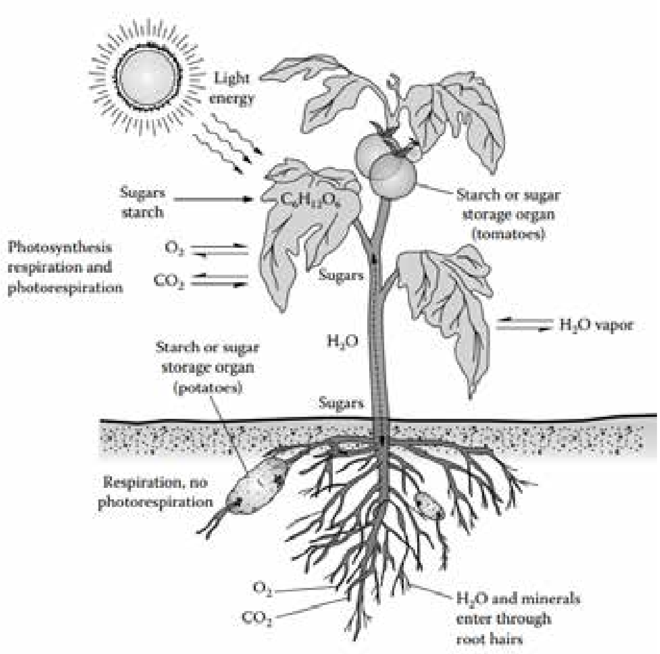
To understand the techniques behind vertical farming it is necessary to know how plants grow.

ABSTRACT:

A plant uses the process of photosynthesis for their growth. Photosynthesis is the process whereby light supplies energy, water from the growing medium provides hydrogen and oxygen, and carbon dioxide from air produces carbon and oxygen that become the building blocks (Sugars) for plants growth. Photosynthesis is expressed in the equation:

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6\ O_2$$

For plants growth also nutrients are needed. In soil this nutrients are saluted and in some other growing mediums as well. In the hydroponic culture a nutrient solution is directly given to the roots of the plants, no soil is needed, only a growing medium where the plant finds its stability.
The nutrients are divided in major elements and minor elements. Each of these elements have a specific function in the plant. If one element is missing the plant is under stress and a disorder will occur, which you can analyse. Crops and other food producing plants need more nutrition to form their vegetables.
Light is an essential element in the plants growth. The sunlight a plant uses is in the visible spectrum between 400 and 700 nm wavelength. Each crop uses has an optimum level light intensity that that maximizes plants growth. Researchers have discovered that each plant has an optimal value of light for growth; these values are called DLI- values. Artificial light is used for year round growing, or for growing on places where no sunlight is available. Artificial lights can emulate the wavelength needed for the plants growth, but it needs energy to operate.
The factors a plant needs to grow are called the key factors. All the key factors that limits growth are called limiting factors. Be aware of the optimum level of light, temperature and the humidity because they can minimize crops` yield.



Plant and photossynthesis
source: Resh, H.M. (2015) . p. 19

Photosynthesis:

Photosynthesis is the process whereby light supplies energy, water from the growing medium provides hydrogen and oxygen and the carbon dioxide from air produces carbon and oxygen that becomes the building blocks for plants growth.[11] All Remaining parts come from the nutrient solution in water or in the soil.

The equation of photosynthesis is derived from the formula[12]:

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6\ O_2$$

Due to photosynthesis animals could exist.

In plants the light is absorbed by chlorophyll, the green pigment in all plants parts. Especially the leafs. Most of the light that the plants use is in our visible spectrum. From the violet-blue tot the red of the spectrum.

There are many complex processes in the plant where sugar is converted into other product. The most important one is the fuel respiration. In respiration, metabolism reactions take place in the cells of plants (and animals) to convert biochemical energy from nutrients into high-energy molecules that can break down into smaller molecules releasing energy in the process. The respiration provides energy for the cellular activity. The nutrient used in respiration includes sugar, amino acids and fatty acids. The energy is stored in the so called ATP molecules. A simplified reaction of respiration is[13]:

$$6H_2O + 6O_2 \longrightarrow 6CO_2 + 6\ H_2O + \text{heat}.$$

It is the main process where plants break down organic compounds into energy, needed for their growth. These Organic compounds are produced during photosynthesis. In plants respiration occurs during the dark, at night the plant uses oxygen and gives of CO_2 and water.[14]

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[11] Resh, H.M. (2015) *Hydroponics for the Home grower,* Boca Raton. CRC Press. P.19

[12] Wikipedia, *Photosynthesis,* Retrieved from: http://en.wikipedia.org/wiki/Photosynthesis on 3th of April 2015

[13] Resh, H.M. (2015) *Hydroponics for the Home grower,* Boca Raton. CRC Press. P.24-25

[14] Resh, H.M. (2015) *Hydroponics for the Home grower,* Boca Raton. CRC Press. P.25

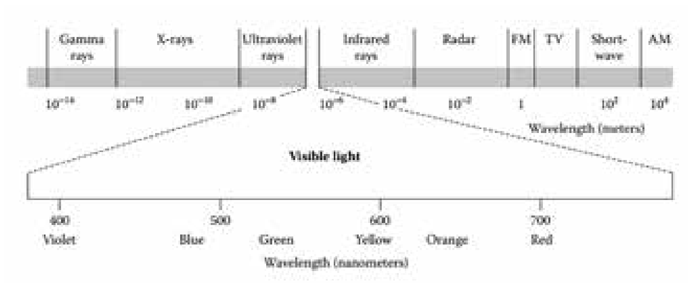
Plants need the correct quality and intensity of light to drive photosynthesis. Artificial light can be a problem to bring plants to maturity[15]. The next section focuses on the aspect of light.

Light:

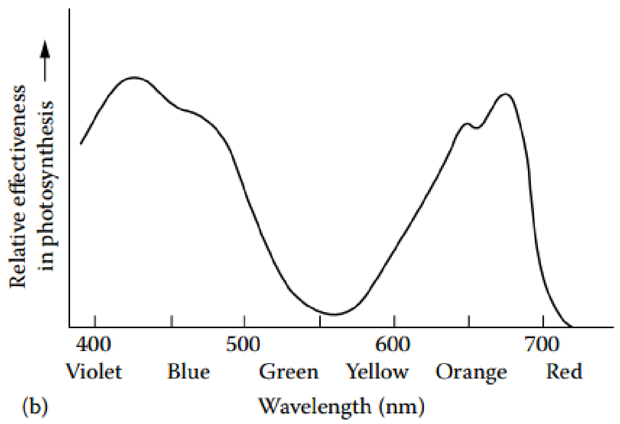
Plants need light as a driver for photosynthesis. The quality and intensity has to be correct for the photosynthesis. Plants require light between 400 and 700 nm wavelengths, which is in the visible spectrum. The light that plants use is called photosynthetically active radiation (PAR)[16]. Each crop uses has an optimum level light intensity that minimize that maximizes plants growth. If there is insufficient light, plants will growth slows down and if there is excess light the plants growth will not increase. In short: The light needs to be between 2 parameters (400-700 nm) to have the optimal growth rate.

Growing plants at home using artificial light you need to get sufficient light for optimum yield. Researchers have developed DLI levels for groups of plants classifying them as low-light, medium-light, high-light and very-high-light crops. Fruit bearing crops like tomatoes, peppers and cucumbers would lie in the very-high-light crops.[17]

The sunlight can also be emulated by lamps, this is called artificial light.



Visible light spectrum
source: Resh, H.M. (2015) . p. 24



Plant and photossynthesis light spectrum
source: Resh, H.M. (2015) . p. 25

Artificial lighting:

Artificial light is used for year round growing. Artificial light makes it also possible to grow inside where no direct sun light is available. In the artificial lighting there are 5 types of lights every light has its own advantages and disadvantages. The stronger the output in Watt the stronger the area it covers[18]. Led is the best option for growing on a bigger scale in long term, based on the low operating costs and life span. For small scale growing the CFL is a good choice, because it can be used without any reflector. A full overview is given in **Appendix A.**

Another key factor of the plants growth is the temperature of the environment. All crops have different optimum temperature for a maximized yield. Crops are divided in two types: cool-season crops and warm-season crops. Some

[15] *Requirements for plants growth,* retrieved from: http://www.aces.uiuc.edu/vista/html_pubs/hydro/require.html, on April 3th 2015

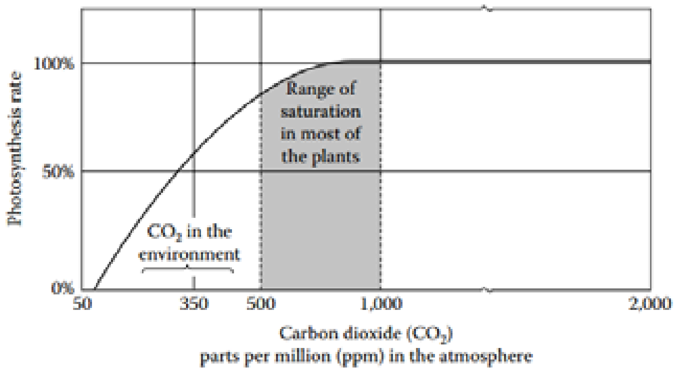
[16] Resh, H.M. (2015) *Hydroponics for the Home grower,* New York: CRC Press. P.26

[17] Resh, H.M. (2015) *Hydroponics for the Home grower,* Boca Raton. CRC Press. P.26

[18] MH Grow Lights, retrieved from: http://www.bghydro.com/grow-lights/mh-grow-lights.html , on April 5th 2015

cool-season crops are: cabbage, cauliflower, broccoli and lettuce. Some warm-season crops are fruiting crops like: tomatoes, peppers, cucumbers and eggplants. In catalogues you can find the optimum temperature for each crops and the DLI-value for the crop.[19]

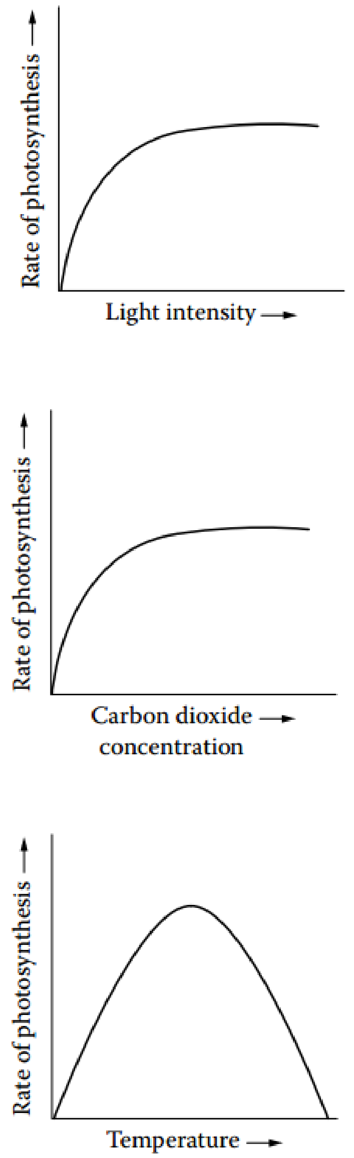
	Temperature day	Temperature at night
Cold season crops	22-23 °C	10-15 °C
Warm season crops	24-27 °C	>18 °C



Carbon dioxide needed for photosyntehis
source: Resh, H.M. (2015) . p. 28

Another key factor is the humidity. Humidity of the air is expressed in percentage of moisture in the air, RH[20]. When the temperature is high and the humidity is low, crops close down their stomata (small pores particularly on the low sides of leaves) to keep their temperature optimum temperature. The closing of the stomata affects the CO2 amount entering the plant for the photosynthesis and it blocks the water in the plant to evaporate for cooling down[21].

All the key factors that decrease the growth rate of the plant are called limiting factors. So be aware of the optimum levels of light, temperature, CO2 and RH for your crops, monitor and regulate them at levels best for your crops growth to maximize yield.



Key factors
source: Resh, H.M. (2015) . p. 27

Water needs of the plant.

Plants exist 80-95 % out of water and 10-20% is dry matter. Water is the medium for plants to take up nutrients. From the beginning of seed germination, water is essential. Water is absorbed into the plants near the tips of the root by specialized root hair cells. When the water enters the plants it is transported from cell to cell by osmosis. The osmosis is based on different pressure levels inside the cells[22].

Water moves upwards in plants through xylem cells, which are long, narrow tubes containing no living matter. These end-to-end connected tubes transport the water through the plants by cohesion force of water molecules. From the leaves the water is evaporated by the earlier mentioned

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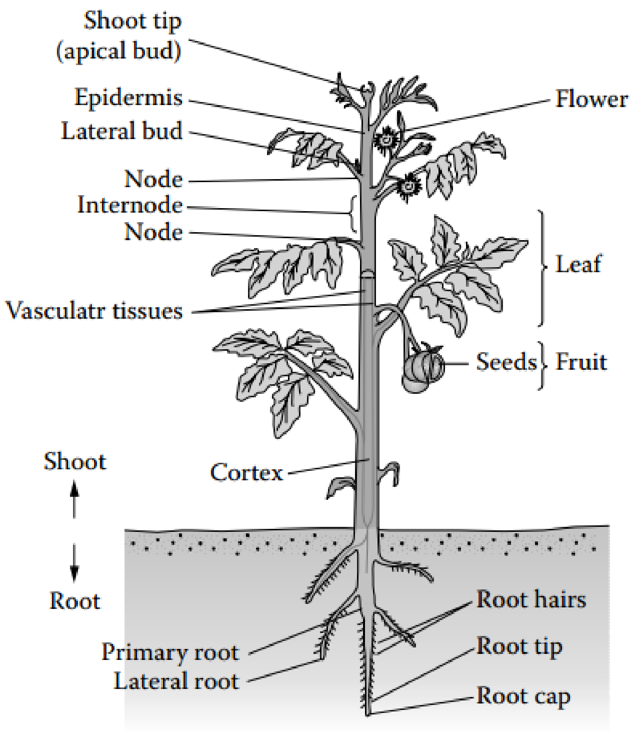
[19] Resh, H.M. (2015) *Hydroponics for the Home grower,* New York: CRC Press. P.28

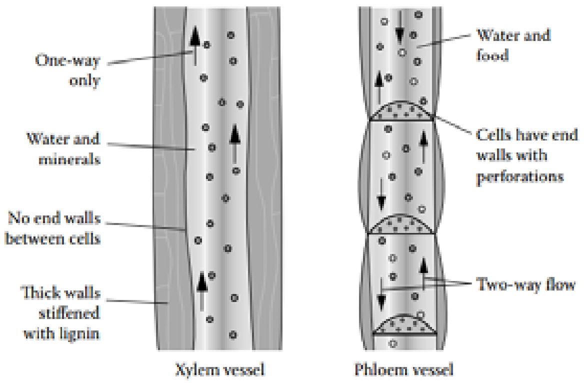
[20] *Relative Humidity* date retrieved from http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/relhum.html on April 10th 2014

[21] Resh, H.M. (2015) *Hydroponics for the Home grower,* New York: CRC Press. P.28

[22] Theme, E. (2014) *Osmosis in Plants: What Does it Mean?* Date retrieved from: https://blog.udemy.com/osmosis-in-plants/ on April 12th 2015



Basic elements plants
source: Resh, H.M. (2015) . p. 32



Conducting vessels
source: Resh, H.M. (2015) . p. 30

stomata. 95 % of the water uptake is evaporated through the leaves[23].
External factors like wind and temperature can increase the evaporation, so the uptake of water needs to increase to keep the plant turgid. If the water evaporation is more than the uptake, the plant will be under stress and closes down the stomata to keep the water in the plant. If the stomata is closed for too long the leaves are wilting and then stems. This mostly happens in soil[24].
In many fruiting crops a water deficit will result in blossom-end rot of the fruit. This is cause by insufficient water uptake and resultant loss of calcium uptake. The symptom is a dry leathery-like black tissue at the blossom end of the fruit. [25]
High humidity reduces evaporation of the leaves. This also slows down the growth of some plants like lettuce. When lettuce is in too humid conditions the plant does not evaporate, this reduces the calcium uptake in the leaves and causes tip burn.
By understanding these conditions you can understand that plants need the right condition for its growing.
The nutrients used in the plants are dissolved in water. The uptake of the nutrients takes place in the sinks (the roots, stems, and fruits). If you permit fruit ripen completely on the plant you will get better flavour and higher nutrition in the fruit harvested. This allows the fruit (sink) to accumulate more of the food substance as is matures.[26]

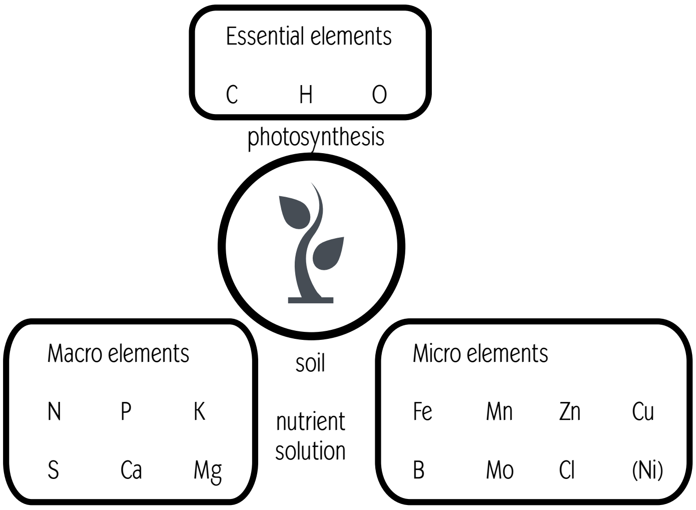
In hydroponics the irrigation can be done automated, it needs monitoring to keep the conditions right. The growing substrate in hydroponics is related to the amount of water it can hold. So every growing substrate needs different irrigation. If you give the plant an excess of irrigation it will slow the plant growth down based on the fact that nutrients will be evaporated instead of used in the sinks[27]

[23] Resh, H.M. (2015) *Hydroponics for the Home grower,* New York: CRC Press. P.31
[24] Resh, H.M. (2015) *Hydroponics for the Home grower,* New York: CRC Press. P.31
[25] Jones, J. B., Jr.(1998). *Plant Nutrition Manual*. CRC Press, Boca Raton, p. 22
[26] Jones, J. B., Jr. 1998. Plant Nutrition Manual. CRC Press, Boca Raton, p. 23
[27] Resh, H.M. (2015) *Hydroponics for the Home grower,* New York: CRC Press. P.32

The essential nutrients to plants.

The nutrients for plants are divided in three categories: The essential elements, macro-/ major elements and the micro-/minor elements[28].
The essential elements are carbon C, hydrogen H, and oxygen O. These elements are part of the photosynthesis process.
The macro-/major elements are nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), Magnesium (Mg), these elements come from the soil or ,in case of a hydroponic, nutrient solution.
The micro-/minor elements are: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl), Nickel (Ni).
Each of the elements has a specific function in the plant. If a plant is under stress disorder will occur. Disorder means that one of the essential elements is missing of there is an excessive supply. With every disorder symptoms occur, which you can analyse.

In the hydroponic culture the pH value shows what elements are missing[29]. An easy way to solve this problem is by using a pH up or pH down.



Essential-, Macro- and Mirco elements
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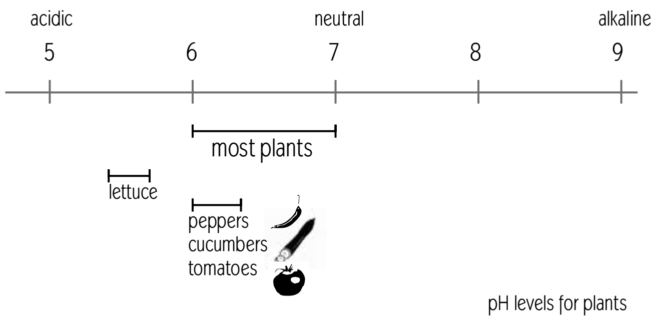
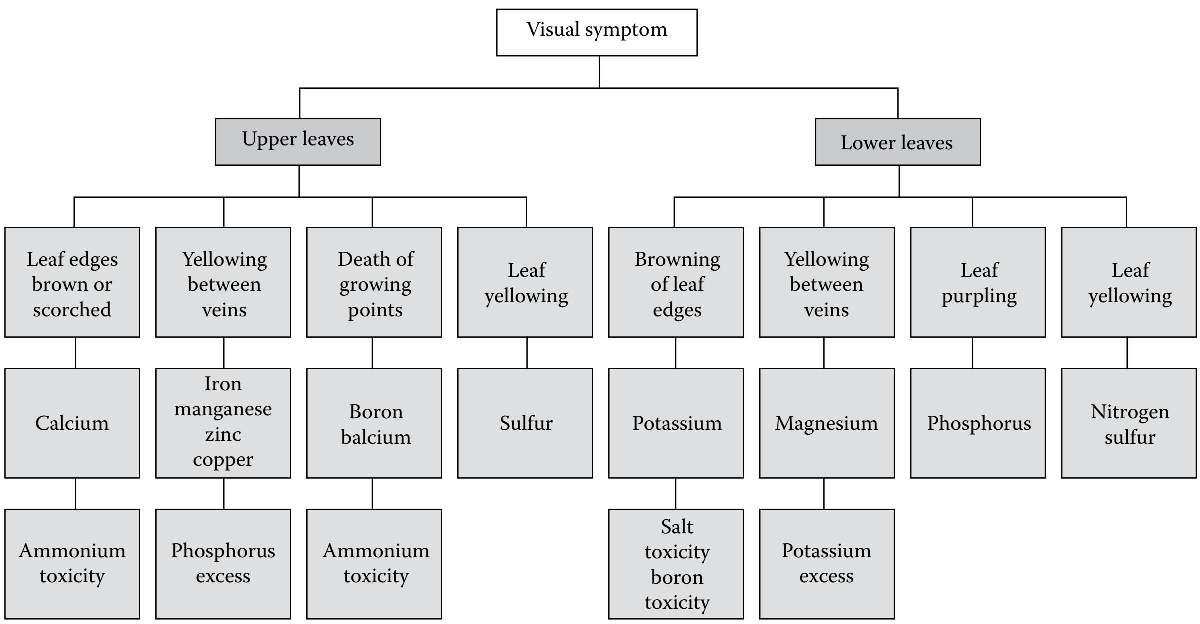


pH Level of plants
source: own image



Visual symptoms of plants:
source: Resh, H.M. (2015) . p. 51

[28] DeMoranville, C. (2009) *Mineral nutrtition: What are the guiding principles? Macssachusetts,* University of Massachusetts.
[29] Resh, H.M. (2015) *Hydroponics for the Home grower,* New York: CRC Press. P.37

Substrates to use and their sources.
Plants will grow in most media as long as they get water oxygen, and nutrients. Between different substrates are different properties[30]. Clay for instants has an high value of water retention so that the oxygen required in the roots is restricted and therefore limiting the plants growth. The important characteristics are explained below. The different substrates are placed in ***Appendix B***

Structure:
The structure must be durable for at least one or more crops and not break down into small particles that will impair oxygenation to plants roots.

Composition:
If the substrate release some particles in the nutrient solution then it will unbalance the nutrient solution. Some substrates that are available must be prewashed/cooked before it is used.

Sterility:
Substrates used must be free of pests and disease organism. By heating some of the substrate at 71 C for an hour the substrate is sterile. Other substrates can be washed with a bleach solution (10%).

Water retention:
The hydroponic substrate must not have properties of very high or very low water retention. However, the acceptable water retention will also be a function of the type of hydroponic system. Water retention must not be excessive causing lack of oxygenation or be insufficient to cause the substrate to dry quickly and starve the plant of both water and nutrients.

Root Support:
The substrate must allow roots to easily penetrate between the particles and anchor the plants as the roots enter the void spaces seeking water. Most of the long term crops need substrate to anchor their roots and take up oxygen, water and nutrients

Availability and cost:
For small hydroponic gardens the cost is not an important factor. Because of the small amount of the substrate needed.

[30] Resh, H.M. (2015) *Hydroponics for the Home grower,* New York: CRC Press. P.63-70

Hydroponics

Growing vegetables in your backyard garden faces lots of challenges with the soil structure, fertility, watering, pests, and diseases. By growing hydroponically these limited factors are eliminated. The definition of hydroponics is givens as: The cultivation of plants by placing the roots in liquid nutrient solutions rather than in soil; soilless growth of plants.[31]

In the earlier chapters is explained what the possible substrates are and what nutrient solution you need for growing plants hydroponically. In this chapter the different systems are pointed out. There is no general division of the systems; different sources give different divisions of hydroponics. In this chapter six systems are explained : a wick system, a water culture system, ebb and flow system, drip irrigation systems, nutrient film technique, and aeroponics[32].

Water Culture Technique:
source: https://www.gothicarchgreenhouses.com/hydroponics-systems.htm

Advantages

There are many advantages of growing hydroponically, the most important ones are listed below.
- Crops can grow where no suitable soil exists.- Labor for tilling, cultivating, fumigating, watering and other practices is largely eliminated.
- No agricultural runoff (big global problem)
- More control of the environment by manipulating nature.
- A hydroponic system can be clean, lightweight, and mechanized.
- Maximum yields are possible, making the system economically feasible in high-density and expensive land areas.
- Soil-borne plant diseases are more readily eradicated in closed systems.

Nutrient Film Technique
source:https://drannelinepadayachee.wordpress.com/2013/05/22/191/

disadvantages

There are also disadvantages of growing plants hydroponically, the most important ones are lister below:
- The original construction cost per acre is great.
- Trained personnel must direct the growing operation. Knowledge of how plants grow and the principles of nutrition is important.

- Diseases may spread quickly if they are linked to the same nutrient tank in a closed system.
- The reaction of the plant to good or poor nutrition is unbelievably fast. The grower must observe the plants every day.

Nutrient Film Technique with plant supporting structure
source:http://www.dpi.nsw.gov.au/agriculture/horticulture/greenhouse/hydroponics

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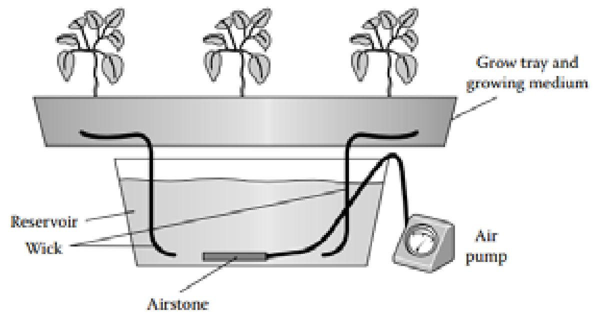
[31] Benton Jones, J. Jr. (2014) Complete guide Growing Plants Hydroponically. Boca Raton, CRC Press. P.5.
[32] Benton Jones, J. Jr. (2014) Complete guide Growing Plants Hydroponically. Boca Raton, CRC Press p 99-114..

WICK SYSTEM

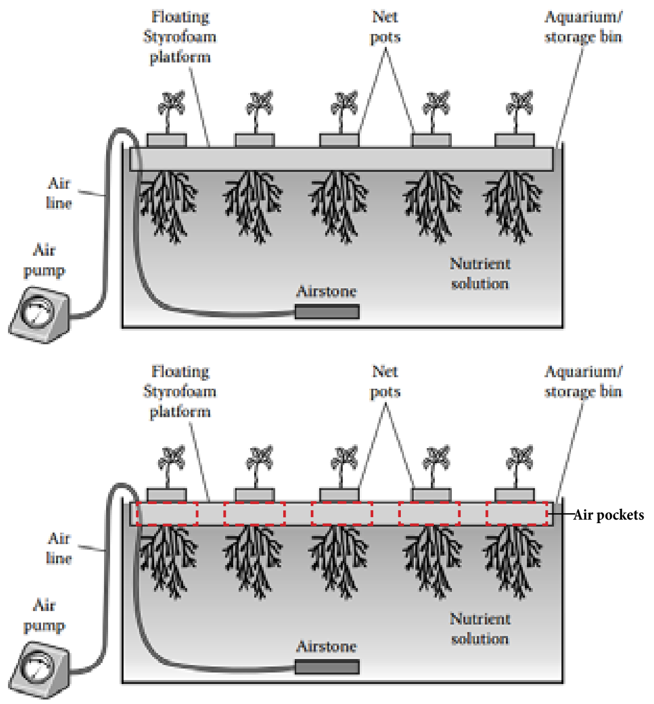


Wick System:
source: Resh, H.M. (2015) . p.74

The wick system is most simple system of hydroponics. It is a passive system; it means there are no moving parts. The nutrient solution is drawn into the growing medium from the reservoir with a wick.
The most used growing medium for this system are: Perlite, Vermiculite, Pro-mix and coconut Fiber. The biggest drawback of this system is that the plant uses more nutrients and water then the wick can supply.

Best Growing medium:
Use a mixture of 50/50 perlite and vermiculite.

THE WATER CULTURE SYSTEM

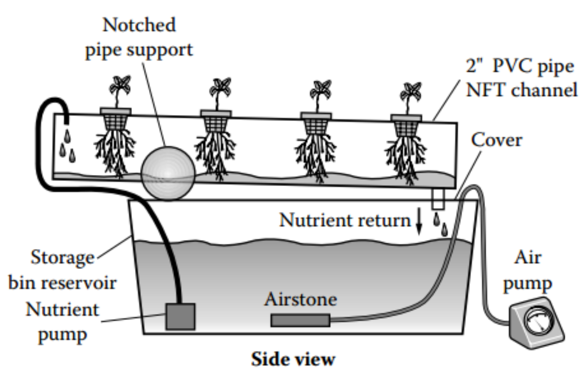


Water Culture technique and Dry Hydroponics with air pockets:
source:(edited from) Resh, H.M. (2015) . p.79

The water culture system is the simplest of all active hydroponic systems. It can also be called the raft system. The platform that holds the plants is usually made of Styrofoam and floats directly on the nutrient solution. An air pump supplies air tot the air stoned that bubbles the nutrient solution and supplies oxygen to the roots of the plants.
The drawback of this system that is doesn't work well with large plants or with long-term plants.

In Holland there is one company who brought the water culture systems to the next level. They built dry hydroponics. This system is based on a water culture technques combined with air pocket surrounding the roots. Some roots are taking the oxygen from the air and other roots are absorbing the nutrient solution.

N.F.T. (Nutrient Film Technique)

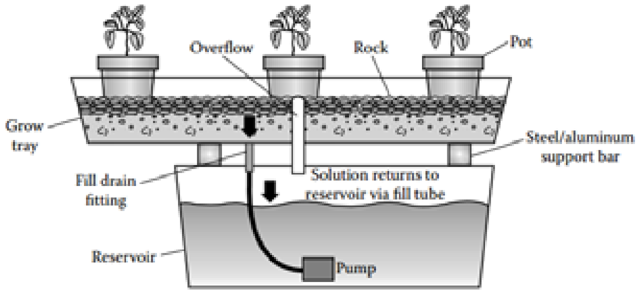


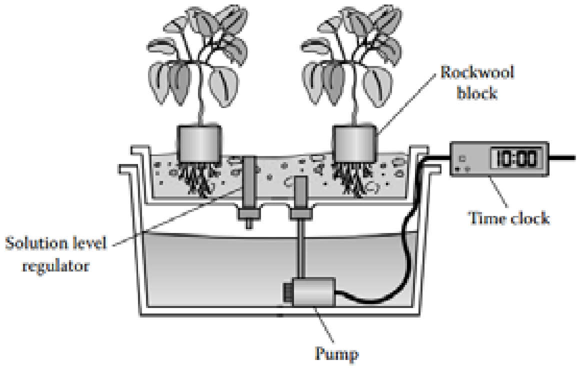
Nutrient Film Technique:
source:Resh, H.M. (2015) . p.82

The Nutrient Film technique is most used technique in the hydroponic industry.. N.F.T. systems have a constant flow of nutrient solution so no timer required for the submersible pump.The nutrient solution is pumped into the growing tray (usually a tube) and flows over the roots of the plants, and then drains back into the reservoir. There is usually no growing medium used other than air, which saves the expense of replacing the growing medium after every crop. Normally the plant is supported in a small plastic basket with the roots dangling into the nutrient solution. N.F.T. systems are very susceptible to power outages and pump failures. The roots dry out very rapidly when the flow of nutrient solution is interrupted.

EBB & FLOW – (FLOOD AND DRAIN)

The Ebb and Flow system works by temporarily flooding the grow tray with nutrient solution and then draining the solution back into the reservoir. This action is normally done with a submerged pump that is connected to a timer. When the timer turns the pump on nutrient solution is pumped into the grow tray. When the timer switches off the nutrient solution flows back into the reservoir. The Timer is set to come on several times a day, depending on the size and type of plants, temperature and humidity and the type of growing medium used. The finer the material, the less irrigation cycles needed per day.
The Ebb & Flow is a versatile system that can be used with a variety of growing mediums. The entire grow tray can be filled with Grow Rocks, gravel or granular Rockwool. Many people like to use individual pots filled with growing medium, this makes it easier to move plants around or even move them in or out of the system. The main disadvantage of this type of system is that with some types of growing medium (Gravel, Growrocks, Perlite), there is a vulnerability to power outages as well as pump and timer failures. The roots can dry out quickly when the watering cycles are interrupted. This problem can be relieved somewhat by using growing media that retains more water (Rockwool, Vermiculite, coconut fiber or a good soilless mix like Pro-mix or Faffard's.

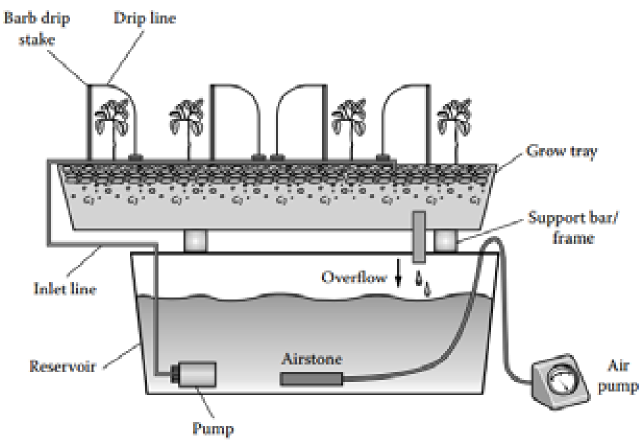




Ebb and Flow (Flood and Drain) System:
source: Resh, H.M. (2015) . p.84-85

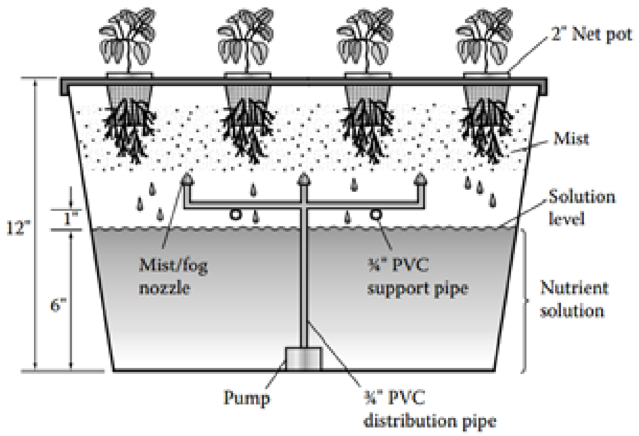
DRIP IRRIGATION SYSTEMS:

Drip irrigation is the most widely used and versatile method of hydroponics. Operation is simple with a timer activating a pump to initiate an irrigation cycle. During a cycle of irrigation, the solution is pumped from the nutrient reservoir to the base of the plants through a drip line. Drip irrigation systems may recycle the nutrient solution to the nutrient tank or it may leach to waste. In a recirculation (closed) system the pH and strength (EC) of the solution must be checked periodically and adjusted. As a result the recycled system is more complicated to manage compared to an open system in which the excess solution drainage is run to waste. In non-recovery design, the nutrient solution is made up and applied to the plants during irrigation cycles with the same pH and concentration without needing adjustments. The nutrient solution may be stored in a large cistern or tank. A drip irrigation system is build up the same as an ebb and flow system. The only difference is that the nutrient solution is pumped up to the top of the tray where it is dripped onto the plants. Most plants can be grown in drip irrigation systems including the vine crops.



Drip Irrigation System:
source: Resh, H.M. (2015) . p.85

AEROPONICS

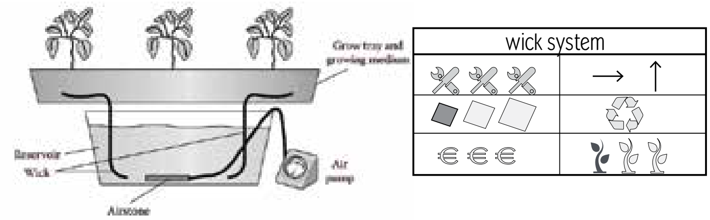


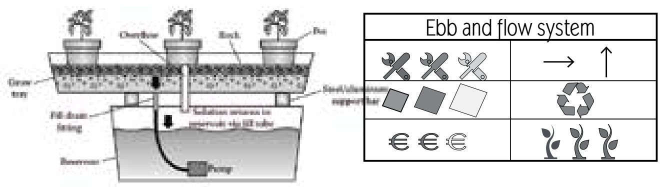
Aeroponics
source: Resh, H.M. (2015). p.92

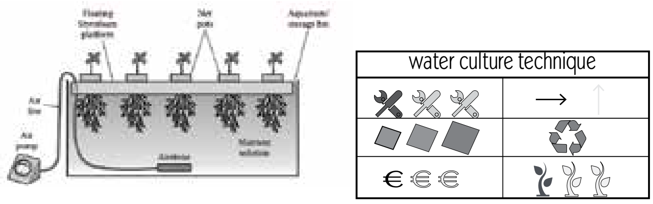
The aeroponic system is probably the most high-tech type of hydroponic gardening. Like the N.F.T. system above the growing medium is primarily air. The roots hang in the air and are misted with nutrient solution. The misting are usually done every few minutes. Because the roots are exposed to the air like the N.F.T. system, the roots will dry out rapidly if the misting cycles are interrupted. A timer controls the nutrient pump much like other types of hydroponic systems, except the aeroponic system needs a short cycle timer that runs the pump for a few seconds every
few of minutes.

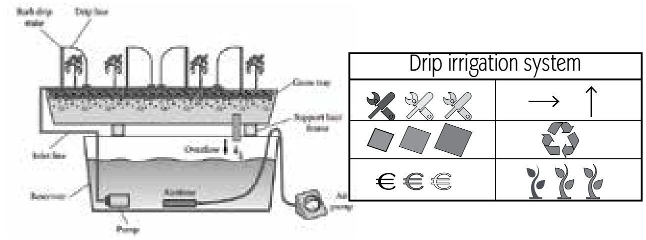
Hydroponic system selection

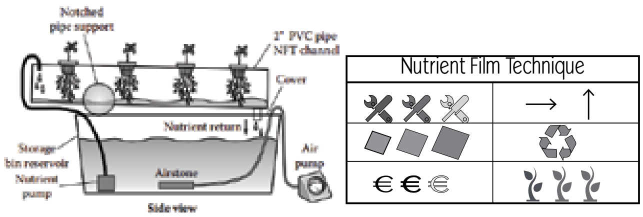
There are 6 types of systems, with all their benefits and disadvantages. The key factors what determines the system is the maintenance, size, costs, direction applicable (vertical horizontal), reuse of nutrient solution, and the variety of plants to grow in.
The wick system can only be applied on small scale. Only small plants will grow in it, but it is cheap, easy to make and maintain. For large growing projects the wick system will not work.
The water culture technique is applicable on large scales. The disadvantages however are the growing direction and the small variety of plants to grow in. This system will work really well in a greenhouse.
The nutrient film technique is a good system for all kind of plants. It installation costs are the most expensive part, but when installed it will last long.
The Ebb and flow system is good system if it is used and controlled well. If the growing medium is not carefully selected, the substrate will block the drain outlet and the system fails. The growing trey is almost directed connected to the reservoir, so it is not used on bigger scales.
The drip irrigation system is the most used system. It can be fully automated so after installing the system it will work on its own. The nutrient solution needs to be checked periodically for optimized growth. This system is used in living walls and in big industrial agriculture.
The aeroponic is the most advanced and expensive system. The mist with saluted nutrients is hard to control. If one nozzle is blocked the system can fail and the plants will die. This system need to be maintained well.

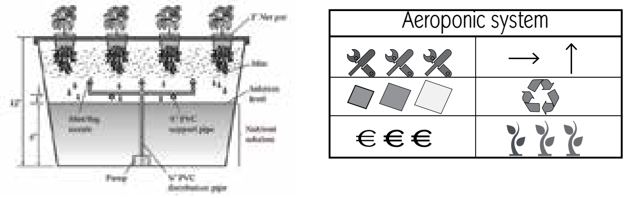












System and their properties
source: Edited from:Resh, H.M. (2015) . p.72-94

Technology: Green Architecture

Understanding the growth of plants and how hydroponic systems work will provide knowledge for the next chapter about green roofs and green façades.

The next investigation contains façade greening and green roofs. Green façades are not new phenomena. They have been considered as standard construction practice for thousands of year. The reason of its use is mainly because of the excellent insulating qualities. In cold climates they help to retain heat in the building, and in warm climates they help to keep the heat out[33].

An ancient historian Pliny wrote about trees being imported for green roofs more than two-thousand years ago. The Roman Empire they put trees on the institutional buildings, such as the mausoleums of August and Hadrian[34]. During the Renaissance, green roofs and terraced garden were common in the Genoa, and in the 16th century they were seen in Mexico, Spain, and Russia.

This following chapters are containing the technological part of green roofs, façade greening and living walls. The parts that contained greenhouse is placed in APPENDIX C, based on the relevance towards this project.

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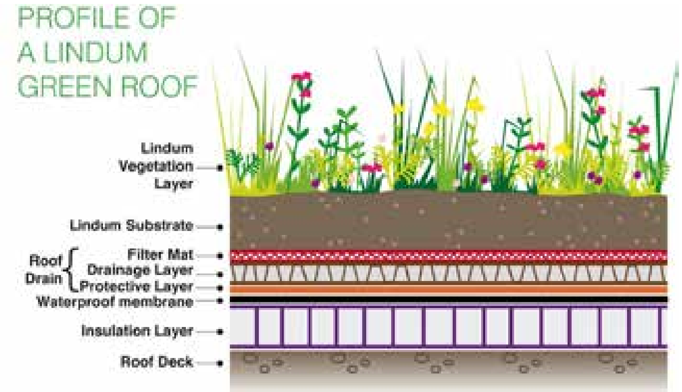
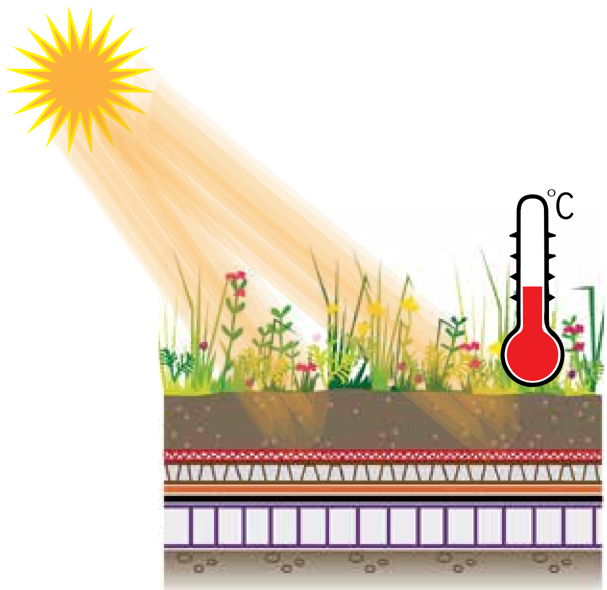
[33] Peck, S.W.(1999) *Greenbacks from green roofs: Forging a new industry in Canada.*Toronto, Canada Mortgage and Housing Corporation. P.11

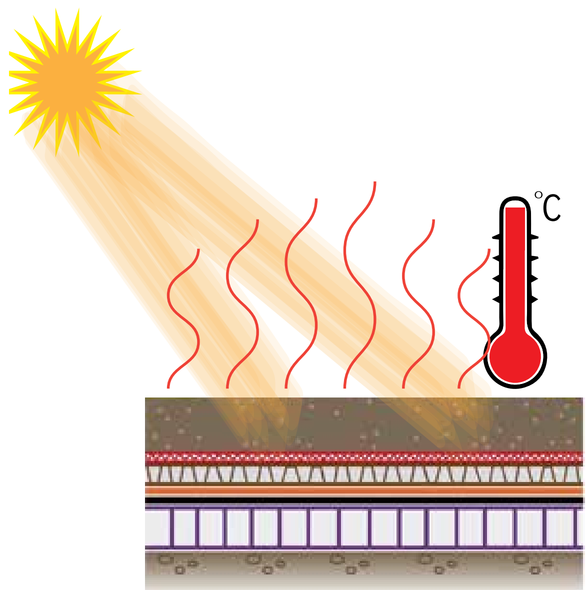
[34] Peck, S.W.(1999) *Greenbacks from green roofs: Forging a new industry in Canada.*Toronto, Canada Mortgage and Housing Corporation. P.11

The Green Roof



Profile Green Roof:
source: http://www.lindumgreenroofs.co.uk/designing-and-specifying/





Heat accumulation Green roof vs Normal roof.
source: Own picture (edit)

The green roof, also known as eco-roofs, living roofs, planted roofs or vegetated roofs, use plant to improve a roofs performance, its appearance or both. Green roofs are often described as falling into two (or three) categories: intensive and extensive[35] (and semi-extensive).

Extensive green roofs are simpler and lighter roofs with a depth of 15 cm or less. It exist out of a mineral growing medium, with plants like sedums and other tough, drought-resistant, low growing plants. These are the most common in Europe[36].

The intensive green roofs are more like conventional roof gardens. They have deeper, more organic growing medium or soil capable of supporting a wide variety of plants, often including shrubs and small trees. They are usually accessible for regular use and often designed as amenities for peoples who live or work in the building. Rooftop farms, urban roof farms or vegetable farms on roofs are clearly intensive green roofs and require higher nutrient applications and focused maintenance[37].

If an intensive and an extensive green roof are combined you get hybrid types[38].

Advantages

- Life span of roof is 60 years, compared to a normal flat roof the life span is 25 years.
- Reduces the storm water runoff.
- Building a green roof gives 15 LEED credits
- Roof is transformed from dead space to garden space where the biodiversity increases.
- Reduces the air conditioning costs
- Reduces the energy demand in the building
- Reduces the heat island effect
- Reduces noise
- Reduces the amount of smog and improve the air quality.

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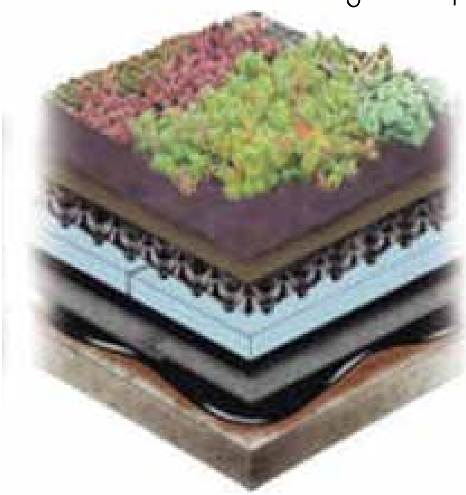
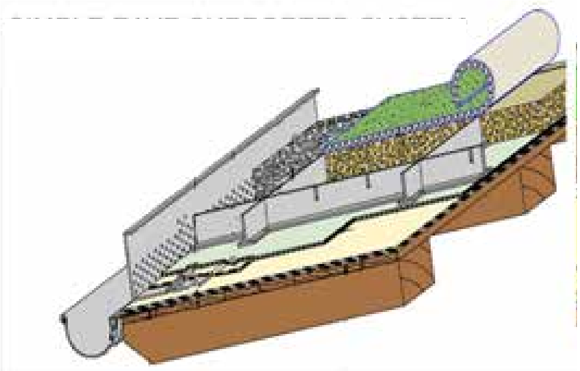
[35] *Green Roof Developer's Guide* (2011), Sheffield, Groundwork Sheffield
[36] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 4
There are no sources in the current document.[37] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 5
[38] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 6

intsensive green roof
Height: 200-500 mm substrate
Weight: 290-970 kg/m^2
Plants: Allmost all climate suitable plants
Source: http://www.wbdg.org/resources/greenroofs.php



Extsensive green roof
Height: 80-200 mm substrate
Weight: 70-170 kg/m^2
Plants: Grass, Small plants
Source: http://www.wbdg.org/resources/greenroofs.php



sloped roof with grid
source: http://www.greenrooftechnology.com/sloped_green_roofs

Disadvantages

The green roofs disadvantages are all based on the existing building.

- When the roof has a slope more than 9,5 degrees an extra grid is applied to resolve the slipping of the layers. Sloped roofs are mostly extensive green roofs.
- The load bearing structure of the existing buildings roofs has to carry the extra weight of the green roof. When the roof is not strong enough an extra construction is recommended and it will results in extra costs.
- In dry climates an irrigation systems is needed to prevent the plants from dehydrations that can lead to the risk of fire.
- A Green is more expensive than an normal roof, but the energy costs will reduce and the investment is worth the money.

If you compare the advantages to the disadvantages investing in green roofs is worth the money.

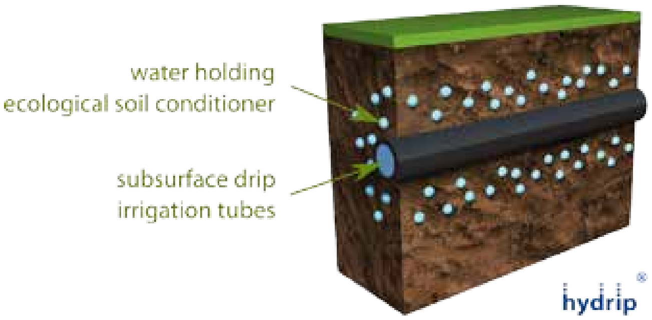
Requirements

The green roof is divided in two systems as earlier explained. The differences between the two types manifest themselves in the visual appearance and the amount of maintenance they may require; fundamentally the classification exists because of their relative overall weight[39]. The extensive roofs are relatively lightweight and can be placed on most modern roof structures. Intensive green roofs have more serious weight and structural implications. Retrofitting a green roof onto an existing building will mean that the roof must fit existing carrying capacity or the owner must be prepared to upgrade the roof structure, this will result in more costs for the building owner.

Extensive lightweight structures with a substrate depth of 15 cm will have approximately weight between 70 and 170 kg/m^2. Intensive green roofs with a soil based substrate will impose an additional weight of 290-970 kg/m^2. It is recommended to ask a structural engineer to calculate if the green roof is fitting the structure.[40]

[39] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 6
[40] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 7

Sprinkler system
Source: http://en.wikipedia.org/wiki/Irrigation#/media/File:Irrigational_sprinkler.jpg



drip and tube system
Source: http://qatar.hydrip.at/en/al_sprinkler.jpg

Capillary system
Source: https://swfsc.noaa.gov/textblock.aspx?id=18479

Standing water system
Source: http://agreenroof.com/green-roofs/green-roof-panel-systems/

One other problem for applying green roofs is the roof slope. The maximum possible slope is controlled by the two most slippery profiles in the green-roof profile[41]. For roofs with slopes steeper than 2:12, 9,5 degrees or 17% it is unwise to apply a green roof. An extra system can be applied, which means using horizontal strapping, laths, battens or grids. With this system green roofs can be applied on a slope of 7:12, 30 degrees or 58%. These structures repose for most granular materials.

Structures on roofs are exposed to high wind uplift especially the edges. The layers on the roof are vulnerable to wind shear particularly in the water proofing layer. This layer is not bonded to the roof beneath and the green roof itself is acting as ballast to hold it down. On the edges, where the wind uplift is the highest extra weight is used to keep the vegetation layer in place.

Normally green roofs are carefully designed with an appropriate plant mix and substrate. There should be no need for irrigation and if irrigation and fertilizers are needed it is less sustainable. On the other hand on semi-intensive or intensive green roofs irrigation is needed for the health of the plants and it can reduce fire hazard. Judicious irrigation may be beneficial. [42]
There are four main irrigation methods used on green roofs.
1. Surface spray with traditional sprinkler systems:
Wasteful of water.

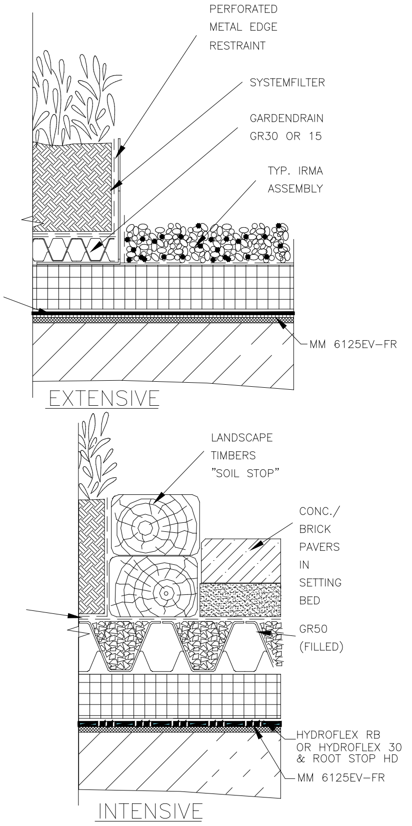
2. Drip and tube systems:
These systems are pegged on the ground or placed in the substrate. The water only goes to the plant roots and is not directly evaporated.

3. Capillary systems:
Porous mats deliver water to the base of the substrate and are ideal for shallower structures (max. 20 cm depth).

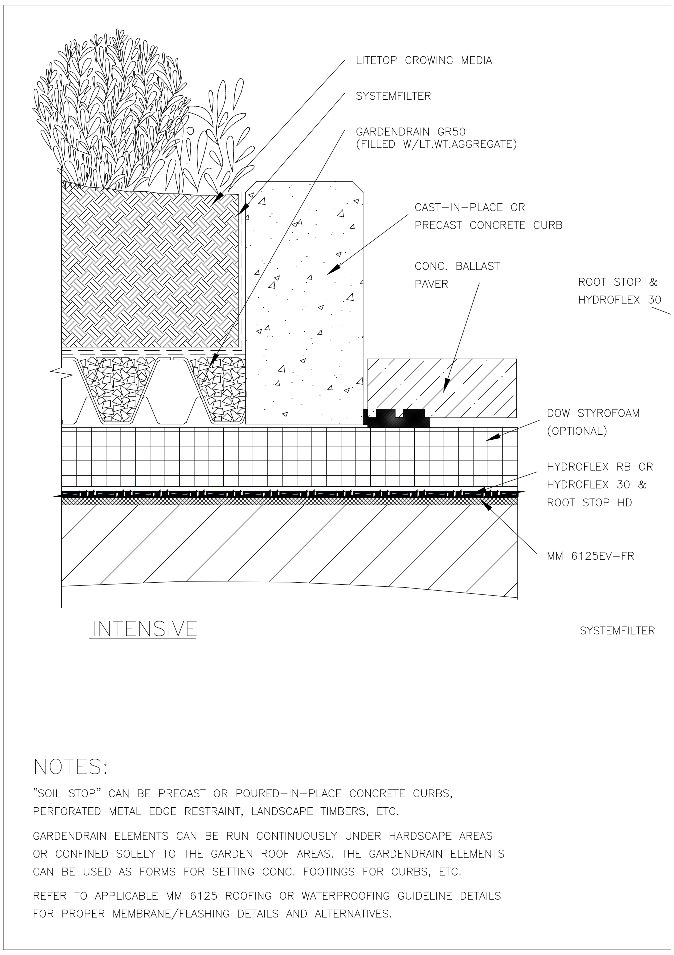
4. Standing-water systems. These systems maintain a layer of water at the base of the roof. These systems can be self-regulating-being filled percolating rainfall but can also be maintained by float-control devices.

[41] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 94
[42] Peck, S.W.(1999) *Greenbacks from green roofs: Forging a new industry in Canada.*Toronto, Canada Mortgage and Housing Corporation. P.13

Components



GENERIC TRANSITION OPTIONS
SOFTSCAPE–TO–HARDSCAPE
GR–5A



The construction of a green roof has the same starting points as a normal roof. It needs the capability of carrying the loads and it needs to be weather-proof. There are a lot of manufactories who have patented their own multilayer system. In the end all systems use the same components[43].

- The main component of a green roof structure is the roof deck. It supports the additional layers and element on top of it.

- The vapour control layer lets water vapour out of the roof. These vapour control layer is mostly protected from sunlight by gravels or shingle.

- The insulating layer keeps the heat in the building. This layer can be placed on top of the roof deck (warm roof) or underneath the roof deck (cold roof).

- The waterproofing layer protects the roof deck against water.

- The root protection barrier protects roof from penetrating roots.

- Drainage layer controlling the water on roof.

- Filter Mat protects water system from small particles.

- Growing medium is used for growing plants. It needs to contain nutrients.

[43] Peck, S.W.(1999) *Greenbacks from green roofs: Forging a new industry in Canada.* Toronto, Canada Mortgage and Housing Corporation. P.13

Materials

There are many commercial systems on the market with their own patented systems[44]. The material of the layers varies, so no further details are given about the material. The vegetation mixtures though will be explained in short.

The extensive green roofs have a mixture of plants that have the similar growth rate and form. Sedum mixtures are used on many shallow-substrate roofs. Mixtures of plants instead of a monoculture are recommended, because of the susceptibility of low-diversity plantings to being wiped out by disease or stress. Diverse mixtures of species are more likely to contain plant that are able to overcome or withstand such environmental hazards and therefore provide long-term integrity to the vegetation[45].
For example, with mixtures of grasses and drought-tolerant perennials in dry climates the grasses grow during the wetter periods and the perennials will flourish and flower during hot, dry periods.

mono-culture green roof

sedum mixture semi-extensive green roof

Costs

The costs of a green roof are depended of the shape (slope, skylights etc.) and size of the roof. The investment and payback time is given as the Whole Life Costs. Analysis is usually using Net Present Value of future inflows and outflows of cash due to a particular asset or change[46]. The energy saved by applying a green roof can be between 4-30 kWh/year/m_2. In the end applying a green roof on the existing roof is a win-win situation and worth the investment.

	Engineered £/m²	Cost £/m²	Natural Construction £/m²	Cost £/m²
Warm roof expose	55		55	
Sedum Blanket	110	+55	95	+40
Sedum Plug	120	+65	80	+25
Biodiverse	120	+65	75	+20
Inverted Roof				
Shingle	70	+15	70	+15
Paving	75	+20	75	+20
Sedum Blanket	110	+55	95	+40
Sedum Plug	120	+65	80	+25
Biodiverse	120	+65	75	+20

Table 6 uses a single ply membrane roof as the base cost and shows the additional cost for the different Green Roof build-ups. Note that for an inverted roof, replacing the paving with a natural Biodiverse roof means no additional cost.

Green roof costs in pounds
in 2011 1 pound was 1,19 euro's
source: Green roof developers guide p. 37

[44] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p.148
[45] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p.149
[46] *Green Roof Developer's Guide (*2011), Sheffield, Groundwork Sheffield. P. 12-14

Maintenance


Maintaining a green roof:
Source: http://www.greenrooftechnology.com/green-roof-blog/calendar/2013/5/

A complete maintenance-free green roof is probably an unreachable goal. Maintenance for extensive and semi-extensive green type roofs can be limited to an annual task. A sustainable goal for the green roof design is minimized maintenance, a reduced or eliminated need for resource input such as fertilizer or irrigation where possible[47].

Feeding:
For extensive green roofs the substrate mostly loses are nutrients after two years. Fertilizers are needed to maintain growth. Slow-release feeds should only be used at low application rates. The amount is twice as high on intensive green roofs compared to the extensive green roofs. On grass roofs equilibrium is reached where a cycle returns nutrients from dead stems and leaves to the substrate. This is the same as it works in the natural habitats.

Moving and cutting:
If a wildflower meadow is created on relatively thin, free-draining and low-fertility substrates on a roof then there should be little need to cut it back or mow in the traditional sense.

Plant protection:
Pest and disease problems are few with green roofs, based on the species selected. Diverse plant communities are used, if one species becomes adversely affected, there are always plenty of others in perfect health around them, so that any problems do no become conspicuous.

Drainage:
Effective drainage is key to the success of green roofs. A blockage it the draining system can lead to pooling of water, which may result in drainage to the roof surface and consequent leakage, together with drainage to plant root systems, followed by fungal damage and decay. If drainage systems may become blocked they need to be identified and their regular inspection specified into schemes of maintenance.

Weeding:
There are several trick to minimize weeding requirements. Continuous vegetation covers the space available for unwanted plants to establish.
Keeping the surface dry and coarse will help to prevent seed germination, which is a common problem for green roofs.

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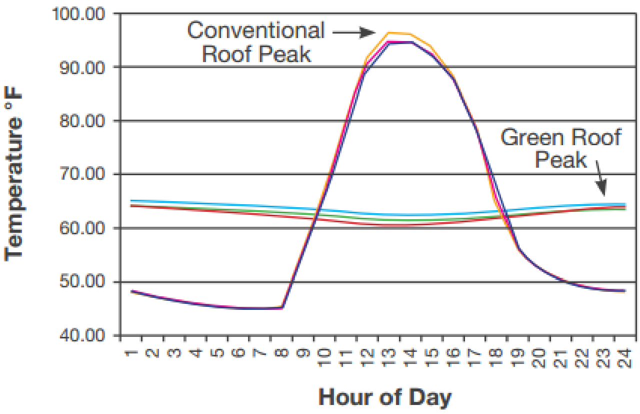
[47] Peck, S.W.(1999) *Greenbacks from green roofs: Forging a new industry in Canada.*Toronto, Canada Mortgage and Housing Corporation. P.45

Unwanted seeds spread by wind can take over the existing vegetation. Checking the roof for unwanted plants is necessary. Weeding twice a year is recommended.

Climate

The green roof is energy saving compared to a normal roof. Normal roofs absorb the heat from the sun and conduct it into the building. By making roofs cooler, designer can reduce the amount of absorbed solar energy, and consequently reduce the amount of heat conduction into buildings[48].
Research shows that green roofs prevent temperature extremes and the insulation value of the soil on the structure lowered the cooling energy costs. Research also shows that a green roof has a constant temperature during the winter months and during the summer months. Conventional roofs have an average temperature of 8 degrees in winter and 36 degrees in summer. So the green roof helps in winter for heating and in summer for cooling.



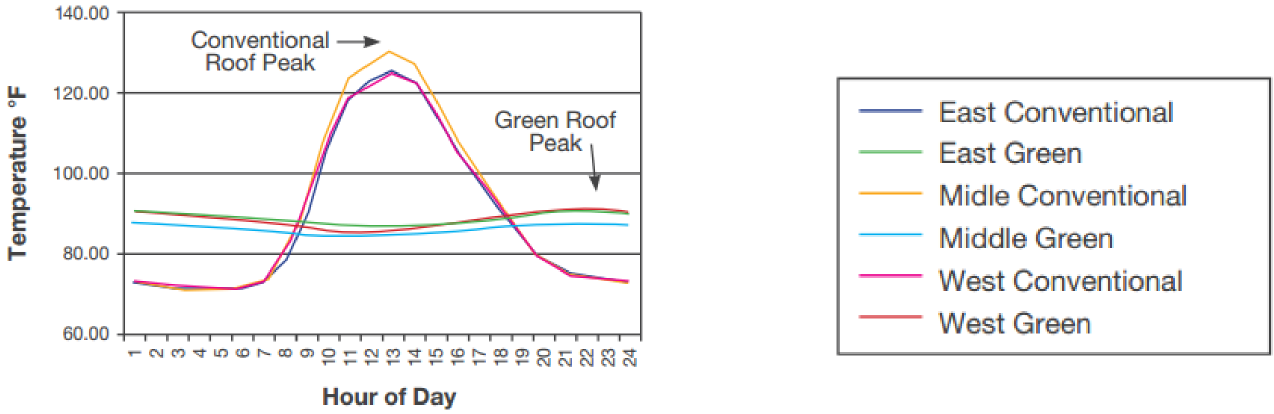


Table 2 Temperature comparisons of Exposed and Green Roofs

Roof Type	Lowest temp	Highest temp	Range	Time of peak
Exposed	8°C	36°C	28°C	14:00
Green	16.6°C	17.8°C	1.2°C	23:00

Green roof temperature
source: Green roof developers guide p. 17-18

[48] Peck, S.W.(1999) *Greenbacks from green roofs: Forging a new industry in Canada.*Toronto, Canada Mortgage and Housing Corporation. P.22

Facade Greening

plant: parthenocissus
source: http://commons.wikimedia.org/wiki/File:Parthenocissus_tri-cuspidata_in_courtyard.jpg

Facade greening by Theo Hotz AG.
source: http://www.archello.com/en/project/sihl-city-green-wall

The terminology "green walls" describes a vegetated vertical surface and is an inclusive description of two very distinct concepts. There are green façades created by vines and climbing plants that roots in soil or containers and grow from there on a structure and there are living walls. This chapter expose the climbers.
A green wall on the outside of you building can be a self-regenerating cladding system. Traditionally self-clinging climber were used where no network of trellis or wires was used. Nowadays it is common to hold plants away from your building surface.
There are two types of plants that can be placed to the surface of al building: The evergreen plants and the seasonal green plants. The evergreen keep it leafs in the winter where the seasonal green loses is leaves during winter[49].

Advantages

Summer

- Façade greening helps to reduce the maximum temperature in a building by shading wall from the sun. The cooling amount in summer is not depended on the thickness of the green wall, but it is depending of the area the leaves shade. German engineers have calculated that the energy reduction in air condition system is reduced by 50 to 70% in summer situations.
- Windows can also be shaded by climbers. On a seasonal basis it reduces the sun entering the building through windows, the foliage blocks the sun.
- Green walls also help to reduce the heat island effect. Due to the space between the foliage a powerful convection occurs that takes the heat away from the stone ore concrete masses.

Winter

- The evergreen climbers reduce the heat loss in winter. The chill winter breeze cools the building of the most; the green façade reduces this amount by 25 percent or more. During winter time the depth of the green façade determines the insulation factor.

[49] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p.98

different species self clinging climbers:
source: http://www.sustainabilityexchange.ac.uk/events/green_walls_exchange

Pollution:
Certain plants in green façades trap the dust of the city. They filter the pollutants out of the air and trap them in there tissues. The leaf area index determines the amount of dust trapped. Some climbers also filter the nitrogen oxide (the exhaust from cars)

Façade protection:
The green Façade protect the surface from: rainfall, hail and UV-radiation. This increases the lifespan of the façade.

Biodiversity:
The green façade attracts insects and birds. It helps to increase the biodiversity in the city. Some birds use the façade to nest. During winter small birds that can't withstand the winter breeze seek for protection within the green façade.

Costs:
A green façade is not really expensive, due to the advantages of energy and façade protection the investment is worth the money.

Structure:
Not all structures a suitable for green façades, due to the fact of increasing wind loads. Although for a sustainable future green façade is a good option.

Visual:
-Visual enhancement due to greening and design quality (stress reduction)

Sound:
-Sonic-absorption or reducing the sonic reflection (surface enlargement)

Disadvantages

A green façade has also its disadvantages. The disadvantages are listed below.

- Chance of damage on façade in case of green façade directly to the wall.
- Maintenance of vertical greening systems.

The following two disadvantages are based on living walls, it is explained in the next chapter.
- Costs of vertical green systems, especially living wall systems.
- Irrigation systems.

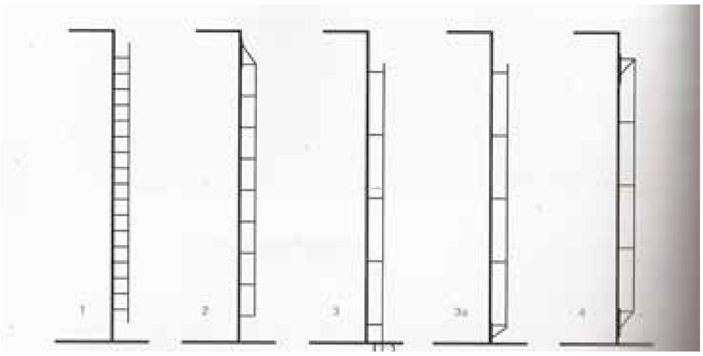
Requirements

There are two main types of climbers systems. One is called the self-clinging climber. The other one needs a supporting structure. To start there growth they need a fertile soil and high level of moisture until they get on size. (Irrigation can be necessary).

The self-clinging climbers are the easiest climbers to as they require no supports. The best options to use these climbers are on windowless walls, because it is difficult to determine the growing direction. The self-clinging climbers need a rough area where they can attach their aerial root hair can grab onto, like brick, cement or render. If there are holes in the wall the plant will grow into it, so holes ore spaces between bricks are not suitable for self-clinging climbers. When the weight of the plant reaches a certain level it can detach from the structure and fall down, at certain points support can be recommended[50].

There are three types of supporting systems:
- Trellis or a framework of horizontal and vertical elements.
- Horizontal supports
- Vertical supports

Support:
If climbers are planned to be constructed over a height of more than two stories supports need to be chosen. These supports are depended on the following factors:
- Climbing mechanism of plant
- Plant vigour and eventual size
- The degree of exposure to various climates variables (especially wind and snow)
- design factors



1. Direct wall fixing
2. Hanging system
3. Rigid rod upright
4. Tensioned systems (steel cables/ glass fibre)

Source: Dunnet, & Kingsburry, N. (2008) p.220

Components

For the self clining climbers you need two components.
- A rough wall where the aerial roots can grab onto.
- A growing medium that is fertile to start in

For supported climbers there are different systems available, but it can be divided in two main components:
- Framework, trellis, or vertical horizontal supports.
- A growing medium that is fertile to start in.

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[50] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 201


Supoorting stainless steel trellis:
source: http://anativegarden.blogspot.nl/2013/06/


Steel cable and wire support system
source: http://secrets-of-self-sufficiency.com/insulating-a-house-with-climbing-plants


Rope climber
source: http://secrets-of-self-sufficiency.com/insulating-a-house-with-climbing-plants

Materials

Wooden trellis: - +- 25 year lifespan (with threatened wood)
- cleaved wood
- painted
- distance between trellis and façade determines lifespan

Metal trellis: - Heavy material but strong
- corrosion proof metal
- section of 55 mm minimal
- no corrosion protective paint (decline lifespan)
- (galvanized metal

in sea area
- stainless steel
- aluminium
- (plastic coated)

Cable and wire:
- easy transport to site
- flexibility in design
- horizontal as vertical

Glass fibre: - 7.75 mm minimal section of wire
- very high tensile strength
- uneven texture necessary for attachment of climbers
- no corrosion
- expensive

Rope:
- not durable
- for short term best option.

Costs

The costs of green façades are approximately five times cheaper than living walls. The costs of façade greening is depended on the following factors[51]:
- Project size.
- Design team costs.
- System type.
- Support structure requirements.
- Building location.
- Complexity of design, use of standard or custom components.
- Site conditions and access.
- Cost of installation labor.
- Local availability of materials.
- Project timeline.
- Type of plants used

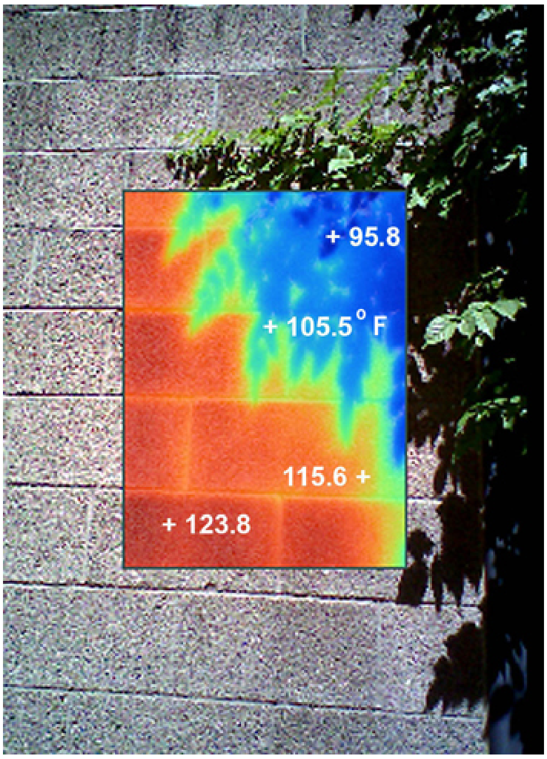
[51] (2008) *Considerations For Advanced Green Facade Design, Greenscreen. P.11*

Maintaining clinging climbers
source: https://www.rhs.org.uk/advice/profile?pid=189

Maintenance

All green walls require maintenance, because it is a living wall. The different systems determine the amount of maintenance needed[52].
Young climbers should be inspected every two years. Large ones, or those that are close installations which could be damages, should be inspected annually. Supports and fixing should be checked every five years.

The essential maintenance tasks are:
- training plants and tying onto supports if necessary.
- Pruning shoots going in the wrong direction or making unattractive loops of growth.
- Clearing shoots and debris out of gutters and cutting back shoots that are near sites where they could penetrate between materials.
- Removing large quantities of dead material, to prevent fire risk.



Infared photography demonstration temperatures on the building surface
source: Greenscreen p.3

Climate

The benefits of green walls all climate have a lot in common with the green roofs.
First of all the heat island effect is reduced by using a green façade. The foliage in front of the wall prevents the wall from heating up in summer, so less cooling in summer periods is needed[53].
In winters the cool breeze will cool down a building. With a green façade the layer of air between the leaves will prevent this and helps to insulate the building.

A green façade will also trap the pollutants and pollen from the air[54]. This helps for creating a healthier climate.

[52] (2008) *Considerations For Advanced Green Facade Design, Greenscreen. P.11*
[53] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 212
[54] Peck, S.W.(1999) *Greenbacks from green roofs: Forging a new industry in Canada.*Toronto, Canada Mortgage and Housing Corporation. P.18

The Green Wall

The terminology “green walls” describes a vegetated vertical surface and is an inclusive description of two very distinct concepts. There are green façades created by vines and climbing plants that roots in soil or containers and grow from there on a structure and there are living walls. This chapter expose the living walls.

A living wall is rooted within the vertical structure. Instead of climbers smaller plants root themselves in the wall where the nutrients are. Climbers root themselves in the soil underneath the wall, so living walls are not depended on the soil at the bottom. Three classifications are made within the living wall section[55]:

-Living walls – vegetation layers are independent of the main wall structure.
-Retaining walls – Rooting of plants occurs behind the wall, where the medium is.
-Retaining wall – Rooting of plants occurs within the wall.

Advantages

Facade USA pavillion 2015
source: http://inhabitat.com/biber-architects-green-walled-usa-pavilion-is-a-living-breathing-tribute-to-sustainable-food/

The advantages of a living wall on your building is listed in the previous chapter. The only difference is the growing medium attached to the wall and has therefore some extra advantages:
- Grow all kinds of plants on your façade, even crops.
- Extra insulating layer.
- Air quality inside (if living wall is placed inside your building.)

Disadvantages

A living wall has also its disadvantages. The disadvantages are listed below.

- Living walls are expensive; it is five times more expensive than climbers of vines.
- Maintenance of living walls, the growing medium needs a constant flow of water and if the systems fail plants will collapse.
- Irrigation systems, the constant need of water for a healthy grow of plants.

[55] 55 Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 245

Requirements

Bracket living wall system
source: http://www.ambius.com/green-walls/services/installation/index.html

Bracket living wall trey system
source: http://www.ambius.com/green-walls/services/installation/index.html

Free standing living wall
source: hhttp://tournesolsiteworks.com/wordpress/index.php/tag/interior/l

Growing plants vertically demands:
- A growing medium, preferably inert and non-biodegradable (no replacement needed)
- A means of delivering water/nutrients in solution.
- A way of holding the growing medium and plants in position.

These main demands are the same demands as the hydroponic culture has. In the hydroponic industry are different types of hydroponics, for a living wall the Nutrient Film Technique and drip irrigation is used. A constant flow of nutrients is provided to the roots of plant.

The most efficient way of constructing a living wall is by making a modular system. If one part of the walls fails, the part can be replaced by a new one. This is the same for the irrigation system, so a drip irrigation system is recommended.

In the living wall industry there are three different systems for constructing a living wall[56]:
Panels systems,
Tray systems
Free standing systems.

There are also natural living walls[57]:
Dry stone walls:
On the outside of your building other types of living walls can be constructed. There are dry stone walls were no mortar is used. The space between the stones plant can root and grow. The maximum height of these dry stone walls is 1 meter. If it is built in a slope form bigger heights can be made.

Stacked construction and modular walls:
If the dry stone wall doesn't reach the required height stacked construction can be made. The stones are interlocked with each other and the plants can grow in between the spaces.

Mortared wall:
In a mortared wall mortar is used to construct the wall. Plants grow here on the surface and sometimes needs an extra construction in front of the wall to stay in position.

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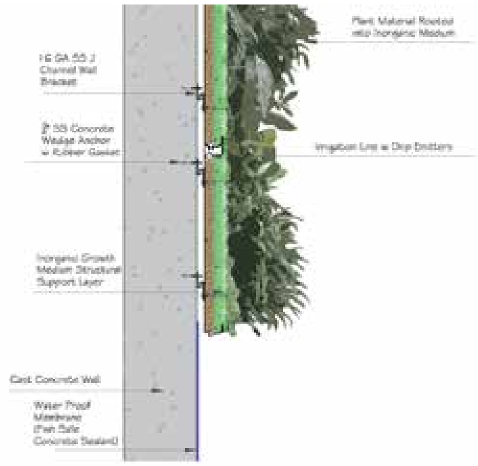
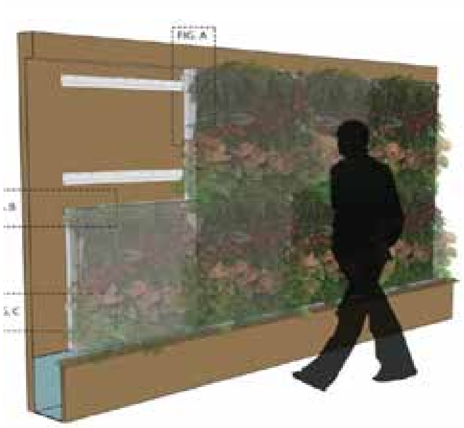
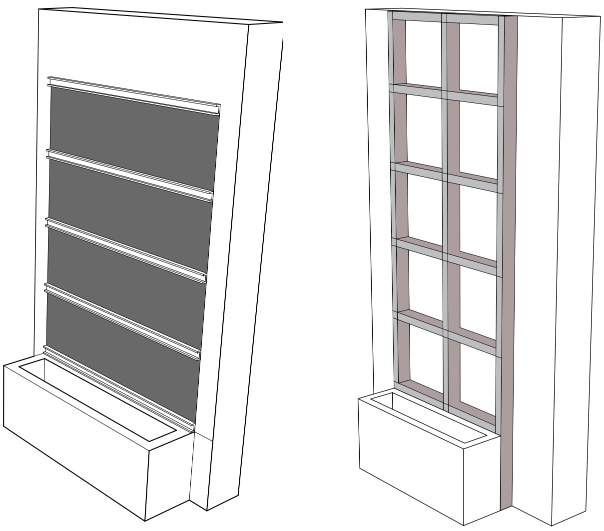
[56] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 212

[57] *Green Roofs for Healthy Cities: Introduction to Green Walls. 2008. Greenroofs.org p.8*





Bracket living wall system
source: http://www.ambius.com/green-walls/services/installation/index.html



Bracket living wall system (left)
Frame living wall sysyem (right)
source: Own image

Components

The components for the created living walls are explained. There are two types of structures for the living wall. One type is with mounting brackets where het panels or treys are hanged into, and the other structure a steel frame where the panels or treys are placed into.

If the living wall is placed on a existing wall a water proof layer needs to be placed to protect the wall against water. The structure holds the living wall in place. The most used system is a frame structure. The panels or tray can easily be installed in the structure and it is an easy way to maintain if problems occur.
(A free standing structure has its own structure)
On concrete or stone walls brackets are used to hold the systems away from the load bearing wall.

The hydroponic system provides nutrients to the plants, mostly done by a drip irrigation systems or nutrient film technique. Located at the bottom of living wall is the reservoir.

The growing medium in trays or pots or integrated in the panels where in the roots find their support.

Vegetation: suitable plants

Materials

Every company uses its own system for living walls. As earlier explained the components have their own materials.

The structure:
For the structure steel or aluminium frame is the most used option. It is strong and has little deflection, so it is easy to place the panels or treys in the system.
For concrete walls steel or aluminium mounting brackets is the best option, based on their strenght.

The panels:
The panels are done in all kind of materials, the growing substrate is integrated in the panel.

The treys:
The treys are hanged in the construction. Most tray are executed in plastic, based on the weight.

Hydroponics:
Hydroponics that provides nutrients to the plants mostly done in plastic tubing, because it is using the same pipes and connections as the plumbing sector.

Costs

Living walls are five times more expensive than façade greening.
The costs of living walls are higher because[58]:

- The irrigation system is expensive
- There is more maintenance needed
- Support structure required
- Plants are mostly already grown
- Cost of installation labour

The costs are also depended on:
- Ease of access: If the installation site is difficult to access.
- Complexity
- Scale: larger projects cost less per square meter

Installing panel system facade greening:
source: Greenscreen p.7

Maintenance

The maintenance of the living wall is very important. The most fragile part is the irrigation system, if it fails plants will be under stress, so proper maintenance is required.
To check if the irrigation system works properly the growing substrate must be checked, when it is dry the irrigation system is not working properly, a leakage or a block in the irrigation system is most of the time the problem.
Depending on the irrigation systems the plants need to be watered 20 to 30 minutes a week.

Living walls on the exterior can have freezing problems in winter, so it is recommended to shut the irrigation system down and blow air through the irrigation lines, so frozen water can't cause any damage[59].

Dry stone walls:

Stacked construction and modular walls:

Mortared wall:

source: Dunnet,N. & Kingsbury, N. (2008),

[58] Data retrieved from: http://livewall.com/faq/#cost on 3th of June 2015

[59] Data retrieved from: http://livewall.com/faq/#cost on 3th of June 2015

The benefits of green walls all climate have a lot in common with the green roofs.
First of all the heat island effect is reduced by using a green façade. The foliage in front of the wall prevents the wall from heating up in summer, so less cooling in summer periods is needed[60].
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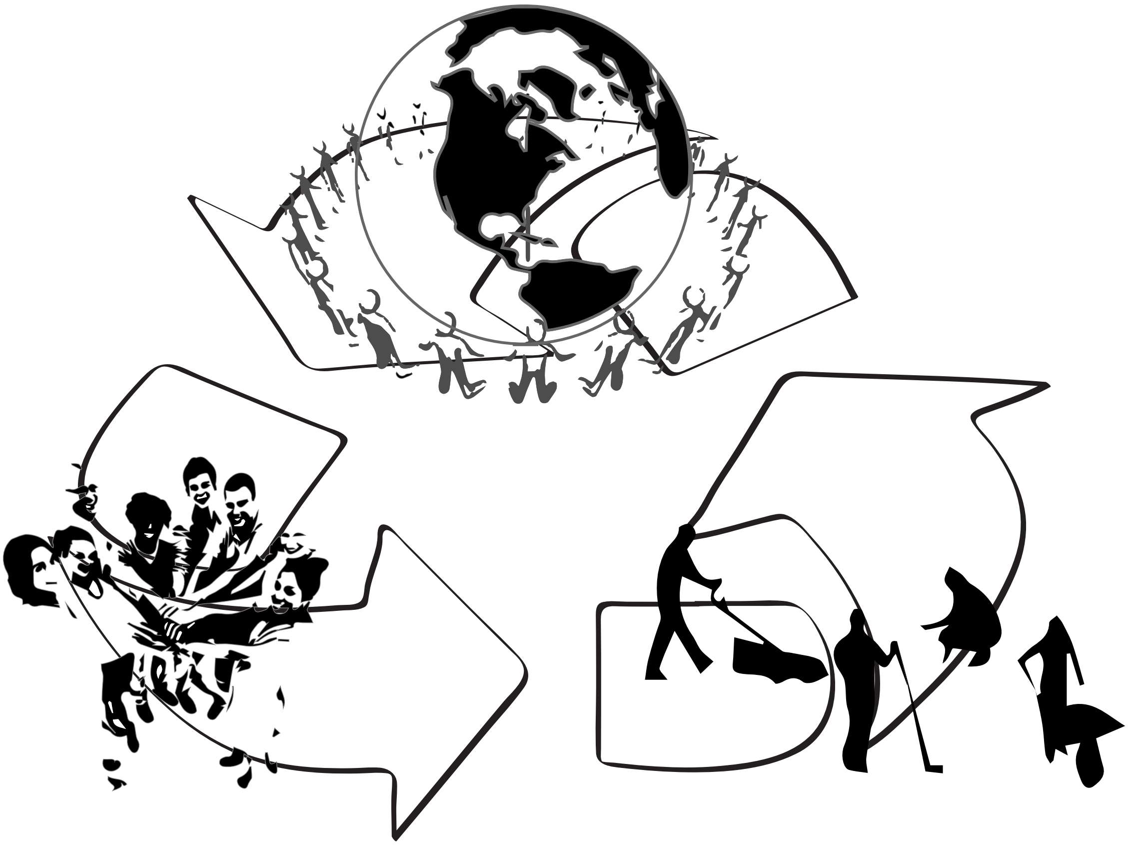
[60] Dunnet,N. & Kingsbury, N. (2008), *Planting green roofs and Living walls*. Portland, Timber press. p. 212
[61] Peck, S.W.(1999) *Greenbacks from green roofs: Forging a new industry in Canada.*Toronto, Canada Mortgage and Housing Corporation. P.18



Urban Agriculture and society
source: Own image

Research project Parnassia Group:

"A tree doesn't grow to pull their branches, but by watering the roots" (Carl Van de Velde)

Research has shown the beneficial effects of green for people in general and people who are patients. The study of Varley-Winter[62] has shown that urban agriculture could add for clients who phase difficulties, such as physical or mental disability, addiction issues and long-term unemployment. A person's change of finding and keeping a place in society is affected by their attributes and skills, their working motivation, the way they present their skills and attributes to the employers. The urban agricultural focus is investigated at the clients of the Parnassia 's locations, the greenhouse(Monsterseweg) and Pluk (Loosduinse Hoofdstraat). Both locations provide day care.

Clients who suffer from psychological problems, addictions, burn-outs or social isolation can find day care in this facility. The goal of this facility is to actively let the patients participate in a day care so they could find a meaningful place in society. By collaborating support and treatments is given for clients that suits in every stage of the recovery process. In the framework of social responsibility they try to reintegrate all clients back in society. In the next part the two site visits are described and compared. The aim is to describe the current approach in dealing with the added value of green in practice in a building facility of the Parnassia Group.

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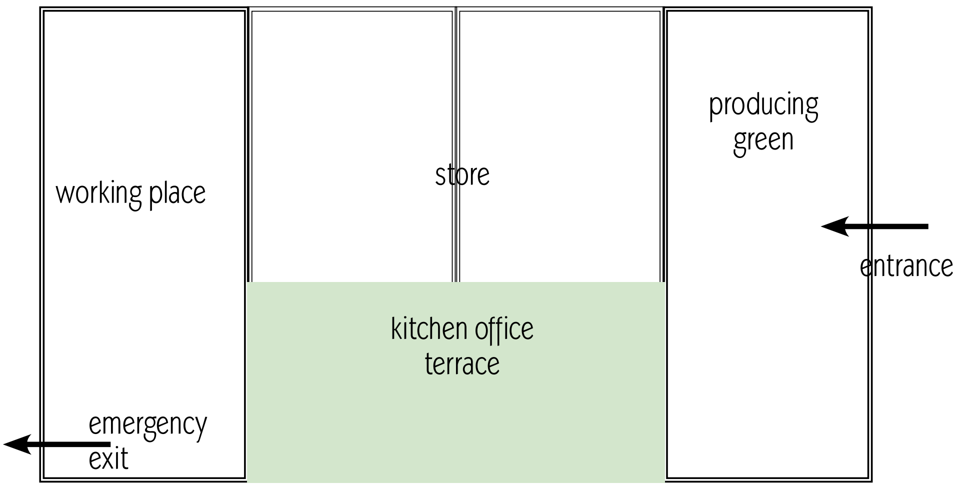
[62] Varley-Winter, O. (2011) *Developing employability through community food-growing and ubran agriculture projects.* Londen. City & Guilds centre for skills development. P. 7-10

The Greenhouse
The greenhouse is a separate facility in a health care area where a hospital and intuitions are situated of the Parnassia group. The aim of the greenhouse is provide green daycare therapy where clients participate in the producing of green.

The goal:
In the greenhouse of Parnassia is it al about meaningful day care and responsibility. The labor the clients deliver is approachable, so they understand what they are doing. The responsibility in combination with approachable labor results in the fact of simple labor, like filling pots with soil or planting one seed in a pot. Caring for plants looks easy but there it isn't. So the supervisors take most of the responsibility of the caring for the plants.
Client and Supervisor:
The people who work in the greenhouse is twofold. One or two professional supervisors and engage approximately eight clients a day. The supervisor formulates the tasks to the clients, considering their abilities to perform the tasks given. The supervisor is a professional and receives income, while the clients get reimbursement of expenses (125 euro a month). In the mindset of the clients hey receive income as well, they mentioned. Thus feeling rewarded as equal with the supervisor.

The work they deliver:
As earlier mentioned the aim of the work is to reach the goal of meaningful day care. What the clients do is rather basic: they plant a seed in a pot, they place the pot on the ground and water it (most of the times the supervisor water the plants). When the plant is fully grown they harvest the crops and sell it in the local store within the greenhouse or prepare it in their kitchen. After the preparation of the self-grown crops they serve it in the restaurant also in the greenhouse. In the entire process failure is taken into account, so if things go wrong they don't mind. The supervisors tried to make it cumulative process, but the average level was below expectation that they gave up on the cumulative process.
When the client is recovered they can't come back to the greenhouse as volunteer, because they need to play another role with other responsibilities.

According to the supervisor the link between producing food more effectively with the help of client was beneficial concept. One side note: "They can participate in the green concept, but the plants 'growth must be done by a specialist".
Since the Parnassia Group facilities are moving from place to place a modular system is recommended.
The approach of my investigation is to improve the building by adding green and let the clients participate in the process in the means of producing green. The formula is the concept.


working place
store
producing
green
entrance
kitchen office
terrace
emergency
exit

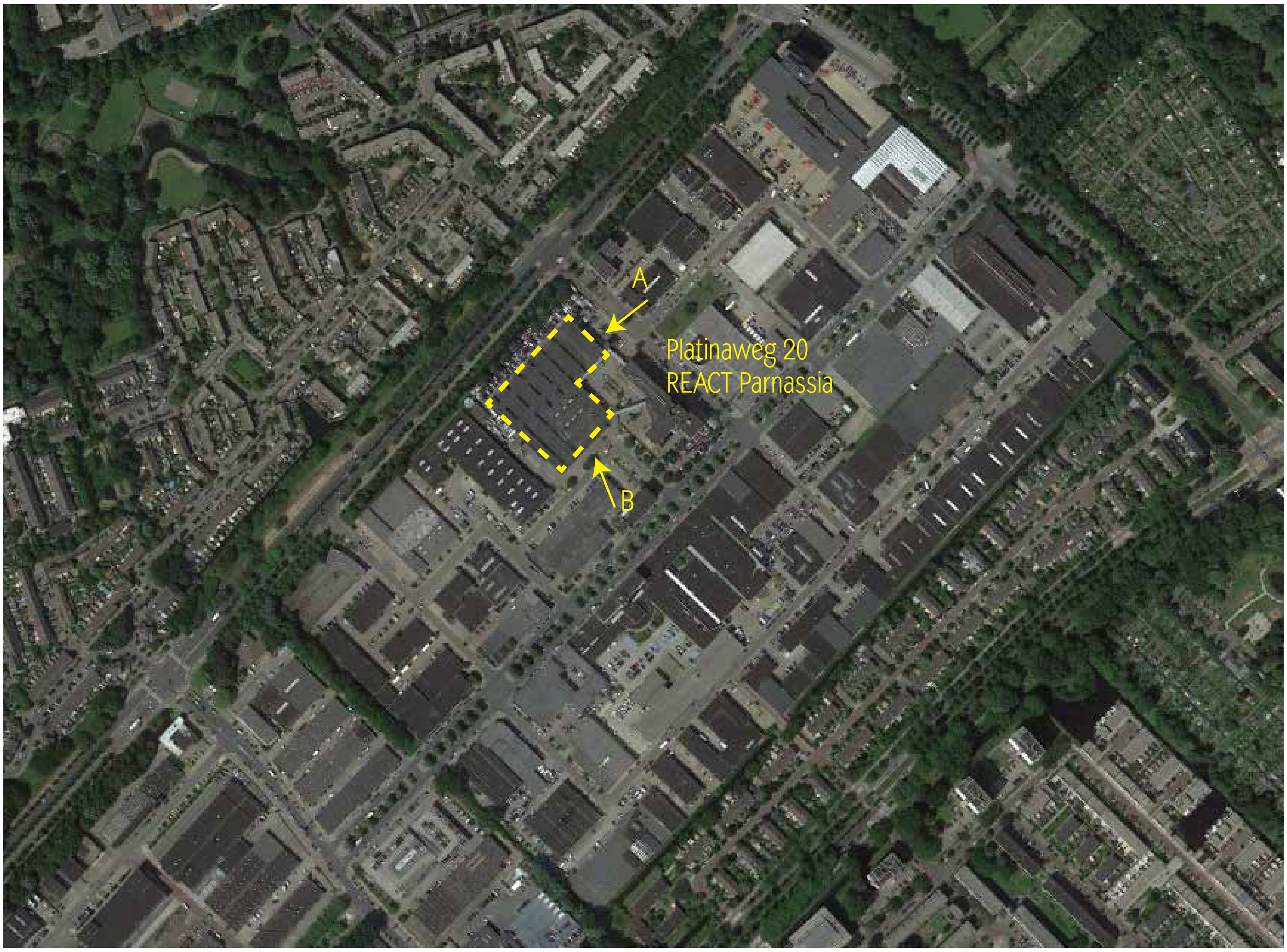
Pluk:
Pluk is nonprofit organization which facilitates the clients of Parnassia. It is a separate green area nearby the health core zone as debribed above.

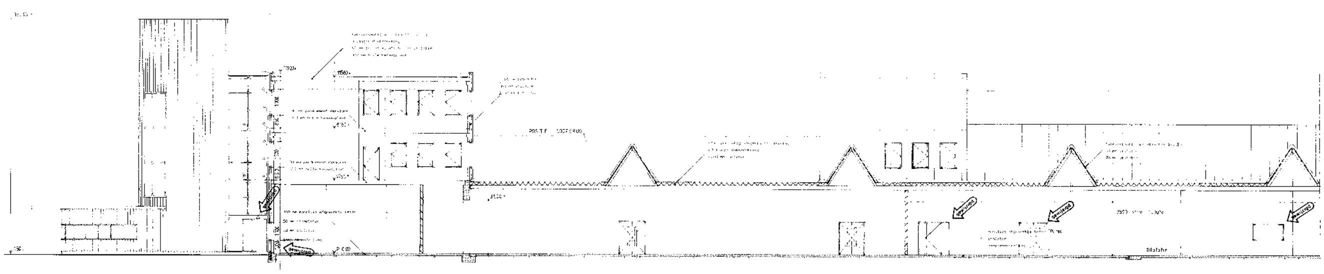
Goal:
The organization Pluk is founded by freelancers which were focused on psychotherapeutic recovery, by creating day care in the form of a kitchen garden and children's zoo's. A site was created for meaningful and therapeutically day care. This was dedicated to growing crops and flowers. Also animals walked around which the clients take care of like, goats, sheep, ducks, rabbits, chickens and guinea pigs. On site was also a small restaurant, a small shop to sell their home grown/ home-made products in. However the quality and the quantity of the products were of poor quality.

The target groups:
The foundation defined the psychotherapeutic clients specifically as participants instead of clients. The idea behind this is a positive affirmation of their strengths as an individual. Also a set of conduct is in place to endorse representative conduct en a certain level of independency in their working contribution. A special attention is on the needs of the clients due to their problems to ensure a friendly climate on the site which is also accessible for visitors. Therapeutic participants receive a fare of 125 euro a month.

Pluk! Den Haag


Pluk! Den Haag
Entree
Pluk!
Dierenstallen
Winkel
Kantine
Keuken
terras kantine
Groente
&
Heemtuin
Dieren wei





Parnassiagroep Platinaweg 20
Source: Google Earth and municipality

Reflection and conclusion

In this chapter the focus is on the reflection and the answering of the research questions. The aim is to conclude with conclusive remarks for future development. The developments related to the innovative strategies regarding green architecture in general and the Parnassia Group in specific.

Reflection
During this research I investigated a wide range of literature for urban farming and different kinds of green building systems related to a healing environment. Some parts of the research did not have any added value (greenhouses) to the main research question, but I was also focused on creating a toolbox that gives a full overview of the possibilities of green inside and outside buildings. If you understand the basics of plants growth, the different systems available on the market you can easily recognize what kind of greening system it is. The toolbox will not be presented due to the complecicicity of the scale of Parnassia Group, benchmark and limited amount of time.

Investigating the systems for green architecture
when I started investigating the systems for green systems, I came across several technologies to create green buildings and urban farming. One of these systems was aquaponics and hydroponics. I interviewed a director-owner of a hydroponics company to learn more about the process. This company had a patent on Dry Hydroponics. It is a water culture technique combined with air pockets, so the roots could take up oxygen. After a tour in the company and the interview I learned that hydro and aquaponic systems were not easily useful, because for aquaponics (plants and fishes) a plant needs their nutrients, so you feed the exact nutrients to the fish so the excretion could be used in the plants. Hydroponic systems are more directly because the nutrients are saluted in water. So the aquaponics are not investigated for this research because I regard this too complex for the healing environment of Parnassia. I focused instead on hydroponic, greenhouses and green roofs and façade.

Investigating a healing environment: the Parnassia Group

My first meeting with the board members of Parnassia was on 21st of April. Our appointment was at Platinaweg 20, an industrialized zone with no green on site. At the office on the third floor we talked about the concept of vertical and urban farming and the existent practice in the day care facility of Parnassia. That was a greenhouse and a green area. However, in the daycare building on the Platinaweg, no green day care facility was available. So green was in place, but externally. Furthermore the Parnassia Group wanted to investigate also the impact of green in relation to a sustainable building in a broader sense, namely a green climate system. The climate inside the building was not comfortable, the building needed an upgrade. The Board of Parnassia hence was interested in both green as day care therapy and a green climate system. For this research we concluded that a healing environment should have two aims: facilitating the clients in a green healing environment both inside and outside the building. In doing so I would research the effect of green day care therapy and I would design a building plan for "greening up" the building on the Platinaweg. This fitted my interdisciplinary approach using the concept of planet, people and profit.

Conclusion

In this paragraph I answer the main research questions:

1. How does green add value to buildings of the health care facilities and its client?

Building value of the facility:
The factors that influence the healing environment on architecture level contain the following: nature, daylight, climate, special organization and smell.
If these factors are linked to the day care facility on Plantinaweg 20, the deduction can be made that the Platinaweg 20 needs improvement for its clients, by applying nature in and around this building.

In the healing environment it can improve patients' recovery rate, which results in cost saving in the health care.

Target group

The requirements of the Parnassia Group were devoted to producing green for and with their clients. For implementing green that focuses on the clients' needs, producing green is the most resulting option.

Research has shown that green reduces stress and contribute to a faster recovery.

For the clients and other participants, research and practice shows that community food growing and gardening projects provide a unique combination of social support, skills development, and supported transition into work, and they are therefore well placed to reintegrate clients back in society. See blow further elaboration.

2. What are the existing techniques available and what are the benefits and risks of these techniques?

The techniques available are depended on: Where to grow, what to grow, scale of growing, costs, year-round growing and maintenance. Growing vegetables soil-based faces lots of challenges with the soil structure, fertility, watering, pests, and diseases.

Hydroponics

By growing hydroponically these limited factors are eliminated. The definition of hydroponics is givens as: The cultivation of plants by placing the roots in liquid nutrient solutions rather than in soil; soilless growth of plants.

There are many advantages for growing hydroponically the main advantages are crops can grow where no suitable soil exists, there is no agricultural runoff, the system can be clean light weight, and mechanized. The big problems of growing hydroponically are the costs and maintenance. To maintain the hydroponics system knowledge is needed and most system needs to be checked every day, this can be a big disadvantage.

Green façade

Green roofs and vertical gardens can help to address the lack of green space in many urban areas.
Research has shown that added greening on roof and façade contribute towards a better climate inside and additionally add value to the urban site. Façade greening and green roofs protect the surface from weather condition, resulting in a longer life span of the exterior.
Growing of herbs and other urban agricultural product are less commonly realized but can add economic value to underutilized roofs and walls.

The available techniques for greening up your building can be conducted on the inside and outside. Applying green on the outside will have more benefits than risks, especially for the indoor climate. Producing food on a building must be done by living wall or an intensive green roof. The costs of green roofs are an investment, but it will pay back in time due to less energy consumption for heating and cooling.

Living walls
A living wall is rooted whiting the vertical structure. The irrigation of the plants is done with a hydroponic system that is integrated within the structure or the growing panels. A constant supply of nutrients and water is available due to the hydroponic system. The essential elements for plants grow are water, carbon dioxide and sunlight. The living wall is depended on the orientation toward the sun.

Intensive green roofs:
There are extensive and intensive green roofs. The extensive green roof is a light weight roof with a small substrate for growing. The intensive green roof is the more massive green roof type and has a bigger substrate for growing. For carrying the green roof the structure has to be suitable, otherwise an upgrade of the structure is required.
Intensive green roofs need a system where the rainwater stays in the growing medium. Also adequate nutrition for food producing plants is required within the growing substrate, or need to be added in the growing substrate.

Light
Light is an essential element in the plants growth. The sunlight a plant uses is in the visible spectrum between 400 and 700 nm wavelength. Each crop uses has an optimum level light intensity that that maximizes plants growth. Researchers have discovered that each plant has an optimal value of light for growth; these values are called DLI-values.
Artificial light is used for year round growing, or for growing on places where no sunlight is available. Artificial lights can emulate the wavelength needed for the plants growth, but it needs energy to operate.

The factors a plant needs to grow are called the key factors. All the key factors that limits growth are called limiting factors. The optimum level of light, temperature and the humidity are key criteria since by deficit it can minimize crops yield.

3. Which criteria are necessary for a healing environment from the perspective of people, planet and profit?

In the Parnassia Group I have investigated the impact of a healing environment and green therapy on two locations
of the Parnassia Group.

In the Parnassia Group in The Hague the two facilities engages in harvesting and production of food and sell food. The difference between the two was the average skill level of the clients. In the greenhouse the level of skills of each client was below expectations, so no cumulative process was possible. Both facilities had their aims on meaningful participation of the clients combined with a small amount of responsibility. According to Varley-Winter working the urban agriculture contributes to:

- building the confidence and social support

The work itself is therapeutic for clients, because it involves hands-on and useful achievements that reduce stress levels and support their mental health. Working routine-based will guide some clients and makes the work easy to understand. The way they encourage self-esteem is through the process of caring for something. Such projects need collaboration, the involved people get the feeling of being a part of something and group, resulting in stress relieve and improved self-esteem.

- developing transferable skills, including teamwork and communication.

Transferable skills can be described as self-management, problem solving and interpersonal skills (for supporting others and work well in a team.)

- teaching technical skills which enable participant to fulfill a particular role.

By participating to agricultural projects they create competences. They can even learn literacy and numeracy if needed.

- Transition into work:

Agricultural project can be a stepping stone for some clients. If they are skilled, the next step could become finding a real job. If the agricultural products are being sold, clients can use this as well to develop skills on other fields.

By talking to the people I get a so much wider inside of what the clients do and what benefits it had. It was all about meaningful day care and therapy.

The next investigation was to the Parnassia Greenhouse located in the center of a healthcare site. Here the average skill level of the patients was below expectations. The supervisor of the greenhouse told me what these clients were able to. He had some insight on my research on vertical farming and told me where the opportunities were with his group of clients. According to him the hydroponic systems seem a good system to bring the agriculture inside Parnassia to the next level. The client who needed day care could place the seeds and when they were ready the client could take responsibility for the harvesting process.

The drawbacks of my research regarding the people planet profit interpretation could not be applied for the short term. Furthermore, the benefits and risks for such an approach needed further investigation for a sustainable strategy by the Parnassia Group. This includes also a financial overview and budgetary implication. To conclude we shall inform each other for further development is this regard.

In short a green environment contributes to a faster recovery. The clients want to contribute but can’t do difficult work, so a supervisor needs to be added to achieve a bigger yield. With this in mind a concept can be created where the clients participate in producing green, keeping in mind that the labor has to be meaningful and approachable. In the building plan which will produced in a later stage the required healing environment will be integrated from the interior and exterior requirements aiming to combine the benefits from the planet, people and profit perspective.

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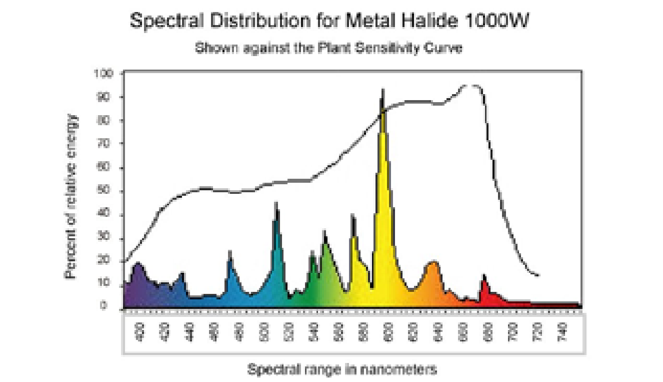
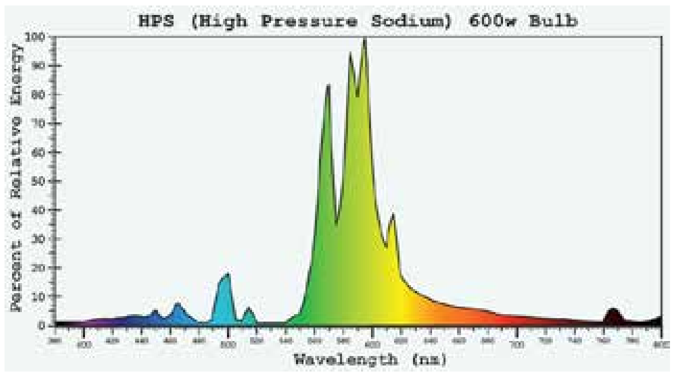
Appendix A: Artificial Lights

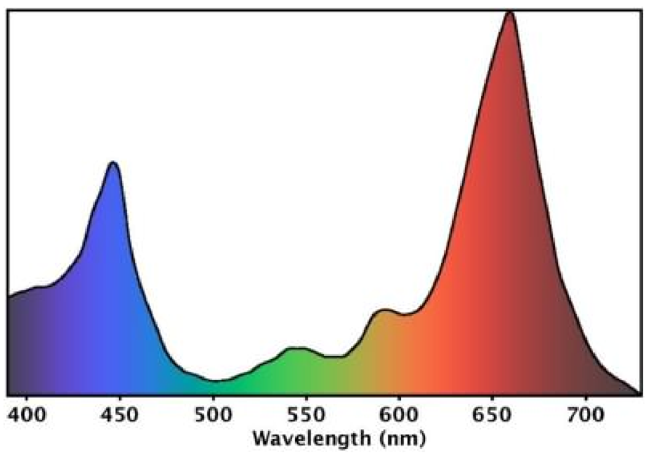
Artificial light is used for year round growing. Artificial light makes it also possible to grow inside where no direct sun light is available. In the artificial lighting there are 5 types of lights every light has its own advantages and disadvantages. The stronger the output in Watt the stronger the area it covers. Led is the best option for growing on a bigger scale in long term, based on the low operating costs and life span. For small scale growing the CFL is a good choice, because it can be used without any reflector.

Name	Metal halide bulbs: [63]
Spectra	400/640 nm Bright summer light: 100.000 lumen
Lifespan	1 year 1000 Watt
costs	200-300 euro's
Properties	High level of photosynthesis Most evolved bulb technique



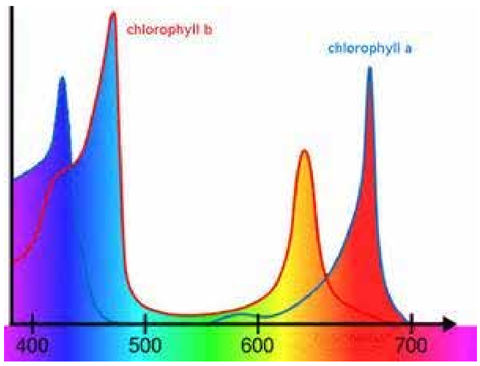
Name	HPS: High pressure bulb 1000 w
Spectra	540-700 nm Bright summer light: 100.000 lumen
Lifespan	2 year 1000 Watt
costs	250-350 euro's
Properties	High level of photosynthesis Compatible wit metal halide bulbs

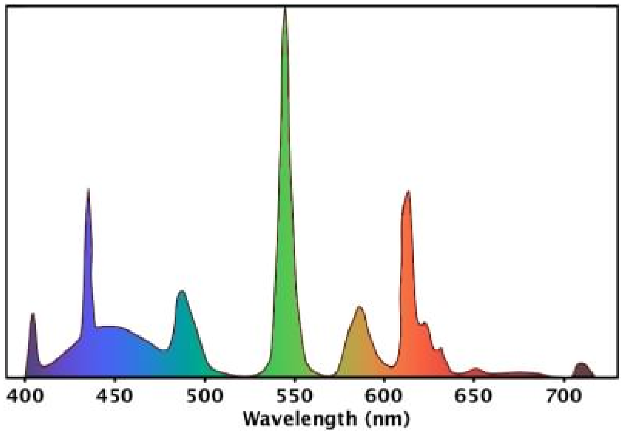


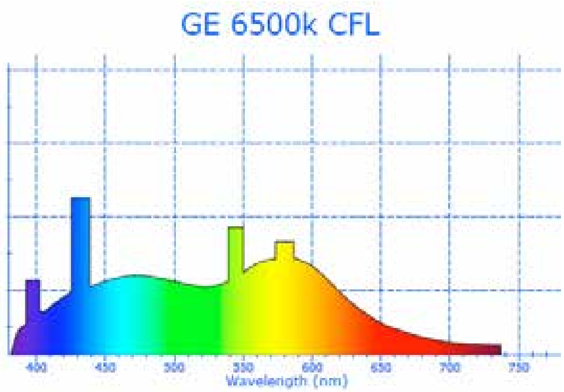


For photosynthesis the chlorophyll parts absorb the light. Green light is reflected, and the blue and red light are the lights that are by plants for photosynthesis.

[63] data retrieved from: http://www.silversunproducts.com/products/bulbs/grow-lights-silversun-mh-1000w-bulbs-for-indoor-growing-not-edited/ on April 10th 2015

Name	LED Lights:[64]	
Spectra	400/700 nm	
Lifespan	5-12 years	
costs	250-900 euro's	
Properties	Lifespan is minimal 5 times longer than other lights. Different colors for different platns	

Name	High Output Fluorescents T5[65] Spectrum: peaks on levels.	
Spectra	400/640 nm Bright summer light: 100.000 lumen	
Lifespan	5 years	
costs	150	
Properties	High level of photosynthesis Positioned close to plants. (small scale growing) inexpensive light	

Name	Compact Fluorescent lights (CFL)[66]	
Spectra	peaks on different levels	
Lifespan	1-3 years	
costs	< 150 euro	
Properties	Low level of photosynthesis only for small plants can be used without reflector	

[64] data retrieved from: http://plantozoid.com/advancedled-ds-200-led-grow-light-review/ on April 10th 2015
[65] Data retrieved from: http://plantozoid.com/t5-grow-lights-ultimate-guide-2014/#T5_Fluorescent_Grow_Lights on April 11th 2015
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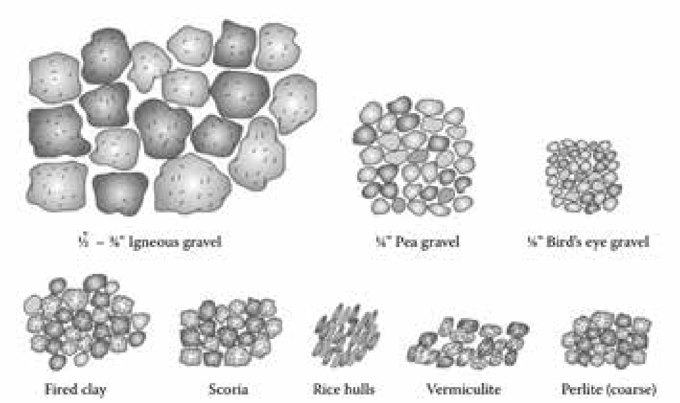
Appendix B: Substrates available:

Substrates to use and their sources.
Plants will grow in most media as long as they get water oxygen, and nutrients. Between different substrates are different properties[67]. Clay for instants has so much water that oxygen plants roots is restricted limiting their growth. The important characteristics are explained below.

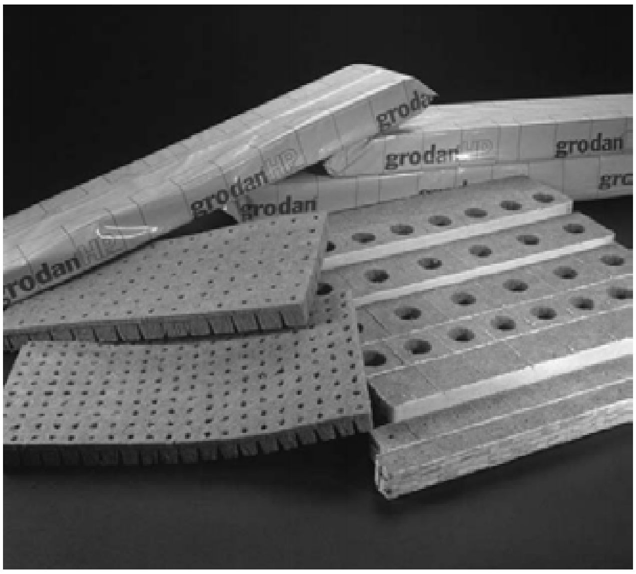


Different Substates
source: Resh, H.M. (2015) . p. 65

Structure:
The structure must be durable for at least one or more crops and not break down into small particles that will impair oxygenation to plants roots.

Composition:
If the substrate release some particles in the nutrient solution then it will unbalance the nutrient solution. Some substrates that are available must be prewashed/cooked before it is used.

Sterility:
Substrates used must be free of pests and disease organism. By heating some of the substrate at 71 C for an hour the substrate is sterile. Other substrates can be washed with a bleach solution (10%).



Different Substates
source: Resh, H.M. (2015) . p. 68

Water retention:
The hydroponic substrate must not have properties of very high or very low water retention. However, the acceptable water retention will also be a function of the type of hydroponic system. Water retention must not be excessive causing lack of oxygenation or be insufficient to cause the substrate to dry quickly and starve the plant of both water and nutrients.

Root Support:
The substrate must allow roots to easily penetrate between the particles and anchor the plants as the roots enter the void spaces seeking water. Most of the long term crops need substrate to anchor their roots and take up oxygen, water and nutrients

Availability and cost:
For small hydroponic gardens the cost is not an important factor. Because of the small amount of the substrate needed.

[67] Resh, H.M. (2015) *Hydroponics for the Home grower,* Boca Raton. CRC Press. P.65-70

Gravel
Choosing gravel takes in account a number of characteristics or properties.
- It should be irregular in shape (crushed is best) with particles of 1/2, 3/4 cm in diameter.
- The particles must be igneous (volcanic) origin and be structurally stable.
- Must retain adequate moisture in void spaces.
- To get oxygen to the roots the substrate must be drained.

Pebbles (Bird's Eye and Pea Gravel):
- Round smooth surfaces
- Drip irrigation or soaker hoses to distribute the nutrient solution to the base of the plants.
- More frequent irrigation cycles.

Leca (expanded clay):
- also known as Haydite or Herculite, light weight and used in constructions.
- Good water retention
- Especially suitable for hobby units.
- It does fracture into sand and silt, but can be replaced.

Scoria (Crushed rock from volcanic origin):
- Dark brown, black or purplish red and light in weight
- Good in retaining water and in same time good oxygenation.
- Various particle sizes can be used in hydroponics.

Sand:
- Best sand is river sand or igneous origin
- Must be well washed by quarry operators.
- No mortar
- drain freely and provide adequate oxygen to plant roots.

Sawdust:
- Good medium to provide the source is from Douglas fir or western hemlock trees
- Some trees are toxic to plants, like red cedar and pines.
- Wash with water before planting

Peat (partially decomposed freshwater marsh)
- Available in compressed mixed form.
- comes with beneficial microorganism
- increase water and nutrient acquisition, symbiotic fungi
Perlite mixes:
- UC mix and Peat-lite mix, in America.
- mix of peat, sand, perlite, pumice, and vermiculite (added for pH)

Redwood Bark:
- Coarser than sawdust.
- Mostly used for growing orchids

Rice hulls (the outer husk or shell of rice):
- It is a waste product of rice milling.
- last 3-5 years.
- smooth surfaces, do not retain water redily and have poor capillary movement of water.
- If burned surface is improves to give more water retention.
- Best mixed with peat or coco coir. (20 % rice hulls)

Vermiculite (expanded mica):
- spongy particles
- with layers (cleavage) water retention is high.
- Irregular shape, good for moisture en oxygen.
- Coarse material in four grades of fineness, smallest size for seed germination.

Perlite (volcanic pumice)
- crushed and heated (expanded particles)
- particles irregular but more structural stable than that of vermiculite.
- contains no nutrients.
- used by itself or mixed.

CoCo Coir (ground-up dried coconut palm husk:
-the processed material includes coir fibres and pulp.
- "Sustainable" renewable product
- dry block expand when adding water.
- On marked with different levels of coir pulp and fibre.
- Can be mixed with perlite, rice hulls or vermiculite/peatlite.
-
Rockwool (made from basaltic rock (Solidified Lave))
- Solidified lava liquefied at 1500 C and pressed into sheets and cut into slabs, blocks and cubes.
- pH must be adjusted before using (between 7 and 8,5)
- good water holding capacity.
- Good hydroponic systems is crucial to avoid mineral build-up in substrate.
- The standard for starting you hydroponic culture, based on easy transplantation.
- DO NOT CONFUSE WITH INSULATING MATERIAL

Water:
- Lettuce, Basil, arugula and some herbs.
- Water source is essential
- Nutrient saluted in water

The Greenhouse

Urban farming can be done in the open air or in greenhouses. There are many types of smaller greenhouses the difference between the types are based on form, material, and place.

There are many types of greenhouses, each greenhouse has its own benefits and disadvantages. Some have a better light transmission, others offer better heat detention and some are more stable in strong winds. It is important to plan how to use the greenhouse, the size and shape have an impact on the interior environment.

Advantages

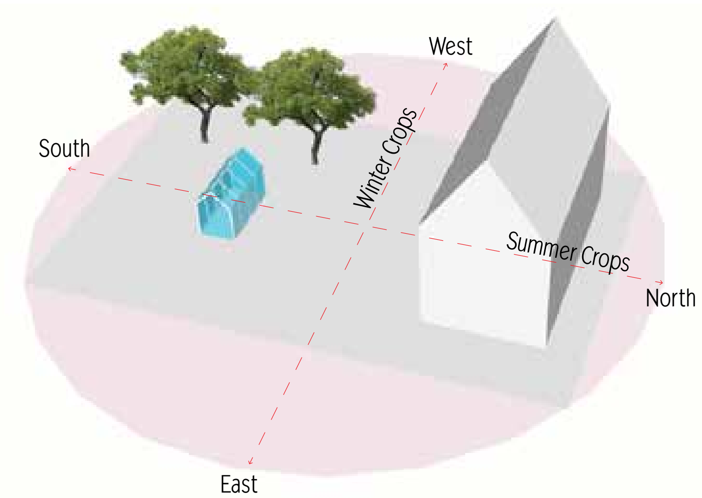
There are many advantages of growing your crops in a greenhouse the following advantages are listed below:
- Year round growing
- Protection of plants against weather and pests.
- Optimum grow environment for plants
- Climate control (temperature and humidity

disadvantages

There are also disadvantages for greenhouse growing:
- Overheat when orientated wrong and wrong material
- costs: A greenhouse can be expensive escpecially if you add climate and irrigation systems.
- maintenance: the cheaper greenhouses are not well insulated and wind can become a problem.
- Most greenhouses are made with a single sheet of glass that can break easily

Before placing a greenhouse some considerations must be made. The first and most important one is the siting of the greenhouse. Greenhouses also require ventilation, water management, heating and cooling. These requirements are explained below.

Siting:



-What do you want to grow is very important for the orientation of the greenhouse. By orientating the greenhouse north-south summer crops are the most effective to grow. If orientating the greenhouse east-west, winter crops are the most effective to grow.
After the site and orientation is selected you need to get rid of all overhanging branches, tall fences or nearby shrubs. They cast shadows and minimie the light intake.
The site needs to be flat, based on the displacement of heat. Warm air rises and the temperature level won't be constant inside the greenhouse.
The surface where the greenhouse is places needs a foundation. If there is no foundation the greenhouse will shift in winds and will cause a breakage in the glass.

Ventilation:
In greenhouses ventilation is very important because It expels hot air, reduces humidity, and provides air circulation, which is essential even during winter to move cold, stagnant air around, keep diseases at bay, and avoid condensation problems.
The ventilation within the greenhouse van be controlled by fans and vents. There are three types of vents in the greenhouses: Top vents, vertical vents and louvered vents. The vents can open manually or automatically controlled. Also ventilators can be used within the greenhouse to create an uniform climate. The most efficient way of vent control is an solar powered opener. It is a system where wax expends within the component and pushes the vent open at a certain temperature. When the temperature drops the wax shrink and the vent closes.

solar-powered vent

Water management:

Water the plants in a greenhouse can be done by a system or by hand. Hand watering helps to pay close attention to the plants. You'll quickly notice signs of over- or under-watering and can adjust accordingly. The systems mostly used in greenhouses are: drip irrigation systems, a tank and tray system, and sprinkling systems. The drip irrigation system is controlled automatically. The tank and tray system and sprinkling systems is controlled manually as automatically. Also rainwater can be collected to water the plants.

Heating:
In winter the temperatures drop to a freezing points. For year round growing your plants won't grow in this part of the season, so heating is required. There are different types of heaters in the greenhouse industry: paraffin heaters, electric heaters and ventilator heaters. Also electric heating pipes and mats at the bottom of the greenhouse are used. These can be linked to the city's heating system. It is important to measure the temperature in the greenhouse itself but also the ground temperature.
In smaller scale greenhouses there are two options: electric heaters and fuel-fired heaters. Before starting building the greenhouse a decision need to be made if you want to heat your greenhouse and if heated which system you want to use.

Cooling:

It is important to maintain a good growing environment. Although vent and fans are the first line of defense other cooling systems are required. With, misting, humidifying evaporative cooling, and shading can help to maintain the ideal growing environment. By blocking direct sunlight, shades protect plants from sunburn and prevent the greenhouse from getting too hot. They can be installed on the interior as exterior. Placing the shades inside the greenhouse will help the solar heat entering the greenhouse.

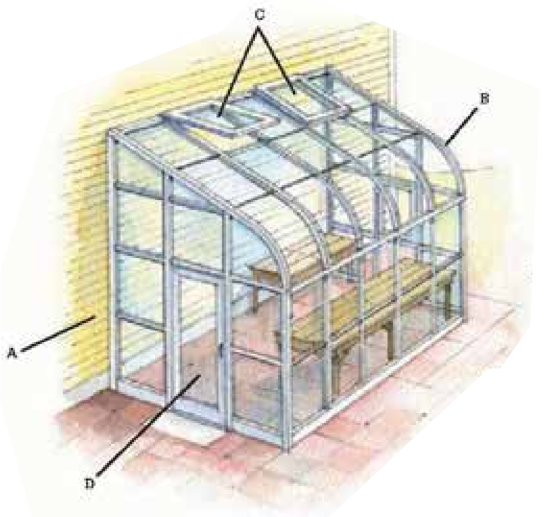
Evaporative coolers cool the air by using a fun to push or pull air through a water-saturated pad. For smaller greenhouses a portable cooler is recommended. For larger greenhouses the cooler unit is places outside where it draws dry outside air through the system.

Components

There are many types of greenhouses, each greenhouse has its own benefits and disadvantages. Some have a better light transmission, others offer better heat detention and some are more stable in strong winds. It is important to plan how you use the greenhouse, the size and shape have an impact on the interior environment.
Most type of greenhouses need a foundation, otherwise they will shift and the covering material will break. So most of the designs require foundation.

Traditional span:
This type of greenhouse has vertical side walls an even-span roof, with plenty of headroom in the center. Side walls are about 1.5 meter high, the roof's central ridge stands between 2 and 2.5 meters. This particular greenhouse has low base wall, known as a kneewall. These kneewalls help to consever heat, but block lights below the benches. There are also fully glass traditional span greenhouses available on the market.

A) Ventilating roof window
B) Hihg gable peak provides headroom
C) 45 degree roof angle encourages runoff
D) Solid kneewalls block wind, provide impact protection and allow insulation



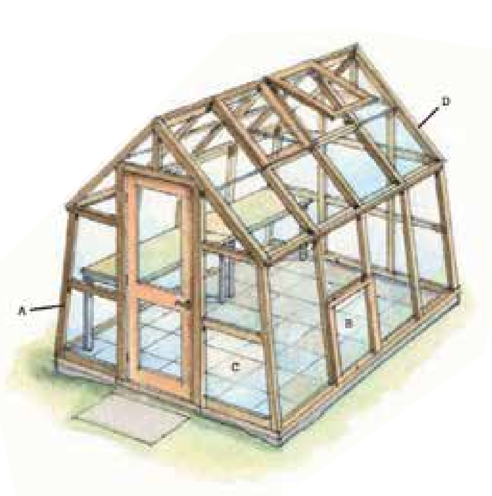
Lean to:
Because attached to the house, a lean-to-absorb heat from the home and offers easy acces to utilities. This model show curves eaves, a glazed roof, and glass-to-ground construction. Lean-tos can be built on kneewaals to provide more headroom and better heat retention than glass-to-ground styles. Sinking the foundation into the ground, about 0.5 to 1 meter can coserve even more heat.

A) Adjjoining house provides structure and heat
B) Aluminium frame is lightweight but sturdy
C) Roof vents can be set open and close automatically
D) Well sealed door prevents drafts and heat loss.

Three-quarter span:

Also attachedto the house, this typeof green house offers the benefits of a lean-to with eve more headroom and better light transmission (though it offers less light than a freestanding model). Because of the additional framing and glazing, this style is more expensive to build than a traditional lean-to.

A) Adjoining in house provides shelter
B) Half-lite door insulates but allow some light in.
C) Operating side vent
D) Cable creates headroom



Dutch Light:

Especially suitable for low-growing border crops, such as lettuce, this design has sloping sides that allow maximum light transmission . However, the large panes of glass, which may be 0,75 by 1,5 m are expensive to replace.

A) Tapered sidewalls encourage condesation to run off
B) Lower side vent encourages airflow
C) Tile Floor retains heat
D) Roof angle minimizes light reflection

Mansard
The slanting sides and roof panels that characterize the mansard are designed to allow maximum light transmission .This style is excellent for plants that need a lot of light during the winter.

A) Full-width door frame
B) Sliding door can be adjusted for ventilation
C) Lower side vents encourage airflo
D) Stepped angles ensures direct light penetration any time of the day or year

Mini Greenhouse:
A relatively inexpensive option that requires little space, this greenhouse is typically made of alum inum framing and ~ can be placed against a house, a garage or even a fence, preferably facing southeast or southwest, to receive maximum light exposure. Space and access are limited, however; and without excellent ventilation, a mini-greenhouse can become dangerously overheated . Because the temperature inside is difficult to control, it is not recommended for winter use.

A) Brick wall retains heat
B) Upper shelf does not block airflow
C) Full-depth lower shelf creates hot spot below
D) Full lite storm door

Alpine House:
Specifically designed for plants that normally grow at high elevations and thrive In bright, cool conditions, this alpine house is unheated and has plenty of vents and louvers for maximum ventilation. Doors and vents are left open at all times (except in winter). Many rock-garden plants-edelweiss, sedum, and gentian, for example-appreciate the alpine house environment

A) Banks of venting windows at both sides of peak
B) Adjustable louvers for intake
C) Cedar siding on kneewall has rustic appeal
D) Fixed roof windows lend stability

Hoophouse
Made of PVC or metal framing and plastic glazing, this light-weight, inexpensive greenhouse is used for low-growing crops that require minimal protection from the elements. Because It does not provide the warm conditions of a traditional greenhouse, it is designed mainly for extending the growing season, not for overwintering plants.Ventilation in this style can be a problem, so some models have sides that roll up

A) Bendable PCV tubes provide structure
B) 4-mil plastic sheeting is very inexpensive glazing option
C) Roll-up door
D) Lightweight base makes hoophouse easy to move

Dome:
This style is stable and more windresistant than traditional greenhouses, and its multi-angled glass panes provide excellent light transmission. Because of ItS low profile and stability, it works well in exposed locations. However, it IS expensive to build and has limited headroom, and plants placed near the edges may be difficult to reach.

A) Geometric dome shape is sturdy and efficient
B) Louvered air intake vent
C) Gussets tie structure together
D) Articulated door is interesting (tricky to make)

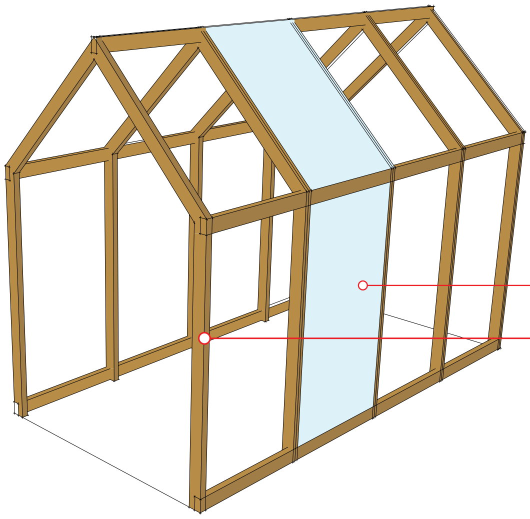
Polygonal
Though it provides an interesting focal point, this type of greenhouse is decorative rather than practical. Polygonal and octagonal greenhouses are typically expensive to build, and space inside is limited

A)Triangular roof windows met in hub
B) Finial has Victorian appeal
C) Built-in benches good for planter or for seating
D) Lower wall panels have board-and-batton styling

Conservation Greenhouse
With its angled roof panels double-glazing, and insulation , the conservation greenhouse is designed to save energy.It is oriented east-to-west so that one long wall faces south , and the angled roof panels capture maximum light (and therefore heat) during the winter. To gain maximum heat absorption for the growing space, the house should be twice as long as it is wide. Placing the greenhouse against a dark-colored back wall helps to conserve heat-the wall will radiate heat back into the greenhouse at night

A) High Peak for good headroom
B) louvered wall vents
C) Sturdie aluminum framing
D) Broad roof surface for maximum heat collection

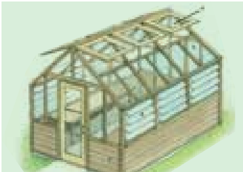
Greenhouses can be made in all kind of materials, each material has its advantages and disadvantages. In the table all materials are showed with their advantages and disadvantages.



Frame Material	Advantages	disadvantages
Wood	Attractive	High in maintenance
	No heat transfer	Bulkier than aluminum
	No condensation problems	Bulkier cast shadows
Aluminum	Light weight and strong	It loses heat
	Low maintenance	More expensive (heating)
	All glass and connectors possible	Condensation problems
Galvanized steel	Extremely sturdy	Heavy
	Extremely strong	Expensive
	Extremely durable	Rusting when scratched
PVC	inexpensive	Not resilient against high winds
	Easy to assemble from kit	Glazing restricted to plastic sheeting
	Starting a greenhouse	

Glazing and covers	Advantages	disadvantages
glass	Excellent light transmission	Single glass pane little heat retention
	Long lifespan	Glass is breakable
	When layered: not flameable	Direct light can burn plants
	When layered retains heat	Can be costly
Polycarbonate	Light and strong	Scratches easily
	Shatter-resistant (when layered)	Reduce light transmission
	Triple wall polycarbonate (16 mm) Excellent insulation	Layered panels are expensive
	Transmit diffused lights (no plant burn)	
Acrylic:	light transmission similar to glass	the panels can yellow
	Lightweight and impact-resistant	Suffers from condensation problems
	less expensive then polycarbonate	
	easy to cut and shape	
	layered for extra strength and heat resistant	
Fiberglass:	UV resistant and resist yellowing	condensation problems
	Light transmission almost equal to glass	inexpensive fiberglass have lifespan of less than 5 years.
	better heat retention	
	good quality can last 20 years	

Good start kit, cooling/heating systems required



Easy to construct but costly.

cheapest and easiest to build, - do not use in windy area

Costs

There are many types of greenhouses as ealier explained. The costs of the greenhouse therefore vary. The cheapest greenhouse is the hoophouse. It is only used for small scale growing. The costs of greenhouses are based on the following factors:

- Size: The bigger the greenhouse the bigger the costs, but when calculated the cost per square meter the real cost can be compared.
- Material (see table materials)
- type of greenhouse
- Complexity of design, use of standard or custom components.

Hidden costs:

- Cost of installation labor.
- Equipment inside the greenhouse, heating cooling, water systems
- Foundation of the greenhouse
- Short and long term maintenance.

Maintenance

The maintenance for the greenhouses is depending on the type and materials chosen.
A steel frame and aluminum greenhouse require less maintenance than a wooden greenhouse. In the steel and aluminum greenhouse condensation problems can occur are it needs extra attention. The wooden greenhouse has no condensation problems, but the wood needs to be checked periodically. The platic greenhouses require a small amount of maintenance but it last a shorter period of time.
The covering material also require their own maintenance. Glass has the most benefits but is expensive compared to the other materials and breaks easily. But it has an long lifespan. Polycarbonate scratches easy and reduces the light transmission, so it needs to be replaced when it is scratched. Acrylic covering turns yellow in the sun and has a shorter lifespan compared to the other materials. Acrylic and fiberglass also cause condensation problems. The fiberglass panels have a lifespan of less then 5 years.

Climate

In the requirements the climate aspects are explained.

Literature used:
Tandem, B. (2010) The complete guide to Greenhouses and Garden Project. Minneapolis, Creative publishing international. P. 12-45

Shelton, D. (1979) Greenhouse Gardener. London, Sundial Publications Limited. P6-29