go city grow

Building communities by growing together in greenhouses adapted to Gothenburg's climate

Charlotte Farrouch and Lisa Kihlström
Master's Thesis at Chalmers Architecture
Master programme Design for Sustainable Development

CHALMERS
UNIVERSITY OF TECHNOLOGY

Go City Grow

Building communities by growing together in greenhouses adapted to the climate of Gothenburg

CHARLOTTE FARROUCH & LISA KIHLSTRÖM

Contact: charlotte.farrouch@gmail.com
lisa.kihlstrom@gmail.com

Final seminar: 2014-05-16
Examiner: Lena Falkheden
Supervisor: Emilio Brandao

Keywords: Greenhouses, Cold Climate, Sustainable Building, Food Production, Local Food, Urban Farming, Systems Integrated Design, HSB Living Lab, Shared Space

Master’s Thesis at Chalmers Architecture
Master Programme Design for Sustainable Development
Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Telephone +46 (0) 31-7721000

CHALMERS

go city grow

Building communities by
growing together in
greenhouses adapted to
the climate of Gothenburg

GREENHOUSES

COLD CLIMATE

SUSTAINABLE BUILDING

FOOD PRODUCTION

LOCAL FOOD

URBAN FARMING

SYSTEMS INTEGRATED DESIGN

HSB LIVING LAB

SHARED SPACES

ABSTRACT

In the perspective of sustainable development of cities, domestic production of food represents an opportunity for urbanites to reconnect with their food and is therefore a potential trigger for food systems change. Sharing spaces appear likewise relevant for the development of sustainable societies as people share resources and build communities.

This master's thesis explores the design of spaces for urban food production all year around in climates and latitudes like Gothenburg, Sweden. The outcome is a shared greenhouse for domestic use – for people living in apartments. The thesis approaches the design of the greenhouse as a sustainable building in terms of energy consumption, materials and social benefits.

TABLE OF CONTENT

THANK YOU

Thank you to our friends: thank you Duncan for you enthusiastic structural tutoring, Linus and Henrik for solving our heating problems, Jonas for your wooden love, Shea for the beauty of nature, Paul for your devotion and the croissants, Eva and Galini for being role models.

We also would like to thank the people we met during our thesis, helping us to understand and learn: Sara Renström at Chalmers, Åke Wikström, Karl-Johan Bergstrand at Alnarp, Anki Caspersson at Gårdstensbostäder, Fredrik Olsson at Tailormade, Göran Larsson at Odla i Stan, Sanna Edling at HSB, Gunnar Nilsson at Göteborg Energi and Martin Allik.

Thank you to our supervisor Emilio Brandao for your patience and support, but also for the lunch dance, our examiner Lena Falkheden for inspiring us to think differently and Maja Kovacs for calming us down.

Thank you to our family for all the support, always, and for making us the way we are.

Charlotte and Lisa, Gothenburg 2014

salut!

hej!

ABOUT CHARLOTTE AND LISA

Charlotte has a Bachelor in Architecture from the school of Architecture of Lyon and Lisa has a Bachelor in Architecture from Chalmers University of Technology. Throughout our master studies in the master's program Design for Sustainable Development at Chalmers, we developed a strong interest in the production of food in urban areas. Indeed, we are profoundly convinced that the way our food comes to our plates needs to be changed: for better quality of food, for respecting our planet, etc.

Taking part in "Solar Decathlon China 2013" during spring 2013 made us interested in and gave us knowledge about energy efficient and sustainable buildings. Building a house made us understand that all aspects of a design are connected; a sustainable design needs a *holistic* approach. In this course we moreover shared a strong experience where we became close friends. More recently, we worked together in a course called "Planning and Design for sustainable development in a Local Context". There we were introduced to local food networks in small towns and how organisations can change food systems at a local scale.

Having the same concerns and knowing that we work well together made us want to do this thesis together.

I. INTRODUCTION
TO THE MASTER’S THESIS

BACKGROUND

Today, there is a raising awareness concerning the need to grow food locally in cities. In the future, cities need, to a much larger extent, provide food to their population at a local level. The task is wide and big, because re-thinking the food systems means re-thinking how we design cities and how we adapt the built environment to a major lifestyle change.

In Gothenburg, urban farming all year round is problematic because of the climate; food production has to be indoor as well.

This is why we, for our master’s thesis, decided to explore a way of producing food at a local scale, since we explore how people can grow their own food in the surroundings of their apartment blocks. For us, the social benefits of common gardening are also important and relevant for the sustainable development of cities. Community greenhouses can become spaces of sociality, and spaces for developing more sustainable lifestyles. Such greenhouses can also build new attitudes and change the relation between people and their food.

The idea of this master’s thesis is the result of a special encounter last semester: a personal will to work with architecture and local food, and an idea from Sara Renström, PhD student at the department of Design and Human Factors at Chalmers, researching on district heating. Sara imagined a concept of shared greenhouses heated by district heating in Gothenburg as a possible solution for domestic, year-round production. From this meeting the idea of our master’s thesis has been developed.

AIM & SCOPE

The overall aim of this master's thesis is to design a greenhouse in order to promote urban agriculture in cold climate cities. The aim is also to promote sustainable approaches to architectural design, and to demonstrate the capacity of design to raise awareness about sustainable development, encouraging sustainable behaviours through learning processes.

During the entire design process, our ambition has been that the final proposal would be detailed enough to inspire and offer material to someone wanting to build a similar greenhouse oneself. After a short interview with Stadsjord[1] and a demonstrated interest for such a greenhouse, we like to believe that this greenhouse designed during our master's thesis could actually activate urban farming in winter in Gothenburg.

A master's thesis can cross the borders of the academic frame: it can be material for future real implementations!

how can we provide space for people to grow food at home in a sustainable (socially, environmentally) and easy way?

how can we enable growing in a cold climate all year around in an energy efficient way?

how can the greenhouse be affordable and simple to build?

1. Stadsjord is an active urban farming organisation based in Gothenburg. Interview with Niklas Wennberg, November 2013.

LIMITATIONS

The frame of our thesis is delimited by different factors as it focuses on the growing of food, all year round, in housing areas in the city of Gothenburg.

The target market is a group of people that have an urban lifestyle with an interest in gardening and growing their own crops. They can be students, workers, kids or seniors. What identifies them as a group is that they live in apartments, and share the will to grow together.

Another limitation is the purpose of the greenhouse: people should be able to grow crops in the greenhouse all year around, but the goal is not to provide space to supply 100% of their needs. The purpose stands in the social benefits of growing together, building communities of friends, sharing knowledge, changing families' habits and educating the population.

Moreover, the proposal should remain hypothetically affordable: if the design was to be commercialized, a community should be interested in buying it. As designers of this shared space, we also have to consider that the users won't be professional farmers. Accordingly, we want to introduce an easy way of cultivating, that doesn't require extensive and difficult maintenance and high costs.

The limitation to housing blocks implies other design criteria such as the possibility to adapt to different kinds of ground conditions and the scalability to different sizes of communities. These limitations have been further developed during our research, resulting in design criteria presented in the design part of the present report.

METHODS

This present report is the result of a work throughout one semester. Different methods helped us driving this work toward our ambitions and goals, and approaching the design in a holistic way exploring specific and new methods of work.

The design has been brought forward with the help of informal consultations with friends in the field of civil and environmental engineering, giving our work a cross-disciplinary dimension and getting closer to a “real” architecture practice.

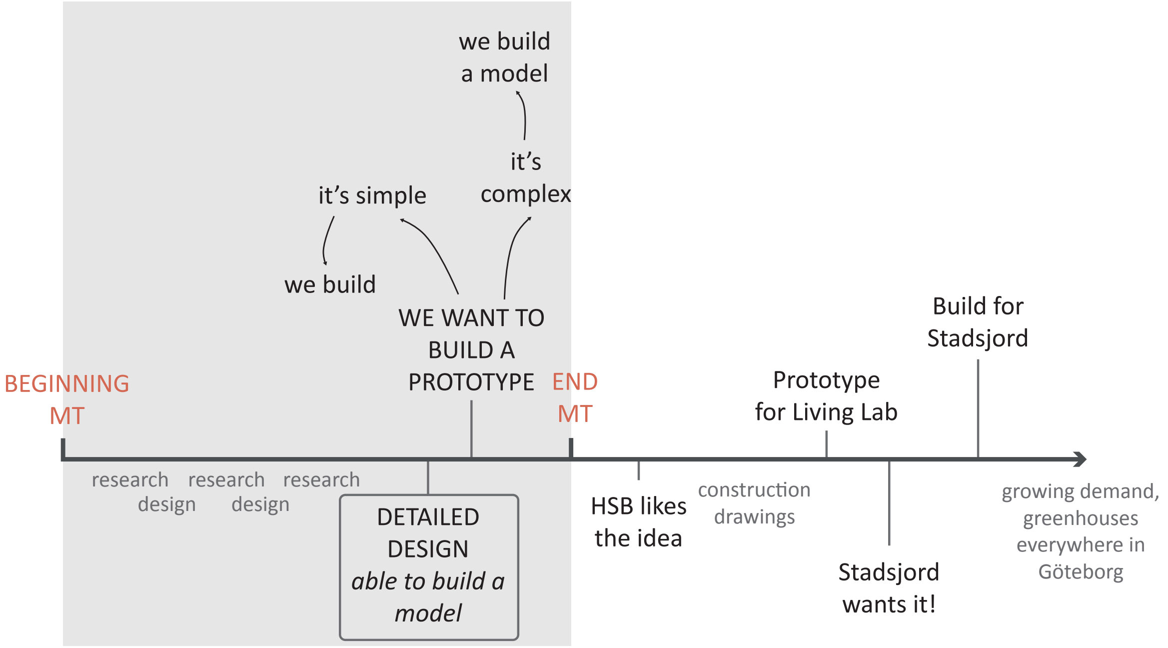
The final proposal is based on and argued around a background research. Acquiring knowledge has been driven by literature studies, field studies in Sweden, interviews and through different online resources such as videos and blogs from growers around the world, mainly from North American farmers.

The design tools used during this master’s thesis vary from physical models to sketching, introducing building performance tools such as sun path analysis or structure analysis.

Discussion has been a very important tool in the design process, as it helped covering many considerations at all scales of the design. We believe that being a team of two open-minded designers brought more efficiency in the design process.

Research and design have worked in parallel during the whole master’s thesis, since new questions, considerations and scales appeared along the design process.

Charlotte and Lisa,
ready for a field study



Timeline for our master's thesis (MT),
from January 2014 to a possible future project.

READING INSTRUCTIONS

This report is divided into two parts, beginning with the research summary and ending with the design proposal. The design project is very much a result of the research, which shall be seen as both motivation and knowledge base for the design.

Chapter 1: “Introduction” contains background information regarding the thesis.

Chapter 2: “Goodbye oil, Hello soil” motivates why this thesis is important and states the role of the designer in the question of local food.

Chapter 3: “Growing Together” desicribes the social and environmental benefits of sharing and gardening together.

Chapter 4: ”Approaching the design of a sustainable building” summarizes our approach toward sustainable buildings.

Chapter 5: “Greenhouse Design Guide” is relevant if the reader wants to build a greenhouse on his / her own. Our final design very much emerged from this information.

Chapter 6: “From Research to Design” describes how the presented research was taken into a design.

Chapter 7: “Go City Grow!” is our final design proposal. Firstly, we present the object, the greenhouse, itself, and secondly we present an implementation on a site in Gothenburg.

Chapter 7: “Conclusions and reflections” outlines our findings in this master’s thesis.

The research and the design process results in Go City Grow, a shared greenhouse for urbanites in a cold climate.

"The financial slump — accompanied as it is by the looming consequences of peak oil and climate change — has given us the opportunity to **question** the status quo and to realign our **values** with our **lifestyles**. The health of people, and the environment, bound together by our **need for food**, is once again making its way up the priority list."

Rob Hopkins, Author of *the Transition Handbook* and *Local Food*
(Hopkins 2009, p.21)

II. GOODBYE OIL, HELLO SOIL

This master's thesis is about designing spaces dedicated to the production of food in cities by the consumers themselves. Earlier we introduced why this idea is relevant in the perspective of sustainable development. In this chapter we describe the current situation of the world's food systems and explore the need for change. Afterwards, we envision new patterns for food systems through the re-introduction of locally produced — and locally consumed — food.

OUR FOOD AND US

Over the past century, we have built a very complex system for producing, distributing, retailing and consuming food. The logistics of this system have created a large gap between us, the consumers, and our food. The current food system is, to a large extent, globalized, and because it is lead by a "web of industrial, technological, economic, social and political factors", its operation becomes difficult to grasp (Millstone & Lang 2013, p.9).

The food system relies on the availability of mainly one energy source, cheap oil, and is driven by the pursuit of cheap food for the consumers of developed countries — and the quest for profit by the multinational corporations of the food industry. Therefore, it is characterized by a large-scale, mechanized and engineered production, which depends on a world-wide distribution network, based on a standardized retail system and influenced by globalized diets (Wijkman & Rockström 2011, Brown 2004, Millston & Lang 2013, Cockrall-King 2012).

What we[1] experience from this food system is the abundance of a diversified range of products, coming from all over the world, allowing us to taste different cultures through our kitchen. These products have traveled an average of 1,500 miles, and on their way lost much of their nutritive capacity and freshness (Orru 2013).

Even if it remains difficult to have a general understanding of the global food system, we perceive that it has been built around optimizing operation costs across its different stages: production, processing, transportation, and retail. For example, production of grain is operated in a way that the yield is maximized (use of chemical products to boost the growth of crops, crop breeding), where the maintenance of land and harvest is efficient (mechanization using the cheapest fuel).

Optimizing operation costs can also mean to outsource production in countries where the labor cost is lower. Because these operation costs might appear lower in spread-out parts of the world, products are transported along their lifetime from stage to stage, e.g that products harvested in one place may be processed in another location.

The transportation of food is also optimized so that food can remain fresh along the different stages (transportation at low temperatures; breeding of crops oriented toward conservation) (Halweil 2004). Food is able to travel for long periods, criss-crossing the world. One possible explanation for this system is that it remains more profitable for the food industry companies to do so, rather than growing the same products in close proximity to where they will be consumed.

1. Here, «we» refers to the average citizen of Europe, living in a city or in the countryside. We include ourselves in this «we».

IMPACTS

At a global scale, our current food system, and particularly the agricultural system, is unsustainable. It greatly degrades the environment, it is inequitable to nations — particularly to developing countries, and encourages the growth of a few multinational companies (Millston & Lang 2013, Brown 2004, Cockrall-King 2012).

•STRESS ON EARTH'S RESOURCES

The agricultural system as well as other systems of the chain[1] has a great environmental impact, as it stresses the Earth's resources such as oil, river water and rainforest land. For example, at a global level, 70% of freshwater is used for irrigation (Wijkman & Rockström 2012). This water, more than being taken out of the natural cycle, is also freshwater that is not accessible for people. Water is already scarce in countries of northern Africa, and as figures shown in *The Food Atlas*, most of Africa and the Middle East may suffer from water scarcity by 2050 (Millston & Lang 2013, p.24-25).

1. Processing, distribution, retailing, consumption systems also stress the planet's resources if we consider the packages produced, the amount of waste generated by the consumption of food, etc.

•GREENHOUSE GAS EMISSIONS

Another major environmental problem is the emission of greenhouse gas due to the agricultural system, contributing to global warming and climate change. The globally increasing mechanization of farming, the increasing production of livestock, the land conversion to agriculture land, the use of chemical and organic fertilizers and pesticides represent more than 24% of global greenhouse gas emissions. Adding to this number are other emissions connected to the food system's operation at different steps such as the production of packaging, canning, freezing, processing of food, the transportation of goods, etc. (Wijkman & Rockström 2011, Millston & Lang 2013).

•SOIL DEGRADATION

Mechanized, large-scale and chemical agriculture, as it is performed today, removes nutrients from the soil over time. Degradation occurs because of monocultures[2], extracting only certain types of nutrients from the soil that cannot be renewed. Further, soils are polluted by chemical fertilizers and chemical pesticides. It will take millenia for nature to build rich soil again (Brown 2004).

2. The cultivation of a single type of crop on a specific land (Oxford Dictionnary 2014)

•WASTE

A report from the Food and Agriculture Organization of the United Nations (FAO 2013) shows that 28% of the world agricultural land is used to produce food that is wasted. This is almost one third of an annual production that contributes to the environmental impact of the food system, emitting more greenhouse gases, taking up more freshwater, etc. This waste is a huge economic cost for the producers. The FAO report states that food waste represents an economic value of $750 billion every year (FAO 2013).

Waste is produced at all stages of the food system: production, post-harvest handling and storage, processing, distribution and consumption (FAO 2013).

•DIET-RELATED DISEASES IN INDUSTRIALIZED COUNTRIES

The consumption and over-consumption of processed, high-in-sugar or additives food in developed, industrialized countries has impacts on people's health (Millstone & Lang 2013). Because this is the cheapest food to buy, they are largely consumed in developed countries. As they are rich in saturated fat and sugars, their over-consumption leads to diet-related diseases such as late diabetes and obesity (Millstone & Lang 2013). In these countries, where most of the population have sedentary lifestyles, obesity and diabetes have become prevalent. Obesity has for example doubled over the past 25 years in the US (Millstone & Lang 2013).

Developing countries like Brazil and China start to encounter similar problems as eating habits are shifting towards "industrialized countries diets"[1] in the more affluent part of the populations. Obesity though is more observed in lower-income parts of the population in industrialized, developed countries (Millstone & Lang 2013). Diet-related health problems, often described as an epidemic, has great economic impacts on healthcare systems as larger parts of the populations are more likely to develop heart diseases and diabetes (Millston & Lang 2013).

•INCREASED INEQUALITIES IN THE WORLD

Social and economic inequalities between the industrialized, rich countries and poor, developing countries depend on many factors, of which some are directly

1. Diets containing more meat, dairies and processed food

connected to the globalized food system. It appears that the countries where the biggest amounts of crops are grown, are the countries where the largest number of people suffer from under-nutrition (Millstone & Lang 2013).

In India and countries of Eastern Asia, Central and Southern Africa, it is estimated that food represents 50% or more of the households expenditures on consumable goods. This means that the price of food compared to the average salary is very high (Millstone & Lang 2013). An interpretation to this number could stand in the exploitation of farmers in these regions, working for such a low salary that they cannot afford to feed themselves.

In comparison, in Sweden, food expenditures have remained at 12% of total goods expenditures between 2000 and 2009 (Jordbruksverket 2010).

On the other side, multinational companies owning the land make bigger profits. Therefore it seems that the food system contributes to increased inequalities between developed and developing countries.

As we mentioned earlier, one result of the complexity of the food system is the disconnection between people[1] and their food. It has become very difficult to know where the products come from, how they have been produced, and by whom. The food system is rather obscure to the consumers, limiting the possibility to make ethical choices when buying their food.

1. Here, «people» refers to the average citizen of Europe, living in a city or in the countryside. We include ourselves in this «people».

CHALLENGES

As the environmental analyst Lester Brown describes in his book *Outgrowing the Earth*, we are using the Earth's resources such as oil, water and land for the production of food faster than they can be renewed. The soils of monocultures are getting poorer, and the chemical fertilizers have reached a plateau in their efficiency. These two factors are leading toward a decline in the world land productivity (Brown 2004).

At the same time, the demand is increasing as the world population continues to grow. Nine billion people are expected on Earth by 2050 (Millstone & Lang 2013). If the production cannot match the demand, a big question is how food security[1] will be ensured on the planet. With more people to feed, especially in the developing countries, the agricultural system as it works today may not be able to meet the challenge.

Climate change will also have an extensive impact on food production. According to Johan Rockström, professor in natural resource management, and Anders Wijkman, advisor at the Stockholm Environment Institute, "agriculture is the first sector to be hit by climate change" (Rockström & Wijkman 2011, p.49). Further, this impact will vary between different regions of the world. The poorest regions of the world are estimated to have the largest reduction in food production (Rockström & Wijkman 2011).

Food security can be threatened at a global level but likewise closer to us at a national level. Currently the food trade is globalized and countries are dependent on each other's production to provide all vital types of food to their populations (Millstone & Lang 2013).

Food export rates are influenced by food prices. Lester Brown has observed that global rise in food prices is linked to export rates, e.g that countries tend to reduce their export volumes if the products are getting more expensive (Brown 2004). This is because the demand is decreasing. If, as it has been observed since 2007 (Millstone & Lang 2013), the price of food keeps increasing with the raising prices of oil, it will be difficult to ensure countries the supply of all kinds of food. Another challenge is to ensure that populations in the developing countries will be able to afford their food.

1. Food security is defined by the Food and Agriculture Organization of the United Nations as "the assurance for people to have physical and economical access to enough food for an active, healthy life" (FAO 1986)

The world's food system, as many experts state, is in crisis. It needs to be reformed and adaptations have to be planned as there are great challenges to face. A sustainable food system will need to embrace a rapidly growing world population, develop traditional and technological solutions for an agriculture that will respect the environment and the consumers, and shift from a system relying on fossil oil towards a renewable energy based system (Rockström & Wijkman 2011). To ensure food security and build more resilience, at regional but also global levels, a new system will have to be built on a wide range of solutions and strategies.

Many experts and activists describe a new world food system based on its localization, e.g the shift toward a network of "local-scale" food systems. This structural change embraces many different aspects, such as more cooperation and networking between producers, retailers and consumers, the building of communities, urban agriculture, etc. (Halweil 2004, Hopkins 2009, Viljoen 2005, Cockrall-King 2012). In that sense, a localized food system seems to actually fulfill the criteria to be defined as a sustainable world food system.

RE-INTRODUCING A LOCAL SCALE IN THE FOOD SYSTEM

A local food system refers to a system where food is produced close to where it is eaten, in a geographic consideration. Though, the definition of what is "close" can vary depending on situations, that is why the definition of a local food system cannot easily be generic. Further, as the United States Department of Agriculture states in a report, other concepts can be underlying within a local food system (Martinez et. al. 2010).

How production is performed can be associated to what "local food"[1] is. For example, farming without the use of chemicals, or farming without growing engineered crops (Martinez et. al. 2010). Organic farming practices are recognized as providing health benefits to the consumers and improve the quality of produce (Thompson et. al. 2008).

Likewise, knowing where the food comes from, and knowing who produced it can be part of the concept of a local food system. This recovers the lost connection between the consumer and its food, and therefore improves the value of the food. "Social connections, trust and mutual exchange" are important characteristics in a local food system (Martinez et. al. 2010, p.4).

Local food, and therefore what local food systems are characterized by, does not have one definition. How local or sustainable a product is, is often defined by the consumers themselves (Hopkins 2009). This is why we have tried to summarize the characteristics of a local food system that we think are emerging from the discussion, but the general characteristics we extracted are not an exhaustive list and are voluntarily not specific. Further in the text, a case study will be used to show what a local food system can look like in a specific context.

1. Here, "local food" refers to the food produced in a local food system.

CHARACTERISTICS

• IMBRICATION OF SCALES

A localized world food system is a network of food systems of different scales nested together, starting from the scale of a small group of persons and going all the way up to the global scale (Hopkins 2009).

In such a system, the supply of all types of products for a given area or community is divided in rings of proximity, which are defined by the local climate conditions and the space needed to grow products (Hopkins 2009). As shown on [Fig.1], in such a structure, one community is supplied at different levels of proximity: vegetables can be grown in a radius of 0-20 km, livesotck can be supplied by farms within 70 km, and other products that cannot be grown close to the consumers are from the rest of the country or imported (coffee, spices, sugar, etc).

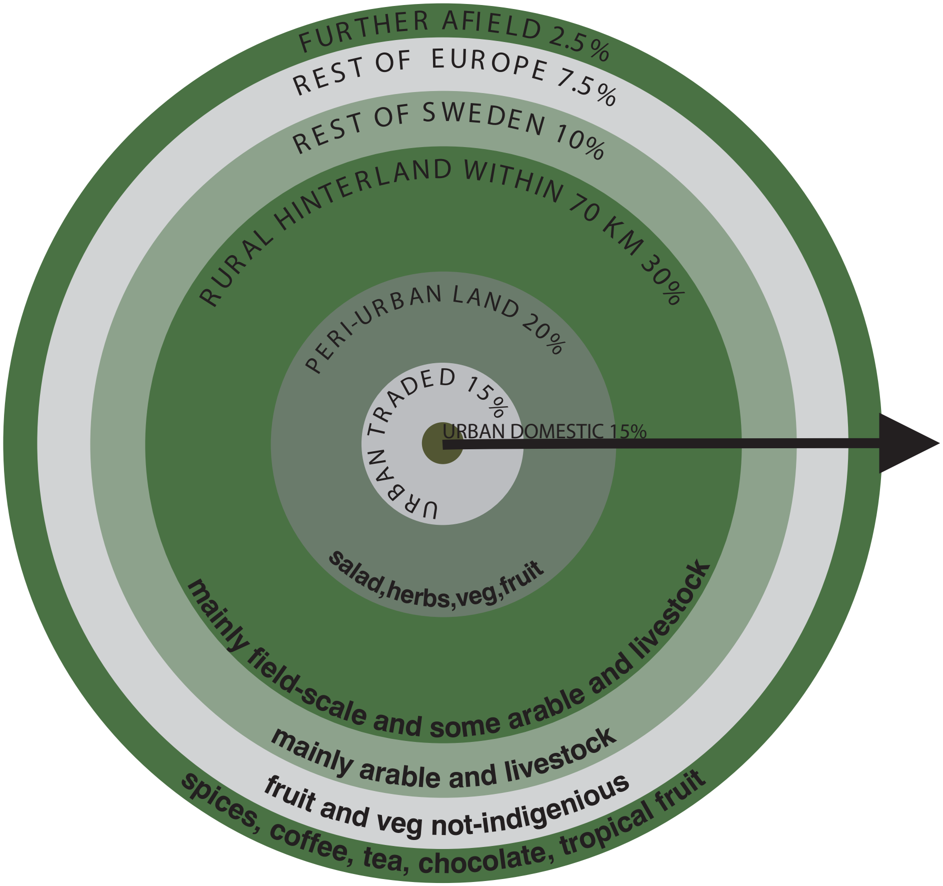
• DIVERSIFIED MARKET TYPOLOGIES

In local food systems, the proximity of the production allows a wider range of patterns for selling the food to consumers[1]. Two types of market typologies are particularly eased in a local food system: transactions directly between farmers and consumers (called direct-to-consumer), or transactions between farmers and restaurants, retail stores and institutions (called direct-to-retail/food service). The first category includes farmer's markets, community-supported agriculture[2], farm shops and "pick-your-own" farms (Martinez et. al. 2010).

Other supplying typologies, that do not include monetary transactions can be considered in a local food system. For example, home gardening, sharing, hunting, etc (Martinez et. al. 2010).

1. Whereas the current globalized food system has mainly developed one type of retail typology: the supermarket.

2. Community Supported Agriculture (CSA) is a direct-to-consumer retail typology where consumers pay a weekly fee to a farm, in advance, to get a weekly supply in vegetables from the farm. A typical CSA offers a mix of between 8 to 12 types of produce and herbs per weeks per member throughout the growing season (USDA 2010). This type of transactions ensure the farmer more economic securiy, and offers locally grown (often organically grown), fresh food to the consumer every week.



[Fig.1] : Food rings

Diagram showing the supply of different types of products in an urban-based, localized food system. Diagram adapted from Robert Hopkins.

Moving from the inner to the outer rings, we get:

•Decreasing perishability of produce

•Bigger plots available

•Increasing mechanisation

•Increasing carbon intensity of transport/distribution

(Hopkins 2009)

In such market typologies, the lost link between the producer and the consumer is re-established. These market typologies are themselves characterized by more cooperation between the production, the retailing and the consuming actors of the food system and more trust, bringing potential economic and social benefits to communities that will be described later. (Martinez et. al. 2010, Halweil 2004, Cockrall-King 2012).

• RE-INTRODUCTION OF URBAN AGRICULTURE

Bringing the production closer to the consumer is the core idea behind the building of local food systems. As it is expected in 2030, 60% of the world population will live in cities (Millstone & Lang 2013). Bringing the production closer to the consumers should therefore mean bringing back the production of food in city centres or suburban areas[1].

Today already, 12% of the world population is fed by urban agriculture (F.A.O 2001), both in developed and developing countries. For example, 42% of urbanites grow food in Vancouver. In Havana, 41% of the city area is for urban agriculture. 58% of Cuba's needs in vegetables are supplied by urban or suburban agriculture. In London, 14% of households grow vegetables in their garden (Millstone & Lang 2013). However, urban agriculture today, whatever the context is, does not fully supply urbanites with all products. In most cases it supplies population with only vegetables (not in meat, grain and dairy products). But for example, 90% of Shanghai's demand for eggs is produced within the city or in suburban areas close to the city (Millstone & Lang 2013).

Two typologies of urban agriculture can be developed: either urban farms as a business where people are employed to farm and sell the harvest; or domestic urban farming, where the growers are the consumers themselves (Millstone & Lang 2013, Cockrall-King 2012, Viljoen, Martinex et. al. 2010). Domestic urban farming can supply part of the consumer's food and can present economic advantages for the consumers. Further, by growing themselves, consumers also learn about the effort it takes to grow, about the seasons, about the local availability

1. Agriculture was present in cities until the industrial revolution at the beginning of the 20th century (Halweil 2004). This is why we speak about re-introducing urban agriculture.

of products, etc (Cockrall-King 2012, Brown 2009, Hopkins 2009). Domestic urban farming is described by local food advocates as a potential trigger for change in attitudes toward food, e.g decrease consumption of imported exotic fruits or decrease in meat and fish consumption.

• LOCAL ACTIONS

Localization of the world food system is an idea that already has taken shape. Some speak about the "Local Food Movement"[1], spreading at very small scales in different places.

In developed countries, where the most easily accessible food is the industrial food, local food initiatives are usually started by communities of consumers, or communities of local farmers, or together (Hopkins 2009, Ringqvist 2013). These initiatives are very inspiring, and, even if they do not reflect the mainstream development of the food system, they reflect a growing interest in locally and/or organically produced food among certain parts of populations in developed, industrialized countries (Martinez et al. 2010, Cockrall-King 2012, Hopkins 2009).

Different types of local actions can be considered, enabling the development of local food systems: creation of farms, creation of allotment gardens in city centres, creation of local farmer's markets or locally produced food retail stores, cooperation between farms and schools, etc (Brown 2009, Rich 2012, Cockrall-King 2012, Martinez et. al. 2010).

The consumption of locally produced food is increasing today, mainly in the United States but also in the United Kingdom and in Sweden, through the development of local actions. Studies show that numbers of farms, farmer's markets, CSA businesses, and farm-to-school programs have greately increased in the United States since ten years or less. Andrew Martins, journalist at the New-York Times, describes that the number of farms has increased by 4% in five years between 2002 and 2007 in the U.S.A, and that these new farms are small (U.S.D.A, AMS 2013). Between 2000 and 2013, the USDA reports that the number of farmer's markets across the United States has increased by 284% (8,144 markets in 2013 against 2,863 in 2000) (U.S.D.A, AMS 2013). Community

1. The development of local initiatives toward the building of sustainable food systems can be identified as a world-wide movement, in the sense that it is a "group of people working together to advance their social, political, economical ideas". (Oxford Dictionnaries 2014).

supported agriculture businesses have increased by 50% in the U.S.A in five years between 2001 and 2006 (Martinez et. al. 2010). Programs of collaboration between local farms and schools in the U.S have doubled in four years, reports the National Farm to School Network (Martinez et. al. 2010).

This demonstrated interest in eating local by consumers and institutions can be explained by a heightened awareness toward climate change and negative impacts of the current globalized food system from the consumers (Brown 2009, Hopkins 2009).

According to Robert Hopkins, the design of local food systems, and at a global scale of a localized world food system, will stand in the development of local actions (Hopkins 2009). But government decisions and policies will have to accompany and support the development of local actions, as well as promoting locally, organically produced food if it appears to be the way out of the food system crisis (Brown 2004, Brown 2009, Halweil 2004, Martinez et. al. 2010).

NÄRPRODUCERAT TIDAHOLM

“LOCALLY PRODUCED TIDAHOLM”

Närproducerat Tidaholm is an example of initiative for the development of a local food system in Sweden. This initiative is at the scale of a small town. We chose to speak about this specific initiative because we had the chance to make small research about it and meet the persons behind it.

Närproducerat Tidaholm is an association of local farmers created in 2012, motivated by the will to build a local food system for a municipality of 12000 inhabitants in Västra Götaland, Sweden. This organization first aims to create a network and cooperations between the farmers themselves; second, to reach the consumers and offer more possibilities to buy local food in Tidaholm. In a future perspective, the goal is to diversify and increase the production locally, in order to supply the inhabitants with as many types of produce as possible (Ringqvist 2013).

This project has been initiated by local producers from Tidaholm, and originates from the observation that farming has steadily declined over the past ten years in a municipality that has a strong historical background in agriculture. More than a decline in arable land surface, the production has become more concentrated and the number of food-related businesses has declined likewise (Ringqvist 2013).

Locally (in Tidaholm and within a distance of about 40km), wheat, oat potatoes and other vegetables are cultivated and cows, lambs and swines are raised. Jonas Ringqvist, owner of a farm in Tidaholm, has made an extensive research about the development of production in Tidaholm, and identified a decline in most branches of production.

“The number of dairy cattle, swine production, the cereals and even potato acreage (where Tidaholm has a strong position) has declined steadily during the period [2001-2012]. Egg production has been completely knocked out of the municipality." (Ringqvist 2013, p.5).

Jonas Ringqvist observed that there is also a missing link between the local production and the local consumption, because the area lacks processing facilities to be able to consume what is produced locally — grain in particular.

Närproducerat Tidaholm aims to invert the trend and to develop another scale of agriculture, including smaller farms supplying a diversified range of products. Today eleven producers are part of the organization, and what is produced is getting more and more accessible to the community as the producers are putting big efforts into developing new direct-to-consumers facilities and direct-to-retail/ food service connections (Ringqvist 2013)

Today, one can either buy produce online, order vegetable boxes from local farms, buy from two farmshops (one localized in a walking distance from the city centre), pick his own berries and buy locally produced meat, mushrooms and potatoes in local grocery stores (Ringqvist 2013).

This newly started organization has done a lot in a very short period of time (less than two years). Närproducerat aims to create a strong local food systems, developing links between producers and consumers but also raise awareness, encourage people to grow themselves, be involved in schools, and offer mainly organically produced items (Ringqvist 2013).

“People think I’m slightly crazy when I tell them to **go home and garden**, or not to involve themselves in a broadscale mechanized agriculture ; but a little thought and reading will convince them that it is, in fact, the **solution to many world problems**.”

Bill Mollison, Author of *Permaculture: a Designer’s Manual.*

(Mollison 1990, p.3)

POTENTIAL BENEFITS

The development of a sustainable world food system, triggered by the development of local food systems, has potential benefits for our societies and for the planet at different levels. Experts tend to assert that a sustainable food system with characteristics described as above can solve the issues and challenges explored in the previous chapter. For example, a sustainable, decentralized world food system could improve food security at regional and global scales; a sustainable food system could activate a shift in diets that fit our lifestyles better and improve public health in developed countries.

As the U.S. Department of Agriculture mentions in a report, it is difficult to assert the benefits of local food systems as empirical research cannot be driven in a sufficient manner (Martinez et. al. 2010). In other words, benefits are not proven yet. Therefore, the benefits engendered by a new, sustainable food system have to be stated as potential benefits.

•REDUCING ENERGY USE AND GREENHOUSE GAS EMISSIONS

Environmentalists and local food systems researchers defend that decentralizing and reducing the scale of the food system will have an impact on air pollution, greenhouse gases emissions and fossile energy use (Wijkman & Rockström 2011). Reducing distances reduces emissions and energy use; but one has to understand that other factors than distance have an influence on the energy use and greenhouse gases emissions. Load size, fuel type, transport mode should be assessed when calculating the benefits of short distances (Martinez et. al. 2010).

Further, a complete assessment of all food system stages is necessary to know if locally produced food is more energy efficient and releases less GHG emissions.

•SUPPORTING AND DEVELOPING LOCAL ECONOMIES

The development of local food systems, and particularly of local production and local, diversified retail systems encourages the development of small businesses (Halweil 2004). For a community, it means more independence and self-reliance (Garrett & Feenstra 1999). It can also activate the breaking of a very consolidated, centralized food system where, as we described earlier, few multinational companies have a lot of control (Cockrall-King 2012).

Direct sales from farm to consumer can be, for the farmers, an opportunity to develop other entrepreneurial activities, such as for example agritourism (Martinez et. al. 2010). It is described in local food systems models that farmers diversify their income sources and do not only produce-harvest-sell to a middleman (Halweil 2004, Martinez et. al. 2010).

• IMPROVING FOOD SECURITY

If we consider that food security is threatened today, both at global and regional levels, local food systems (at different scales) have the potential to make areas more self-sufficient and to improve food security at different levels. This, since the need for importations would be reduced — if the local production meets the needs of populations.

Although, when we get more specific, another kind of food insecurity can emerge with local food systems if local products remain more expensive than industrial food (Martinez et. al. 2010). Indeed, access to locally and/or organically produced food, e.g better quality food, can be limited to higher income parts of populations, and create food insecurity for parts of the populations that already are struggling (Martinez et. al. 2010).

•SOCIAL BENEFITS

Creating social links between growers and consumers and knowing the origin of products would definitly re-build the lost connection between people and their food (Martinez et. al. 2010, Terra Madre 2006).
Local food systems, and domestic urban agriculture in particular are potentially beneficial for the building of communities. Social benefits of sharing and doing things together is further described in the booklet in its own chapter.

BARRIERS AND CHALLENGES FOR THE DEVELOPMENT OF LOCAL FOOD SYSTEMS

It is important to be aware that the localization of the world food system, as promising as it sounds, will not be able to take shape rapidly. Its construction might take several decades, and in today's context the very much consolidated, globalized food system is a great limit to the development of a new food system. Local actions might solve problems locally but it is difficult to estimate their success at a global scale.

As it is difficult to understand all dimensions and factors taking part in the food systems, we summarize some barriers that our research brought up repetitively. The list is not exhaustive, and does not get very specific, but show general main challenges and barriers to the development of food systems.

•PROCESSING AND RETAILING LOCALLY

Brian Halweil, researcher at the World Watch Institute, explains that a major barrier to the development of local food systems is the very consolidated processing and retailing systems of today's world food system. It will be very difficult to bring processing factories down to local scales, for example slaughterhouses and canneries.

This issue was personnally related to us by Jonas Ringqvist when researching about Tidaholm's local production of food. In this municipality, a lot of grain is produced but it cannot be grinded locally. Therefore, wheat and oat seeds are sent to a mill further away, and then eventually consumed locally (Ringqvist 2014). Halweil also says that supplying only vegetables locally, the products that seem to be the easiest to grow close to us, is not sufficient to build strong sustainable food systems. This is one big challenge in the building of sustainable food systems.

•RELYING ON CHANGED ATTITUDES TOWARD FOOD

As mentioned earlier, the demand and the interest for locally produced food seems to be rapidly increasing in certain regions. It is difficult to measure what part of the population is taken in consideration, and, since the price of local or organic food is higher than industrial food today, we can suppose that higher-incomes part of the population have access to this food.

It cannot be assumed that all parts of the population will want more locally produced food, and will be able to access locally produced food.

• FARMERS AS ENTREPRENEURS

Re-introducing a local scale in the food system means an increase in the number of farms in most regions, since not all areas have a local supply in food today (Martinez et. al. 2010).

Increasing the number of farms in one given area is directly translated in an increase of number of farmers in a given population. It is, in a general perspective, a good thing because more jobs are available and the local economy has the potential to be developed. Nevertheless, the farming expertise today is decreasing, and the lack of knowledge in farming is today identified as a challenge for the development of local food systems (Martinez et. al. 2010, Halweil 2004).

Furthermore, local food systems have the potential to develop farms' activities and therefore farmers would have the possibility to increase their income by diversifying their business. Farmers have the potential to become entrepreneurs. The task is not easy, and people that are not trained or supported may struggle to successfully start businesses. "Leadership and training for young farmers and farmer's market participants has been reported to be a necessary element for local food systems growth", says the USDA report. (Martinez et. al. 2010, p. 27)

The localization of the world food system has, at a general overview and at a global scale, the potential to meet environmental and humanitarian challenges, and presents the potential to solve some of the “world problems” (Mollison 1990, p.3). When we try to get more specific when assessing the benefits of local food systems and question its operation, though, barriers and uncertainties are raised.

Local initiatives are very inspiring and are real living labs for testing the feasibility and operation of local food systems. In our master’s thesis, the greenhouse aims to give a tool to communities to start building their own local food system. In the next chapter we gather research around social benefits of sharing and growing together and summarize the results of the research to the reader. The benefits are limited to the frame of growing together, but could possibly be extended to other local actions in the building of food systems.

"We know all our neighbors, except the ones who moved in this fall. We don't know them yet since they haven't been in the **greenhouse**. So we will meet them during spring."

Grower from Solhuset's shared greenhouse in Järnbrott,Göteborg

from the book *Solhuset i Järnbrott*
(Örneblad 1997, p.109, our translation)

III. GROWING TOGETHER

As discussed earlier, communities, relationships between people and attitudes toward food, are as important as the actual growing of food in an urban context. Urban agriculture is a potential community builder, creating prerequisites for new values and increased health. In this chapter we will explore the potential benefits of sharing and growing together.

THE ACT OF SHARING

While the development of western societies is going towards individualization and consumerism, a tendency towards sharing can be observed in Europe and the United States, according to sociologist Mikael Klintman in the radio program *Filosofiska rummet* (2013). Collaborative consumption describes a shift in consumers' values from ownership to access. The hub of Collaborative Consumption[1], the website that accompanies the book *What's Mine is Yours* (Botsman & Rogers 2010), states that "...entire communities and cities around the world are using network technologies to do more with less by renting, lending, swapping, bartening, gifting and sharing products on a scale never before possible" (Collaborative Consumption 2014).

Private ownership might be a parenthesis in human history. In former societies there was no possibility for a

1. The hub of the Collaborative Consumption refers to the website www.collaborativeconsumption.com

large quantity of material possessions, and status was shown in the amount of power rather than material possessions. Further, a great part of our consumption is already shared: roads, health care, libraries, public transportation and schools. We are just not considering this as consumption, according to Mikael Klintman. (Filosofiska rummet 2013).

As written in the article *All eyes on the sharing economy* in *The Economist*, it is not a coincidence that rental firms are developing rapidly these days, but rather a reaction to the aftermath of the global financial crisis. Sharing can be seen as a “post-crisis antidote to materialism and overconsumption” (The Economist 2013).

THE BENEFITS OF SHARING

The act of sharing can build social capital in a local community. The political scientist Robert Putnam describes social capital as “...features of social organizations such as networks, rooms and social trust that facilitates coordination and cooperation for mutual benefits.” (1995, p.2)[1]. If the social capital is high, it means that people’s trust and confidence is high. These factors play a major role in counteracting crime and violence, but also for stimulating democracy and economic business exchange according to recent research on resilient communities (Christiansson 2012).

Mikael Klintman says that a common space can lead to more sharing, more meetings, and taking back social interactions from the internet to the neighborhood. In this way, life may become more culturally and socially rich (Filosofiska rummet 2013).

Sharing can moreover save resources, states Bahare Haghshenas in the same radio program. Haghshenas works with sustainable development at the accountant firm Deloitte and perceives today’s scarcity differently from the scarcity of the past when there was a real lack of resources. Indeed, she says, we still have physical access to resources but we realize that they are becoming scarce. Therefore we need to make better use of them. One solution is to share them: by sharing, we can still have access to the same amount of wealth and prosperity such as cars, boats, washing machines, tools etc., but use fewer resources (Filosofiska rummet 2013). One example of more efficient resource use is

1. For further information on social capital, see Rothstein’s *Socialt kapital - ett genombrott för en ny samhällsvetenskaplig teori* (2002).

the car pool. An average European car is used only 29 minutes a day and is parked during 23.5 hours. In a car pool, one has access to the car just when one needs it (Mont 2011).

SHARING RESPONSIBILITIES

Sharing something requires a commitment, since a social relationship is launched, according to Mikael Klintman (Filosofiska rummet 2013). Someone has to take responsibility for creating a structure for the act of sharing, which is difficult to achieve in spontaneous networks. Shared responsibility can end up as nobody's responsibility. It can cause problems known from for example collective student housing and shared summer houses where nobody is in charge.

This dilemma has been described as "The tragedy of the Commons"[1] (Hardin 1968). The act of sharing can be difficult in an individualized society. This is the reason why organizations and institutions in many cases manage the structure. Trusting an institution is many times easier than trusting a group of people, says philosopher Magnus Jiborn (Filosofiska rummet 2013).

1. The tragedy of the commons is a dilemma arising from the situation in which multiple individuals, acting independently and rationally consulting their own self-interest, will ultimately deplete a shared limited resource even when it is clear that it is not in anyone's long-term interest for this to happen. (Hardin 1968)

SHARED GREENHOUSES

The benefits of a shared greenhouse have been researched upon at Chalmers University of Technology. The architect Eva Örneblad has evaluated a common greenhouse in Järnbrott, Gothenburg, belonging to an apartment building called *Solhuset* (Örneblad 1997). The greenhouse was designed by architect Christer Nordström in 1986 during a renovation of the house originally built in the 1950s'. The aim of the greenhouse was to raise satisfaction, feeling of community and improve the social conditions in the area. Another aim was to visualize the solar heating principles used in the heating system of the house. Örneblad researched how the tenant's behaviour had changed since the introduction of the shared greenhouse and what the benefits of such a space could be. She describes positive, long-term effects of the greenhouse (Örneblad 1997).

The greenhouse is managed by a greenhouse group formed by the tenants. The technique, e.g. the irrigation in the greenhouse, is manual and the tenants have to help each other to water the plants. This is beneficial for the feeling of community, since the tenants have to communicate with each other. The growing space is not heated, even though it has been discussed to extend the growing season in this way. "We left the thought because we would then lose the fascination of growing in the spring, to start putting down a little bit and see how it grows." says one of the tenants (Örneblad 1997, p.73, our translation).

THE BENEFITS OF SHARED GREENHOUSES

According to Örneblad, the biggest benefit with the greenhouse experiment in Järnbrott is the positive social climate that has arised in the house since the renovation. An increase in social interaction is shown as many of the tenants stay in the common spaces or on the allotment garden instead of in their apartment during the growing season. This has lead to a decreased loneliness and a greater social security. Örneblad (1997) quotes the tenants of Solhuset:

"Now we know each other better. I can ask someone to water my plants and look after my apartment while I am travelling. It makes you feel more secure."
(Örneblad, 1997, p.109, our translation)

"The greenhouse is perfect, it is very nice. During the growing season you can visit the greenhouse even though you don't have anything specific to do there. You can have a coffee. You always meet someone when you enter."
(Örneblad, 1997, p.110, our translation)

Further, the tenants' self-reliance has increased since they were dedicated to this greenhouse. The feeling of participation in their neighborhood has lead to an increased trust and encouraged creative processes.

Ecological, pedagogical and social aspects are all interwoven in a greenhouse. In Järnbrott, the households have become more economically independent, and more able to control the quality of their vegetables. Domestic growing is also a natural way to take care of the organic household waste. The tenants tend to use garden compost, including egg shells and coffe grounds, more than before. A majority of the tenants in Solhuset think that their environmental interest has increased. Some of them believe that talking about toxic free cultivation makes them buy more organically grown food in the stores, and that by understanding the need for household compost, the overall recycling increases, as [Fig.2] shows.

Interested in environmental issues	
Very interested	6 (all cultivate)
Pretty interested	8 (6 out of 8 cultivate)
Does not care	2 (none cultivates)

[Fig.2]: table showing the tenant's interest in environmental issues
(based on Örneblad 1997, p. 111).

Several factors support change at an individual level when aiming to encourage people to grow at home, according to Eva Örneblad. Growing has to be practical, affordable and easy to perform. It should also provide a fast, visible, positive feedback. Gardens, allotment gardens and greenhouses are spaces that give direct feedback by clearly showing the loops of nature and therefore are prerequesites for starting a process for raised awareness and change (Örneblad 1997). Örneblad's study shows that the cultivation activity partly has worked as a pedagogical instrument for raising the awareness of sustainable development. The cultivation has made some people curious, wanting to know more, and supported people in changing their everyday habits.

FIELD STUDY

SOLHUSEN

GÅRDSTEN, GOTHENBURG

SHARED GREENHOUSES

GREENHOUSE GROUP

INDIVIDUAL GROWING

1 M2 EACH

LESS VANDALISM

The greenhouses attached to existing multi-stories houses in Gårdsten, Gothenburg, were designed by the architect Christer Nordström. The greenhouses are meeting places which strengthen the community. The inhabitants have organized a "greenhouse group" where common rules are set up concerning cleaning, decoration, layout of growing etc. The janitor helps the group with specific tasks, such as buying soil. The group meets at the beginning of every new cultivation season.

The tenants grow their crops individually in their own lot. This has been decided by the gardener's themselves in order to preserve their independence. Every household provide 1m^2, but since only 25% (appr. 64 tenants) of all the tenants are gardening, the lots are shared among the gardeners.

The tenants living in surrounding houses also wish to have a greenhouse as a meeting place. The rent will be slightly more expensive due to the greenhouse, but they still wish for it. Supporting such a project is a cheap investment for the housing company, resulting in decreased vandalism in the area and a positive atmosphere.

Interview with Anki Caspersson, Gårdstensbostäder, 5 February 2014.

Pictures: Kihlström

IV. APPROACHING THE DESIGN OF A SUSTAINABLE BUILDING

In a cold climate like Gothenburg, the natural conditions don't enable the growing of crops outdoor all year round. Thus, designing for urban, year-round agriculture here means designing a building. If the aim of introducing urban agriculture is to decrease a certain environmental impact, the house hosting the production itself has to support this same idea. This means that the design of the greenhouse has to be approached as a *sustainable building*.

What exactly is a sustainable building, and what should be considered in the design of such a greenhouse? Approaches, concepts and methods for designing sustainable buildings cover a very large amount of research, literature and studies. In this chapter, we chose to summarize the concepts and approaches that have been a starting point for our design process.

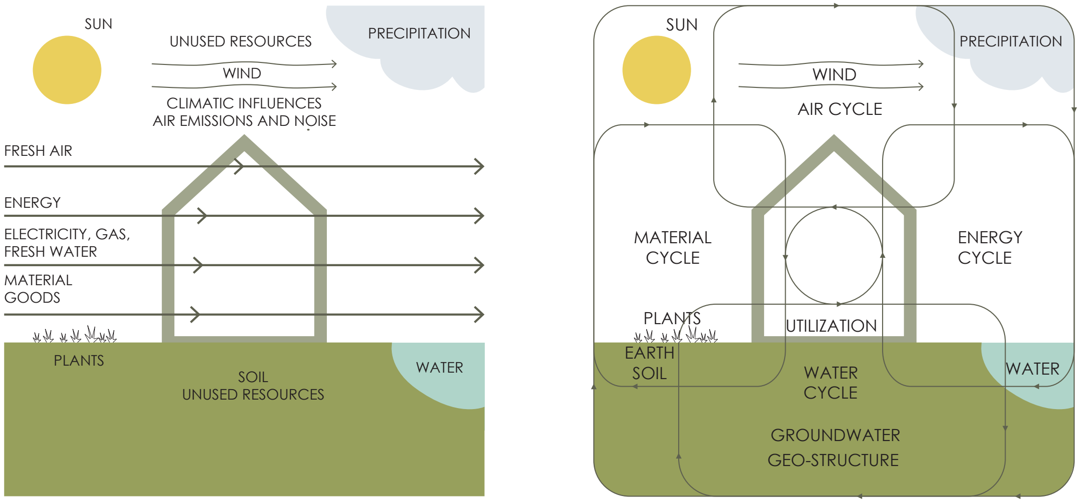
OUR APPROACH

BEING AWARE OF CYCLES AND SYSTEMS

In today's society, most systems are designed as linear systems. Resources are extracted, shaped into products, sold and eventually thrown "away". But actually "away" does not really exist. On earth, nothing disappears, everything always transforms. Awareness is raising that the way we consume has a harmful impact on the planet. Since we are not mindful about the loops of nature's cycles, our everyday life is breaking the balance of the natural system, causing great depletions and impacts at a global level (McDonough 2002). But our way of producing and consuming hasn't always been like that.

As William McDonough, architect and co-writer of the book *Cradle to Cradle* explains, being aware of the laws of Nature completely questions the way we design objects and buildings. A responsible approach to design, according to McDonough, would be to consider all the inputs of a product, examining how they can go back to the nature or be re-used. In that case, loops could be closed and society could shift from a cradle to grave- to a cradle to cradle-concept, where waste equals food and nothing is wasted.

Approaching the design of a building in a "cradle-to-cradle" way requires the assessment of the environmental impact of the whole building throughout its lifetime. This can be achieved by doing a "Life Cycle Analysis" of the building. The analysis looks at different categories: energy consumption, material use, water use and waste management at all stages of the building´s lifetime (from extraction and manufacture of raw materials, construction, operation and disposal).



[Fig. 3]: Linear, conventional use of a conventional building vs. cyclical use of a sustainable building (based on Brophy 2011, p. 35).

The environmental impacts of buildings are diverse and problems which result from construction-related processes, such as global warming, depletion of resources and release of toxic pollutants, are well known today. Talking about “closing the loops”, we have to understand that all systems on earth are connected and that the building is part of a broader system, as well as being a system on its own. The two diagrams in [Fig.3] illustrate the linear, open systems of conventional buildings and the closed, cyclical, sustainable system, representing the alternative (Brophy 2011, p.35).

LEARNING FROM THE PAST

Vernacular architecture can teach us how to build energy efficient by taking advantage of the location, the materials, the climate, the ground conditions etc. Architecture was initially about building a shed for weather protection. This resulted in high quality, in human scale and ecological design (Afentoulidou and Pirri 2013).

The industrial revolution brought people the ability to step away from nature. Today, we see a devotion in conserving energy, increasing efficiency and creating zero-footprint buildings, all fundamental actions for reducing environmental impacts. Energy-efficient designs achieve financial savings; well-insulated and efficiently ventilated buildings provide more comfortable and more productive environments. Still, the place-specific design has high architectural quality and shall not be forgotten. There are many examples of modern projects where energy saving is prioritized, but origin of materials, human scale and adaptation to landscape is not taken into consideration. Buildings with more natural and fewer artificial inputs are very often places that feel more comfortable. Day-lit buildings are, in general, more enjoyable than artificial lit ones, natural ventilation is more acceptable than mechanical, the fewer heat emitters, the better, and so on (Brophy 2011).

Sustainable design is place-sensitive. A great opportunity in a globalizing world is the potential to make place-specific architecture by responding to a certain climate and site, and using local materials.

COLLABORATIVE DESIGN

By conceptualizing the building as a system being part of a broader system, the complexity in the architectural design is increasing. Designers need to have an accurate understanding at all scales and levels of the building's systems and their interactions. Engineering also becomes an integrated part of the design, rather than a separated-added technique upon a spacial concept. We believe that the architectural practice is shifting towards a "holistic" approach, meaning that all aspects are thought-through at an early stage in the design process. Systems such as energy, space, materials, economy, social structures, nature and technique are constitutive parts of a building. This concept encourages multi-disciplinary design teams, and favoritize practices where architects and engineers become designers with different background and knowledge brought together for better designs.

The architect Christer Nordström said during a lecture at Chalmers, that if the architect has broader knowledge about technical issues, he or she also has a saying in the whole design, rather than just designing space and surfaces: "If you know the systems, you can be part of the decisions" (Nordström 2014).

WELL-BEING FOR PEOPLE AND NATURE

Sustainability includes social aspects, and human well-being is an important part of the concept of sustainability. Being aware of how space is going to be used, and by whom, can make the building last longer, as well as anticipating the aging and developing of the building over time. Reducing the consumption and waste of natural resources can be done by designing buildings that will age in a nice way and last long. Durability is also a matter of emotion and a personal feeling that designers can consider. We can speak about "emotional durability", and affirm that a qualitative object, made of good material and well-designed is an object that people will take care of. Choosing quality instead of quantity is a matter of saving resources.

Sustainability is also about re-setting the comfort needs of today. Our western lifestyle results in too high consumption of energy and resources. To achieve a sustainable society, we have to change the way we travel, eat and live. This means changing our focus from quantity to quality, from material consumption to non-material well being, including using less oil, eating less meat and living in energy-efficient buildings (Bokalders 2010). Questions we need to ask ourselves are e.g. "how often do we have to wash ourselves?", or "how warm does my apartment really have to be?". Designers can influence users' behaviors and encourage them to change their attitude[1].

Conditions inside a building, such as poor air quality, toxic materials or lack of daylight clearly affects the occupants' health and comfort. Harmful chemicals and materials in common building materials pollute the air and water supplies, causing damage for the close and global natural environment (Brophy 2011). Toxic materials have to be handled as hazardous waste with no possibility to be taken care of by nature and a high amount of energy is used for cleaning polluted areas.

Planning for healthy environments from the beginning results in a better health for the users in the end.

CONCLUSIONS

The different ideas and approaches in the literature are all heading towards the same goal: being aware of the interconnected systems we live in and design in collaboration with Nature insead of in opposition to it. Designing entirely mindful might be visionary, but not impossible.

During our process we had input from other disciplines regarding structure, thermodynamics and construction, as we think this is crucial for designing holistically. In the design choices we made, we kept this approach in the back of our heads at every level, questionning many different aspects into a detailed scale. Even a small building can become very complex!

Vernacular architecture illustrate well that a building should take advantage of the local context it is built in. It should smartly use the available local resources in order to ensure its inhabitants the interior comfort they need. Designing in a cold and rather rainy climate, it was very important to learn and understand the local conditions to design according to them.

We also tried to consider the design as a product that people would appriciate and a space where users would like to be. The choice of materials and the different architectural details have been though through to make it a well-designed building, even though it is just a place to grow food. The object should fit the Gothenburg housing stock and become a nice insert in the residential context.

1. Read more about the power of design regarding changing behaviors in "Benefits of shared greenhouses" in Chapter 3: "Growing Together".

FIELD STUDY

"HÄLLUNGEN ORGANIC FARM"

SVENSHÖGEN

ORGANIC LIFESTYLE

NOT HEATED

ORGANIC MATTER

NO WASTE - ONLY TRANSFORMATION

SIMPLE SYSTEMS

Åke Wikström is a former IT professor at Chalmers who bought a property with land in 2006 in Svenshögen with the will to start his own production of organic vegetables. Åke's house was built with wood from his own forest and is powered by solar energy. His greenhouses are not heated but extend the growing season anyway. In winter green leaves are grown and the food is stored the whole year. Åke makes his own compost with organic matter and manures collected from farms around.

The seeds in his production are pre-cultivated indoor with low-energy consumption lights. Åke makes sure that there is a variety of crops on the same area to keep the soil good.

Åke's approach is that we have to be aware of the cycles of life. Nothing is wasted, things are just being transformed and re-used. Closed loop cycles can get very complex but having simple systems is a solution to be able to maintain closed loops.

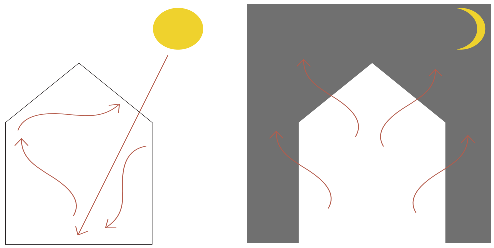
Interview with Åke Wikström, Svenshögen, 7 February 2014

Pictures: Lindahl. Pictures taken during a rainy day of the deep swedish winter.

V. GREENHOUSE DESIGN GUIDE

Plants require light and a certain temperature to grow, something that is not naturally available all year round in all European climates. Greenhouses are a solution to prolong the growing season in order to sustain a population's needs in food.

A greenhouse is basically a solar panel for food production. A positive greenhouse effect is caused by sunlight (shortwave radiation) penetrating the glass, absorbing and converting into heat (long wave radiation), which are then prevented from getting out through the glass. The "glass" house is heated during the day, but radiates the captured heat out into space at night.



[Fig.4]: Illustration of the greenhouse effect occurring in a greenhouse during day vs. night.

Greenhouses are largely used for commercial purposes, in a monocultural way[1] in most cases. A greenhouse can also be used in a smaller scale for domestic purposes. Private greenhouses are popular in Sweden and can be bougth in department stores or on the internet.

Indoor production in greenhouses can enable the growing of food in raised beds, more convenient to harvest the crops, or can keep the growth of crops in the natural soil at the ground level.

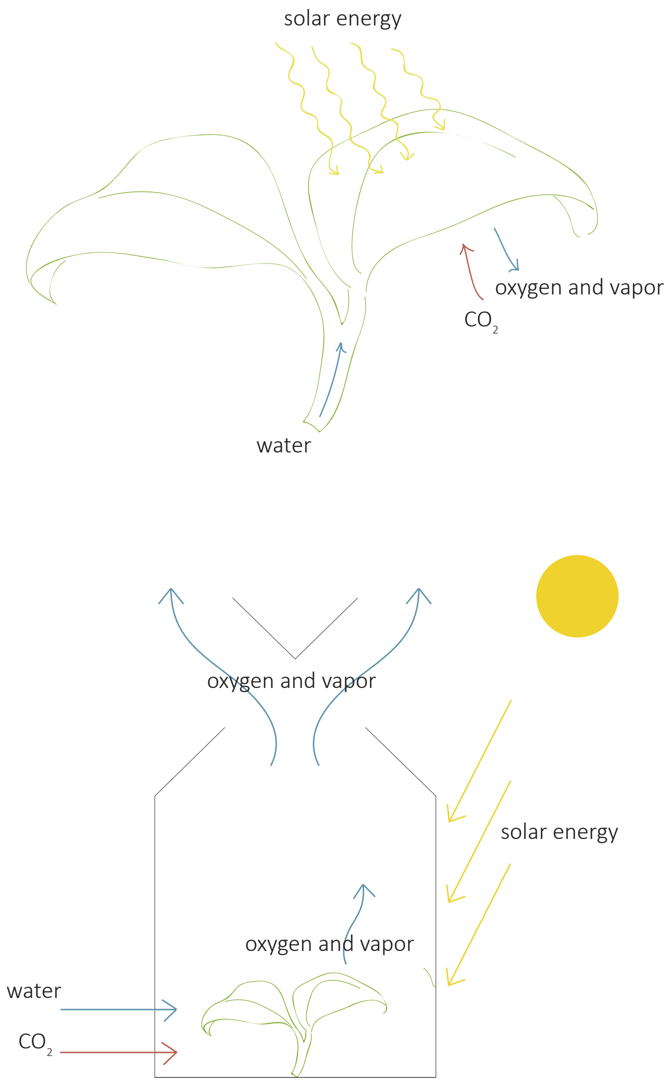
This chapter contains the following sections: *The growing of plants,* simply a short introduction about how plants grow. *The Greenhouse Design Principles* follows, explaining different aspects to consider when planning a greenhouse. The chapter ends with *The palette of sustainable operation solutions,* presenting different ways to operate a greenhouse in a cold climate. The information in this chapter origins from *Restvärme för växthusproduktion* (Alnarp 2013) and the *Cold Climate Greenhouse Resource Guide* (University of Minnesota 2013).

1. Monoculture: the cultivation of a single crop in a given area (Oxford Dictionnary 2014).

THE GROWING OF PLANTS

In order to understand what is needed in a greenhouse, we have to understand the growing process of a plant, operated by the photosyntesis. Photosynthesis, as defined in the Oxford Dictionnary, is the process by which green plants and some other organisms use sunlight to synthesize nutrients from carbon dioxide and water (Oxford Dictionnary 2014). With the help of solar energy the plant builds energetic nutrient out of carbon dioxide and water, particularly the sugar glucose. The leave emits gaseous oxygen and water as vapor. [Fig. 5] shows how photosynthesis works.

Photosyntesis has to be enabled in a greenhouse. Water and CO_2 have to come in, as well as solar radiation. Oxygen and vapor, produced by the photosynthesis, have to exit the greenhouse, as shown on [Fig. 5].

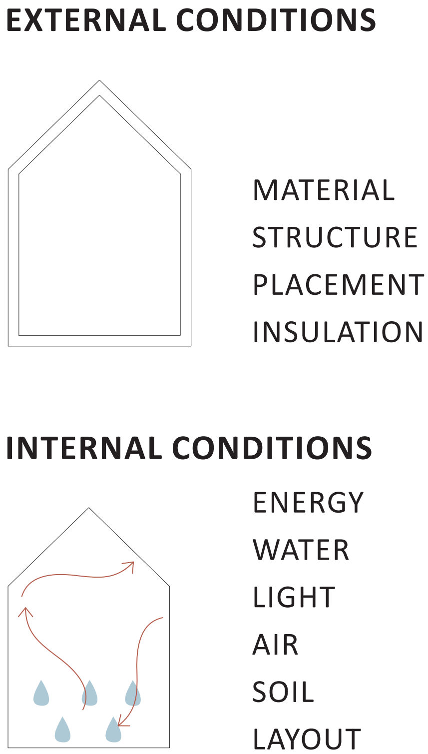


[Fig. 5] The photosyntesis principle and its occurence in a greenhouse

GREENHOUSE DESIGN PRINCIPLES

Greenhouses have one function: to provide the right conditions for plant growth when the natural conditions can't ensure it. In the concern of yield improvement and after optimization of the design over time, some design principles for greenhouses have been identified as common and relevant to all designs. We have summarized these generic design principles or considerations in this chapter.

The design of a greenhouse relies on external and internal conditions.The external conditions include the material of the construction, the design of the structure, the placement of the greenhouse and the choice of insulation material. These factors determine how efficiently the greenhouse functions. The internal conditions group the features or the strategies necessary to operate the greenhouse so that it can supply everything plants need in order to grow (Christiansson 2012).



[Fig.6]: Conceptualization of the design elements framing the design of a greenhouse (Adapted from Christiansson 2012).

MATERIALS

In its most simplistic representation, a greenhouse consists of a glazed envelope supported by a light structure. Depending on the purpose, the period of use and the budget for the greenhouse, different materials can be chosen.

The choice of materials affects the construction cost, the durability, the insulation capacity and the aesthetics of the greenhouse (an assessment of all materials used in our design is shown later in the booklet).

•GLAZING MATERIAL

The glazing material is important for a greenhouse. Today, two types of materials share the market: glass and plastics. Between different materials, different parameters can influence the choice such as the cost, the lifespan, the insulation capacity and the light transmission capacity. [Fig.7] is a comparative table of three glazing materials commonly used in greenhouses. Data has been collected from the Cold Climate Greenhouse Resource Guide by Barbara Bellows (CCGRG 2013, p. 31-33).

•FRAMING MATERIAL

Structural materials that are commonly used for greenhouses are wood and aluminum. The advantage of wood is its low environmental impact. A wooden structure is never as thin as an aluminum one, and creates shadows. [Fig.8] compares aluminum and wood considering relevant criteria.

GLAZING MATERIALS

	GLASS	POLYCARBONATE	POLYETHYLENE
Light transmission	85-90% single panel 70-75% double panel	83% Double Wall 75% Triple/quad Wall	80-90% single layer 60-80% double layer
Insulation capacity	R-Value: 0.9 (single panel) 1.5-2.5 (double panel)	R-Value: 1,4-1,8 (double wall) 2-4,1 Triple/Quad wall	R-Value: 0.87 (single layer) 1.5-1.7 (double layer)
Lifespan	~ 100 years	10-12 years	3-4 years
Cost	Expensive	Expensive	Cheap

[Fig.7]: Compared assessment of different glazing materials considering different relevant criteria
Source of data: Cold Climate Greenhouse Resource Guide 2013.
R-Value is a measurement of the resistance of heat flow (heat transfer) through a given thickness of a material. A higher number indicates better insulating properties (source: ecofoil.com)

FRAME MATERIALS

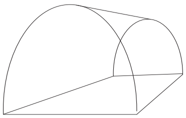
	WOOD	ALUMINIUM
Solidity	Very strong *(in the sense of fiber)*	Poor to strong *(depends on the way it is used)*
Water tightness	High	Correct
Water vapor tightness	Very low	Full
Insulating capacity	Medium to high	None
Grey energy *energy required to extract, manufacture or process the material*	Spruce 0,906kWh/kg *results for dressed, air-dried spruce* Oak 0,800 kWh/kg *results for dressed, air-dried oak*	6,694 kWh/Kg
Durability	Very high for raw materials (centuries) *(lower for industrially made materials)*	Poor (requires a lot of maintenance and renovation)

[Fig.8]: Compared assessment of wood and aluminum considering different relevant criteria
source of data: Dutreix 2010.

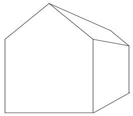
STRUCTURE

- SHAPE

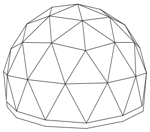
A greenhouse provides necessary conditions for plants to grow by creating a greenhouse effect in a closed environment. Therefore, its construction usually remains very simple. Over the years, different greenhouse shapes have emerged in order to improve efficiency for performance, cost and construction. Below, different greenhouse shapes identified are illustrated.



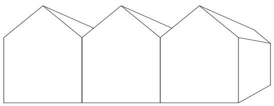
Hoop House
Usually aluminum tubes and plastic sheet glazing



Pitch-Roof House
Aluminum or wooden frame; glass or polycarbonate glazing



Geodesic Dome
Ususally wooden frame and polycarbonate glazing

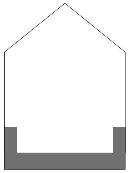


Repeated Picth-Roof House
Aluminum or wooden frame; glass or polycarbonate glazing

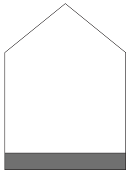
- FOUNDATIONS

A greenhouse is not expected to have a lifespan as long as a normal building. Therefore, simple foundations should be prefered as well as a lightweight, flexible structure. The foundations can be designed according ro different principles: molded walls, a concrete slab or plinths (the most common way).

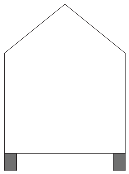
In cold climates, foundations need to be poured below the frost level of the ground to avoid damages over winter. Also, it is preferable to insulate the foundations in cold climate to limit heat losses through the ground.



Molded walls



Concrete Slab



Plinths

PLACEMENT

The placement of the greenhouse affects the amount of solar radiation entering the greenhouse. The strategy is to orientate the greenhouse so that the glazing material will receive the maximum amout of solar radiation. In the northern hemisphere, the sun radiates from the south. Therefore, an east-west direction with a lot of solar transmission through a long southern wall is preferable.

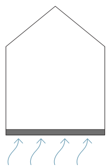
Maximum amount of solar radiation from the south

INSULATION

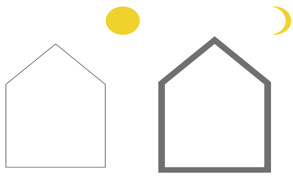
Heat losses can be reduced in greenhouses by reinforced insulation, especially during cold nights in the Swedish climate.

We have identified two strategies for insulating a greenhouse: temporary insulation and permanent insulation. Temporary insulation is to put over night and remove every morning, in order to limit heat losses during the night and still get the maximum of solar radiation during the day. This insulation layer is usually a fabric.

Permanent insulation can also be used. By insulating the foundations of the greenhouse, heat losses through the ground are reduced and the insulation provides a better growing climate, particularly important when the growing occurs on the ground. An interesting strategy seen in some greenhouses from the mid-west of the United States is the insulation of the roof and north facade of free-standing greenhouses.



Permanent insulation strategy: foundations



Temporary insulation strategy

ENERGY

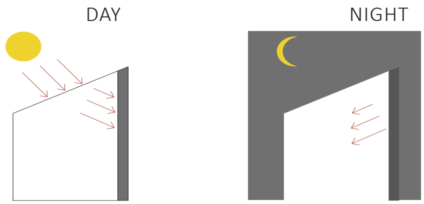
• HEAT

The photosynthetic process demands a certain minimum temperature both day and night. Every plant specie requires specific climate condition. Cucumbers and tomatoes require a high temperature, whereas green leaves can grow even in winter. The average temperature for vegetables to grow is between 15°C and 26°C. Considering that most domestic greenhouses are not monocultural, temperature can be looked upon more generally.

If the greenhouse needs to be heated for winter production, a heating system should be integrated to the design. A relevant design strategy is to think of combining different heating strategies and heat storage to limit energy consumption and operational costs. Different heating solutions are presented further in the booklet (p.74-77).

• HEAT STORAGE

There is a possibility to store heat during the day and release it during the night using passive or active techniques[1]. Thermal mass walls, i.e masses that are able to store thermal energy, can be used in greenhouses as a passive solar heat storage. Materials such as bricks, earth, or water (in barrels) can be used as thermal mass walls.



The thermal mass wall principle

Active heat storage in the ground[2] can be used to get an earlier start of production in hoop greenhouses where cultivation takes place on the ground.

1. A passive technique refers to a natural physical process whereas an active technique refers to a mechanical, forced process, requiring energy to function.

2. See p.79 of the booklet.

WATER

• IRRIGATION

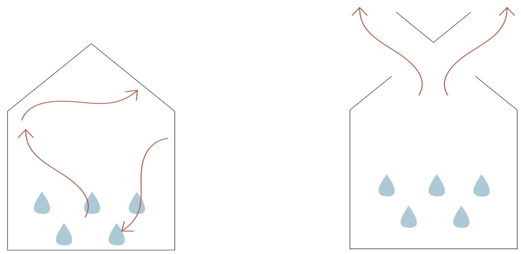
Access to a water source is necessary for a greenhouse. In the *Cold Climate Greenhouse Resource Guide*, growers interviewed either had automatic watering system with pumps and pipes, or had staff to water the plants everyday. In a shared greenhouse, the irrigation system can be regulated by the level of sharing: if plants are shared, then the watering schedule could be shared. If they are not, meaning that plants are different, then the irrigation could be an individual responsibility.

Rainwater for irrigating the plants can be collected in barrels, preferably integrated in the design.

• HUMIDITY

The plants need access to water for their growth, but also the humidity level in the air is of great importance. The relative humidity in the greenhouse may not be too high nor too low, as this affects growth negatively.

When humidity reaches a certain level, the greenhouse has to be ventilated. This includes a loss of heat, though. Dehumidification in the greenhouse can also be done by installing dehumidifiers, a relatively expensive investment.



Humidity trapped in the greenhouse vs. released by natural ventilation through windows

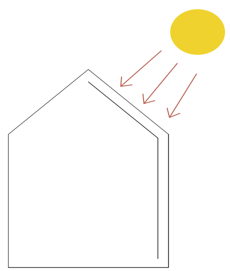
LIGHT

• LIGHTNING

Light is usually a limiting factor for plant growth in northern latitudes. With low level of light, growth is occurring slowly. To optimize growth in greenhouse production, artificial lights have to be used during fall and winter. Keeping the glazed material clean and minimizing bulky details of construction and equipment, increases the light transmission.

• SHADING

During times of high solar radiation shading is required to protect the plants. The disadvantage of permanently installed weaves is that they also provide some shade even when they are not in use. Thereby they cause a reduction in the desired light intensity.



Shading is needed during warm summer days

AIR

• INTENDED VENTILATION

Ventilation is important in greenhouses since the air becomes humid. Two strategies can be integrated to a design: natural ventilation, that uses the natural principle of air convection, or forced ventilation that uses fan coils and ducts for a mechanized and controlled air flow in the greenhouse.

A natural ventilation follows vernacular construction methods using basic thermodynamic principles but cannot be regulated precisely. Controlled forced ventilation ensures a stable environment and a good level of humidity in a greenhouse, but uses energy to be operated.

• UNINTENDED VENTILATION

Unintended ventilation can lead to heat loss by transmission through ceilings, floors and walls. A dense material such as a plastic sheet results in a lower air change rate than eg. a leaking single glass house. A leaking single glass house rapidly increases the air circulation when wind occurs outside.

SOIL

• SOIL AND CONTAINERS

Growing can occur directly in the soil or in raised beds. This influences the comfort of the grower, but also the preparation of the soil. Preparing the soil is important and complex and the quality of soil will determine the quality of products. For a rich, healthy soil, different ingredients need to be mixed. Every year the soil should be renewed or mixed again, something to consider when designing a greenhouse.

Drainage is important whether growing directly in the soil or in raised beds to avoid excess moisture and fungus proliferation in the greenhouse.

Seeds first need to be seedled, e.g planted in small containers before being transplanted in the growing bed.

• NUTRIENTS

Nutrients for growing are often waste products from the food industry, typically pelleted chicken manure, blood and bone meal and manure from nearby organic milk farmers. Natural systems in the greenhouse can control pests in a biological way.

INTERIOR LAYOUT

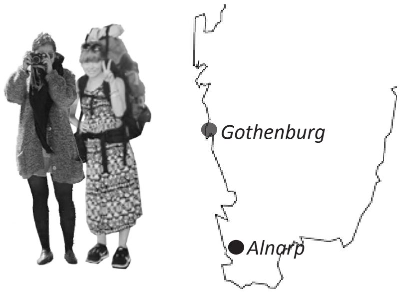
For using the space efficiently, growing can occur both horizontally and vertically. The frame of the greenhouse can for example be used to hang additional raised beds. If tall pants are grown in the greenhouse, they should be placed in the back so that they don't shadow smaller crops. Using shelves for vertical growing also provides shading to other growing beds.

The comfort of the grower needs to be taken into consideration, and his/her movements should be at ease. Accessibility for everyone is an important aspect to consider in the design of shared greenhouses.

FIELD STUDY

RESEARCH GREENHOUSE

SLU, ALNARP



The big research greenhouse at SLU in Alnarp is controlled through a computer; the heating, the light, the ventilation, the screens and the irrigation. The air is heated through district heated water pipes. The ventilation windows provide cooling. The irrigation goes through a pipe with gutters. A capillary mat underneath makes the plant take up the water. This is the conventional way of irrigating in small pots. When growing in bigger containers, e.g. cucumbers and tomatoes, drip irrigation from above is used instead.

Usually, the glazing in greenhouses is polycarbonate, but that material has to be changed after 10 years since it gets yellow. In Alnarp, the glazing is well insulating acrylic, but that is very flammable, almost explosive. Instead, multiple screens for both insulation and shading can be installed, even when using single glass.

The growing occurs in soilless material mixed with lime, fertilisers, sand, clay etc., and is mainly conventional cultivation.

In winter artificial lights is used all day long, 16 hours per day. The structure of the greenhouse is shading a lot. In summer artificial lights are only needed mornings and evenings. The lamps should be placed 2-3 meters above the plants to get an even distribution. The quality of light, the spectra, is the same for all plants but the amount of lights differs.

The normal temperature in the research greenhouses is 18 degrees. The humidity is controlled manually by wetting the floor in order to increase the humidity. Modern greenhouses have active dehumidifiers, but that demands energy. Plants need a humidity between 50%-80%.

Interview with Karl-Johan Bergstrand, researcher in greenhouse cultivation, 14 Februar 2014

Pictures: Kihlström

TECHNOLOGY

DISTRICT HEATING

VENTILATION WINDOWS

16 H ART. LIGHTS IN WINTER

HUMIDITY BY WETTING FLOOR

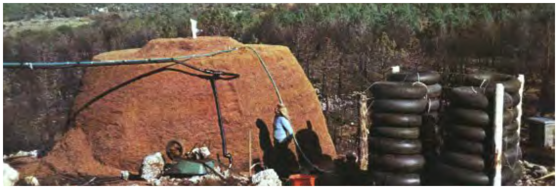
PALETTE OF SUSTAINABLE OPERATION SOLUTIONS

The relevance of winter production in cold climates can be discussed, since in the common mindset it is very energy consuming; the greenhouse needs to be heated and it needs additional lightning since the daytime is too short. That is why we tried to research about heating, lighting, ventilation and insulation solutions to understand what is most energy efficient and how we can try to save energy at the furthest extent possible, either by lowering the needs of the greenhouse or by producing energy in the greenhouse itself.

Most of the solutions gathered here have already been inventoried in the *Cold Climate Greenhouse Resource Guide* (University of Minnesota 2013) based upon visits in farms from southern Minnesota and central Wisconsin. Even if the difference in climate between the mid-west of the US and Gothenburg is quite significant, the solutions developed by these farms ensure year-round production in locations where winter temperatures are much colder than in Gothenburg.

Other solutions have been studied based on the big database of knowledge that Youtube is. Indeed, many people around the world have tested building service solutions by constructing them themselves and uploaded videos on the web. Seeing people doing and explaining it is an informal way of learning but very efficient and accessible too.

The research is collected in what we have called a palette of solutions. The list is not exhaustive but is representative of what is available today as sustainable solutions to enable crop growth all year round in greenhouses. A lot of variations among the solutions presented are possible, but they won't be developed here. The aim is to make an assessment of these solutions afterward in order to choose the most suitable solutions in terms of heating, ventilation, lightning and irrigation systems for our design according to our criteria. Choosing solutions will take the local conditions of Gothenburg in consideration, such as the climate data and the local resources (materials, energy, etc).



PALETTE OF SUSTAINABLE OPERATION SOLUTIONS

HEATING SOLUTIONS
• SOLAR AIR COLLECTOR
• DISTRICT HEATING
• BIOMASS BURNING
• COMPOST WATER HEATER

TEMPERATURE REGULATION SOLUTIONS
• PASSIVE SOLAR HEAT STORAGE
• ACTIVE SUBTERRANEAN HEAT STORAGE

ARTIFICIAL LIGHTNING SOLUTIONS
• LED RED AND BLUE LIGHTS

NUTRIENT SUPPLY SOLUTIONS
• COMPOST

ALTERNATIVE GROWING TECHNIQUES
•HYDROPONICS
•AQUAPONICS

SOLAR AIR COLLECTOR

PRINCIPLE

The principle is the same as solar panels but it heats air instead of water. Corrugated metallic sheets are placed on facades or roof where air circulates and is heated by solar radiation. The air is then driven into the interior space to heat or pre-heat the interior air.

COST

Not expensive.

ELEMENTS NEEDED

Corrugated metalic panel and a fan.

REQUIREMENTS

Having available surfaces on the building exposed to the sun (whether on the roof or on facades).

ENERGY CONSUMPTION

The fan to drive the air in the building

ADDITIONAL INFORMATION

The surface of metallic panels is quite important compared to the volume of air it can heat.
This technique has been tested by the architect Christer Nordström in Sweden and more recently in housing blocks in Falkenberg (CNA 2009).

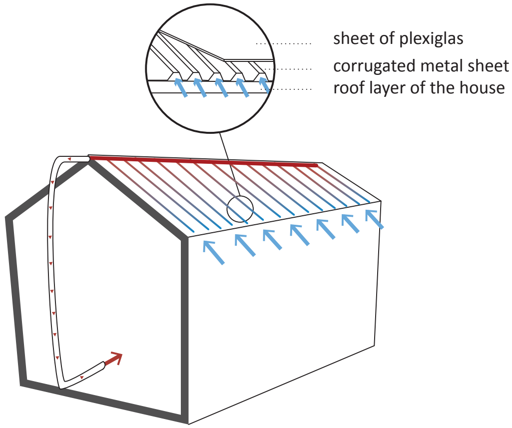


Diagram: solar air collector principle
Diagram adapted from Christer Nordström Arkitekter

Solar air collector panels on a roof (1) and on a facade (2), by Christer Nordström Arkitekter.
Image source: www.CNA.se

DISTRICT HEATING

PRINCIPLE

Connection of the greenhouse to the district heating system of a city. The greenhouse uses the heat that is distributed to the city; it is part of the city's system. Hot water pipes run around the greenhouse and heat radiators in the greenhouse to heat the space. Smaller pipes can be placed under the growing beds to heat only the roots and save energy.

COST

Installation: expensive
Operation: depends on the price of district heating

ELEMENTS NEEDED

A connection to the district heating (heat exchanger, pipes to run water around the greenhouse, ducts if the system uses air).

REQUIREMENTS

Having a district heating system in the location of the greenhouse. It also requires digging and connection work that can't be done just for one domestic greenhouse. This system would be efficient for integrating greenhouses in new buildings (housing, offices, schools) or for commercial greenhouses.

ENERGY CONSUMPTION

Energy used by the district heating system

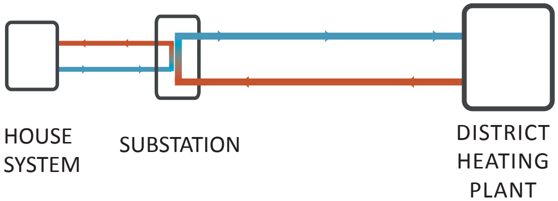


Diagram: district heating system of a city.
The red line symbolizes the hot water distributed in the houses after being heated in the plant. The blue line is the colder water coming back to the plantt after its travel around the city.
Diagram adapted from GoteborgEnergi.

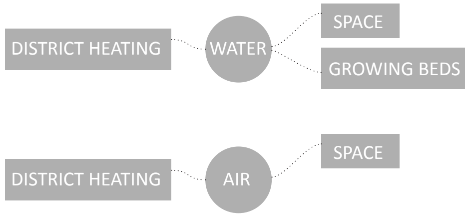


Diagram: different ways of heating a greenhouse with district heating

District heating by hot water pipes running through the research greenhouse and heating the space at SLU, Alnarp. *Image source: Kihlström*

BIOMASS BURNING

PRINCIPLE

Burning biomass (organic matter) to heat the greenhouse. It is basically the same distribution system as district heating except that the heat source is located in or next to the greenhouse.

COST

Installation: depends on the system
Operation: costs are limited to buying biomass and maintenance.

ELEMENTS NEEDED

A boiler or a stove, biomass (wood or other organic combustible matter).

REQUIREMENTS

Space to store the biomass and maintenance for the appliance

ENERGY CONSUMPTION

Biomass

ADDITIONAL INFORMATION

A system that radiates heat should be placed far enough from the plants to avoid burning and should be distributed evenly in the greenhouse. Most growers use a combination of different heating sources, and this technique is mostly used when the temperatures get very cold. It usually doesn't run all winter long.

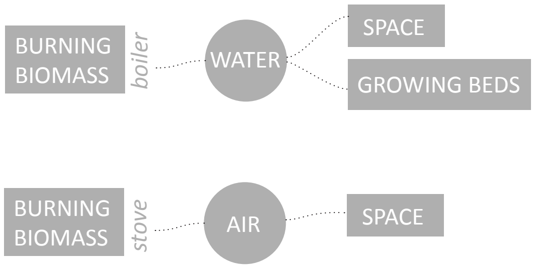
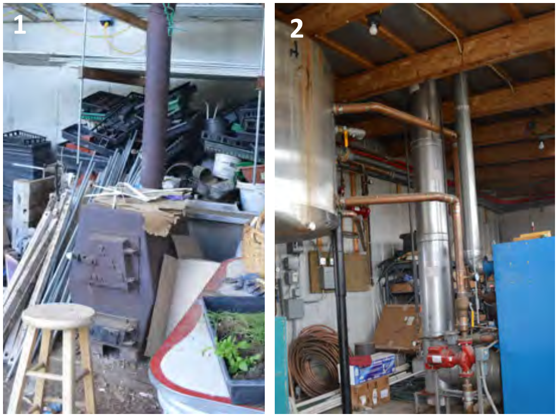


Diagram: different ways of heating a greenhouse with a biomass burning system



Different biomass burning systems: wood stove (1) at Sweet Earth Farm in Gays Mills, Winsconsin; boiler (2) at Pork and Plants Farm in Altura, Minnesota.
Image source: Jody Rader, source: Cold Climate Greenhouse Resource Guide.

COMPOST WATER HEATER

PRINCIPLE

To use the heat naturally generated by the fermentation of organic matter to heat water. It consists of a compost pile throughout which plastic pipes filled with water are running in a concentric pattern. This method is recognized as the 'Jean Pain' method (see diagram). The pipes are then connected to the house system and can heat water up to 54°C.

COST

Cheap

ELEMENTS NEEDED

Polyethylene pipes, a metallic tank, organic "green" and "brown" matter to make a compost, pumps to make the water circuit.

REQUIREMENTS

A rather large area to build the compost pile. The pile has to be placed closed to the greenhouse as heat is lost when the water travels across large distances.

ENERGY CONSUMPTION

Electricity to run pumps

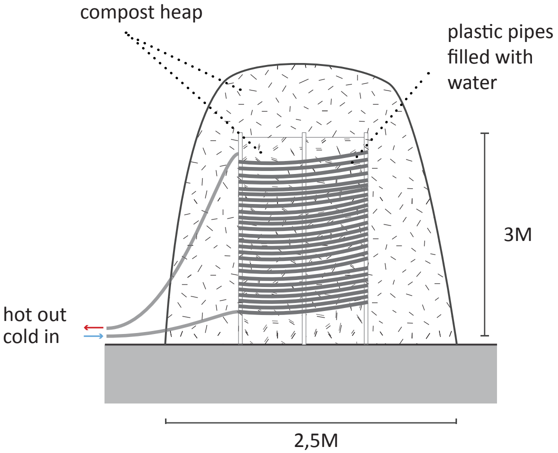
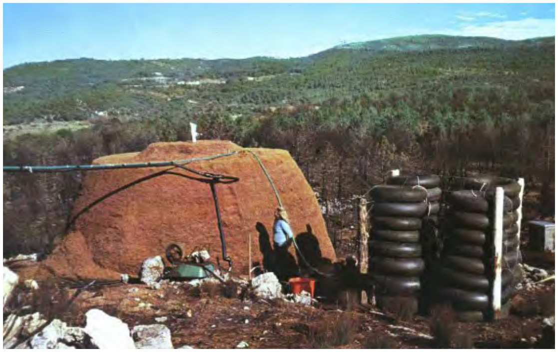


Diagram: The compost heap water heater, developed by Jean Pain. Combined with the heating system, the compost heap was used to collect methane from the fermentation of organic matter to produce energy for cooking.The compost was, after fermentation, used as rich matter for soil. *Illustration adapted from Jean Pain's cylindrical thermal compost pile diagrams.*



Jean Pain's compost heap water heater
Image source: www.integralpermanence.org

PASSIVE SOLAR HEAT STORAGE

PRINCIPLE

Heat from the sun is stored in materials with high thermal inertia like concrete, bricks, ceramic tile, water or soil during the daytime. When the temperature drops the heat stored in these materials radiates back out and regulates temperature in the greenhouse.

COST

Depends on materials used; rather cheap

ELEMENTS NEEDED

For thermal mass walls*:*
-Plastic or metal barrels filled with water
-Earth, brick or concrete wall; at least 10cm thick.
For thermal mass grounds:
-Sand, earth or bricks.

ENERGY CONSUMPTION

None

ADDITIONAL INFORMATION

The system needs to be associated to a heating system to ensure a correct temperature all the time.

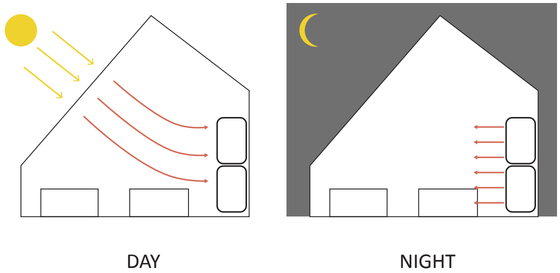


Diagram: Heat storage principle (example of water barrels)

Water barrels wall in a solar greenhouse.
Image Source: midwestpermaculture.com

ACTIVE SUBTERRANEAN HEAT STORAGE

PRINCIPLE

Hot air, which naturally rises to the top of the greenhouse, is captured at the top of the greenhouse and conducted down in the ground through ducts that heat a bed of rocks under the growing beds. The rocks radiate the heat to the growing beds during night time.

COST

Unknown

ELEMENTS NEEDED

Fan, ducts and rocks.

REQUIREMENTS

Plants need to grow on the ground. The system installation requires ground digging work.

ENERGY CONSUMPTION

The system needs electricity to run the fan that brings hot air from top down into the ground.

ADDITIONAL INFORMATION

This system functions best on sunny days. In winter it can raise the temperature of the beds up to 6°C (sunny day) (*Wang &Liang 2006*).

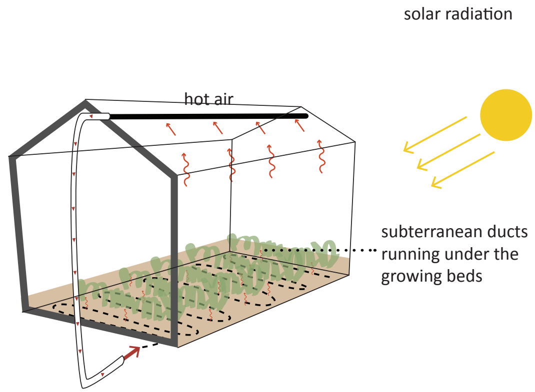


Diagram: subterranean heat storage principle.
The sun's radiation heats the greenhouse. Hot air is naturally driven to the ceiling; hot air is collected in a duct, then driven back under the growing beds.

Subterranean heating storage system at Elk's Bluff Farm.
image source: Cold Climate Greenhouse Resource Guide, photo Chuck Waibel.

LED RED AND BLUE LIGHTS

PRINCIPLE

Compensating the lack of daylight in winter with a device that supplies an efficient and low-energy consuming lightning. Plants absorb only blue and red wavelengths for photosynthesis, therefore this type of artificial lightning is optimized for plant growth .

COST

Installation: rather cheap
Operation: depends on electricity cost

ELEMENTS NEEDED

LED lights, electricity, strings or hangers.

ENERGY CONSUMPTION

20 W per m^2

ADDITIONAL INFORMATION

During winter time in Sweden, a greenhouse needs 16 hours of artificial lightning per day. This technique is currently developed for industrial indoor farming, known as “pinkhouse” farming. The strategy is to grow plants replacing the daylight by “Pink” (mix of red and blue) LED lights that make plants grow more efficiently .

Example of product sold on internet, produced by a Chinese company.
Image source: www.growlight.cn.

Seedlings growing with LED Pink lights at Åke Winström’s farm in Svenshögen, Sweden.
Picture: Farrouch

COMPOST

PRINCIPLE

Starting a small scale decomposition cycle of organic matter. By letting a pile of organic matter (kitchen waste, leaves, animal manure) age, micro- and macroorganisms will destroy the materials and produce soil full of what plants need to grow.

METHODS

Passive composting
Building a pile of organic matter letting it age outside or in an enclosed bin. This method takes three to eight months to produce a good soil. The process can be accelerated by turning and mixing the pile several times during the decomposition process (active composting).

Vermicomposting
Worms can accelerate the decomposition process by eating and destroying the organic matters. Their poo will also provide good nutrients for the plants.

COST

Free (use of waste)

ELEMENTS NEEDED

Space to make a pile, and a container if necessary.

REQUIREMENTS

If the compost is in a closed bin:
Air it and wet it once in a while

ENERGY CONSUMPTION

None

Passive composting
image source: www.greenspire.se

Vermicompost
image source: http://msucares.com

HYDROPONICS

PRINCIPLE

Hydroponic growing is a technique that abandons soil from the growing cycle. Plants are grown either in water or in a growing media where nutrients are directly given to the roots by a nutrient solution (nutrients+water). This nutrition is monitored by devices (pump, timers, etc).

COST

The different elements are relatively cheap to buy but the operation costs can raise the bill. The more monitored the system is, the more expensive it will be (installation+operation).

ELEMENTS NEEDED

Tank, water, nutrients (bought in store - artificial), pump, timer, plastic pipes, growing trays (plastic most of the time), air pump and air stone (roots need oxygen to capture nutrients), growing media (rockwool, vermiculite, clay pebbles, water, etc)

ENERGY CONSUMPTION

Electricity needed to run the pump and monitor the system

ADVANTAGES AND DRAWBACKS

Less diseases, fungus or weeds because there is no soil; plants grow faster as they don't have to "look for their food" in the soil; space-efficiency as you can grow vertically; "Dirt-free": convenient for people living in apartments; water-saving ; best for plants that are water-loving; relies on electricity resource to work; maintenance and knowledge are needed.

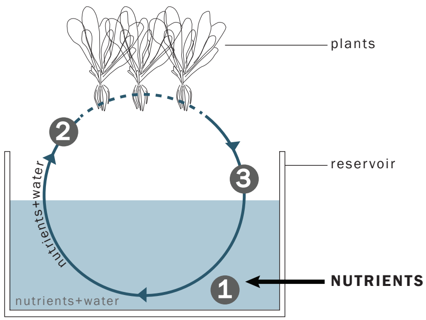


Diagram: hydroponic culture's principle

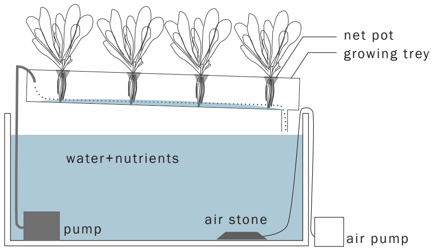


Illustration: The most common method of hydroponic growing

Hydroponic rhubarb growing at the Science Barge, NYC, USA.
image source: urbanacupunctureblog.wordpress.com

AQUAPONICS

PRINCIPLE

This is a combination of aquaculture and hydroponic agriculture. In an aquaponic system, the nutrients are supplied by fish manure that grow directly under the plants' growing beds. According to the scheme, the water from the fish tank full of organic nutrients(1) is pumped up in the growing beds (2), and as the water runs through the roots they clean the water for the fishes (3). The clean water goes then back to the fish tank, and the system works in a closed loop. The only provision to add to the system is the food for the fishes.

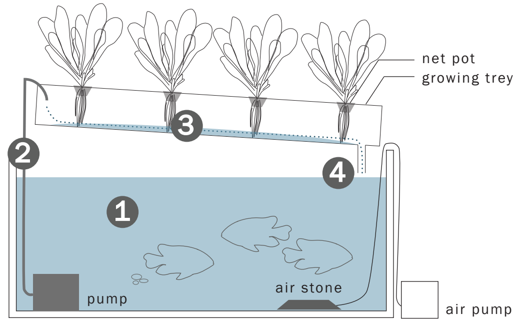


Diagram: Aquaponic culture's principle

COST

Expensive but it provides the grower both vegetables and edible fishes.

ELEMENTS NEEDED

Tank, water, pump, timer, plastic pipes, growing trays, air pump and air stone, growing media, fishes like perches, tilapias or trouts.

REQUIREMENTS

Fishes need to get food every day, either manually or in a automatized, monitored way.
The tanks need to be adapted to the adult size and the amount of fishes.

ENERGY CONSUMPTION

Electricity is needed to run the pump and monitor the system

Aquaponics at Growing Power Farm, Milwaukee
Photo: Ryan Griffis from Urbana, USA.

BENCHMARK

This chapter aims to collect specific, technical knowledge about greenhouse design in order to build a strong basis that will argue our design. We now know what design considerations and operation solutions can be implemented to provide good growing conditions in a cold climate.

Since our design proposal is targeting domestic use, it is important to know what greenhouses for domestic, private use can be bought today. This section presents a small research about kit greenhouses available on the market, trying to evaluate if they already fulfill the criteria we aim to implement in our design.

We studied three standard models from three different companies, reflecting the current kit greenhouse market in Sweden. We discussed these products considering different aspects such as materials used, impact on the ground, presence of insulation, aesthetics and compared the results. We arrived to the conclusion that, even if the prices vary, the designs are very similar and not innovative.

From the products found on the internet, the kit greenhouses that one can build himself are not meant to be shared: they are very small and the design is basic (design optimized for growing only). They are neither designed for all year round purposes, nor with nature in mind. Indeed, they aren't adapted to a cold European climate since they are not insulated and the angle of the roof is classic. Features such as waste-water treatment, compost station or energy efficiency solutions are not integrated.

Meanwhile, we found two innovative greenhouse designs. These designs, more than being kit greenhouses, bring innovative solutions for indoor urban farming. The two case studies are summarized in the coming pages. They represent inspiration and open the field for us to interesting design solutions.

MULTILINE
ByggMax

Picture: ByggMax

Small polycarbonate greenhouse of $9m^2$ for private use. The structure is not insulated more than the polycarbonate and has no foundation.
Cost: 8’500 SEK

+ No permanent foundation
+ Easy to build
- Not shared
- Aesthetically poor

EURO-SERRE MAXI
Willab Garden

Picture: Willab Garden

Aluminum greenhouse for private use. The foundation is made of a concrete slab. The structure is only insulated in the ground and uses single glazing.
Cost: 17´000 - 39´000 SEK

+ Masonry as thermal mass
+ Adaptable to different ground conditions (concrete slab)
- Aluminum structure
- Not shared
- Concrete slab

VÄXTHUS UTAN BYGGLOV
Sweden Green House

Picture: Sweden Green House

Wooden greenhouse for private use. The foundation is made of a concrete slab. The structure is only insulated in the ground and uses single glazing.
Cost: 92´000 - 124´000 SEK

+ Wooden structure treated with “organowood”, environmentally friendly product
+ Masonry as thermal mass
+ Adaptable for different ground conditions due to masonry
- Not shared
- Concrete slab

GROWUP
London, UK

Picture: Growup

GrowUp London is an urban farming project consisting of an aquaponic, compact and transportable farm. Designed by two students and founded by KickStarter, this product has been showcased in central London. It uses high technology to operate a very efficient farming in a pure glass house.

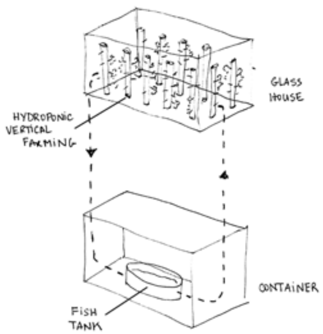


Illustration of design principle

- **GROWING TECHNIQUE**
  aquaponics, vertical growing

- **FRAME**
  lower level: re-used container
  upper level: glass box, aluminum structure

- **PRODUCTION CAPACITY**
  according to description: 400 salads at the same time (lettuce, ruccola, spinach, etc)

- **HEATING SYSTEM**
  not designed to be heated

- **VENTILATION**
  the top of the glass box is openable by motorized, monitored devices.

- **ENERGY RESOURCE**
  not specified

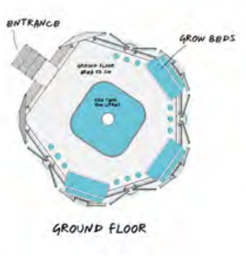
- **SPACE**
  people are not meant to stay in the box. space between the growing units is enough to harvest but is very dense for better yield

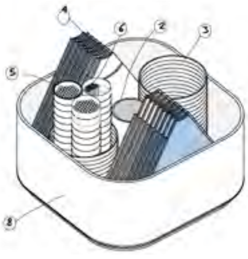
- **SHARING**
  box meant to be placed on public spaces as a showcase. when the doors of the container are open a temporary café or benches invite people to come and learn about the project.

GLOBE / HEDRON

Picture: conceptualdevices

GLOBE/HEDRON is a concept of greenhouse that can be placed on rooftops in city centres. Very light, compact and quickly assembled, it can be mounted and unmounted very fast. Globe/Hedron contains a hydropponic farm that can sustain four families all year round (according to description). Choice of materials have been assessed by their environmental impact, and operation solutions are integrated to the design so that it can an autonomous unit.





- **GROWING TECHNIQUE**
  aquaponics, vertical growing (layers of growing beds)

- **FRAME**
  geodesic shape, bamboo structure
  easy assembly

- **PRODUCTION CAPACITY**
  according to description:
  400kg veggies;100kg fish
  scaled to feed four families all year around

- **HEATING SYSTEM**
  not designed for cold climates

- **VENTILATION**
  cooling fans powered by solar energy

- **MATERIALS**
  FRAME: bamboo
  GLAZING: polycarbonate

- **SPACE**
  fish tank in the centre. possibility to move around the tank. No storage space

- **SHARING**
  only a production greenhouse. No space dedicated to meet, have a talk, sit down.

GLOBE/HEDRON illustrations: Plan(1), Elements(2), Picture: *www.conceptualdevices.com*

VI. FROM RESEARCH TO DESIGN

The explorations gathered and summarized in this booklet were determinant for the design of our greenhouse. It helped us being conscious about the right way, according to us, to design this building by analyzing and defining an approach to the design.

The research also raised our confidence about the relevance of the design in the perspective of sustainable development of Gothenburg. It highlighted the benefits that communities and the city would gain from implementing such greenhouses in residential areas of Gothenburg.

Our greenhouse design guide has been particularly solicited during the design process. The design principles built a strong base for a thought-through design, and the sustainable solutions palette was here as a tool when deciding upon the most adequate operation solutions.

We also kept in mind to improve the kit greenhouses that are available on the market today by making domestic greenhouse spaces to enjoy being in, and environment-friendly buildings.

The space we are designing aims to bring a new dimension to the design of greenhouses: it is a common space where the growers, more than growing food, have pleasure to be in and are proud to use and share. It is also an object that should be pedagogical about sustainability and nature's cycle. Therefore, we believe that such a greenhouse has of course to provide good conditions for plants to grow, but in an energy-efficient way; the design should go hand in hand with the local conditions, and be innovative and appealing so that people enjoy using it. The case studies were inspiring for us since they show that greenhouses can be innovative as buildings and can get closer to a field of temporary pop-up architecture with real space qualities.

The next part of this booklet is dedicated to the presentation of our design work, and explains our design step by step. First comes the frame of our design: criteria, program and reflections. Then the design is presented in different sequences: the modular conception, the smart building, the details, materials and asssembly process, ending with an example of implementation in the HSB Living Lab.

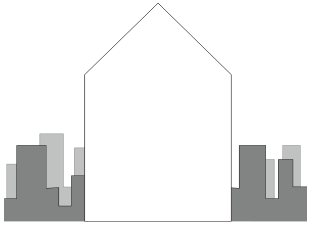
As this greenhouse is supposed to be adaptable, the design does not have a specific site and is more seen as a product like a kit greenhouse. The implementation in the Living Lab is an example of its possible implementation in a residential building. Why we chose this case will be explained further in the report.

VII. GO CITY GROW!

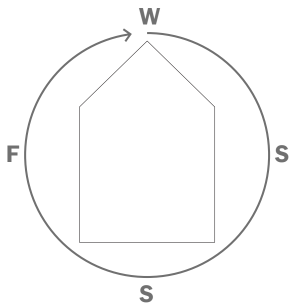
DESIGN CRITERIA

We see the purposed greenhouse, GoCityGrow, as a small building that one community of people living in apartments could buy and place on any type of available plot. It is supposed to encourage people growing their own food and learn about sustainability, therefore it should be affordable (people should have a direct benefit from it). Since the owning community can vary in size, needs and desires, the design must have a certain level of flexibility in its dimensions, but also in its inner features. One could choose to have a kitchen, someone else could choose to have an outdoor deck, etc. It is important that the community decides how they want to use their greenhouse and appropriate the space inside.

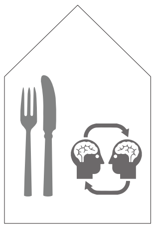
The purpose of the greenhouse is to supply food, to make people conscious, to enable sustainable lifestyles, to build communities and to educate sustainabilty through the building itself and the activities inside.



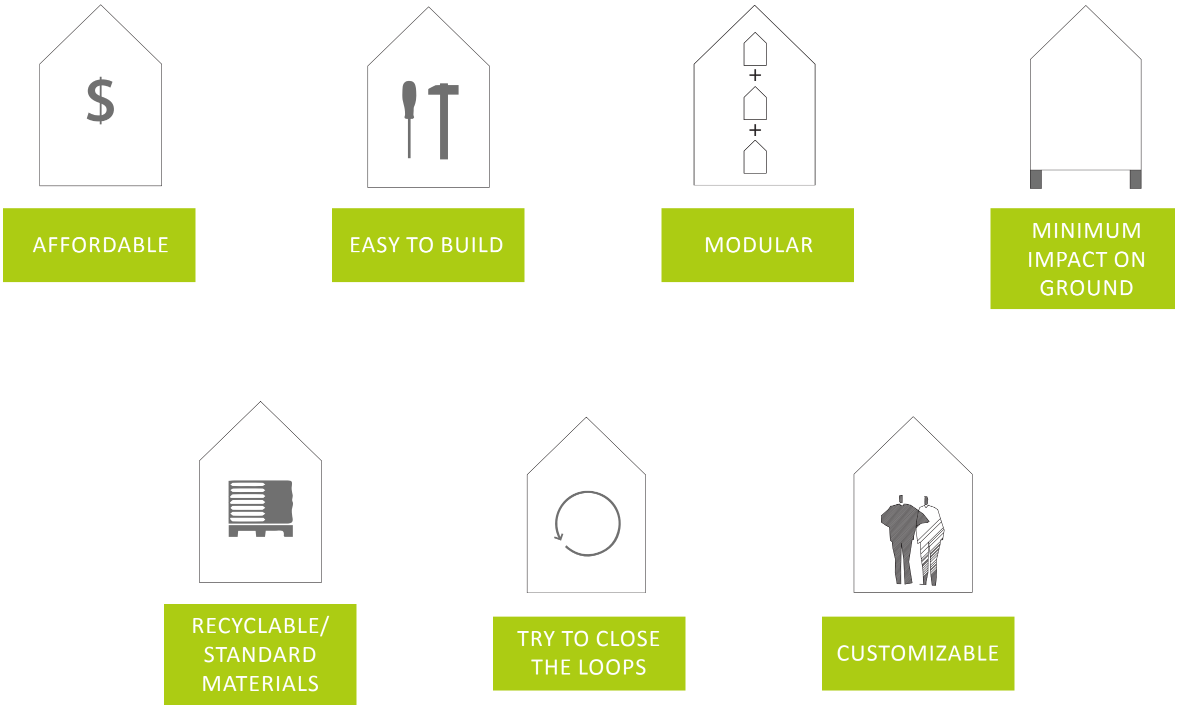
GREENHOUSE FOR URBAN DOMESTIC FARMING



ALL YEAR ROUND PRODUCTION IN THE CLIMATE OF GOTHENBURG



PROVIDE EDUCATION ABOUT FOOD



AFFORDABLE
EASY TO BUILD
MODULAR
MINIMUM IMPACT ON GROUND
RECYCLABLE/ STANDARD MATERIALS
TRY TO CLOSE THE LOOPS
CUSTOMIZABLE

PROGRAM
GROWING SPACE

Go City Grow aims to inspire people to change behaviors rather than making the urban farmers self-sufficient in food. Still, we want to give an indication on how much space is needed for growing.

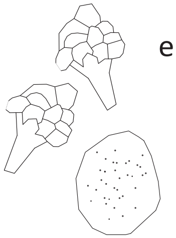
Calculations made at the University of Gävle[1] show that the space needed to feed a family of 2 adults and 2 children with home-grown vegetables for a whole year is $500m^2$. The calculations assume that the family eats a mixed diet without rice and pasta but supplemented with meat, poultry and fish or proteins of different origin. The gardening work is expected to take one hour a day, at least during the spring as well as during the harvest season.

In Go City Grow, the growing space depends on how the users divide the space versus how many modules the specific greenhouse consists of. Using half a growing module, equals $1,9m^2$,

In a northern European climate

$500m^2$ gives:

332 kg potatoes, 198 kg cabbage/ broccoli/beans/peas, 133 kg root crops.



enough to feed
2 adults
2 children

1 year

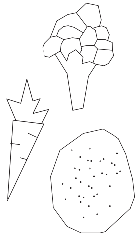
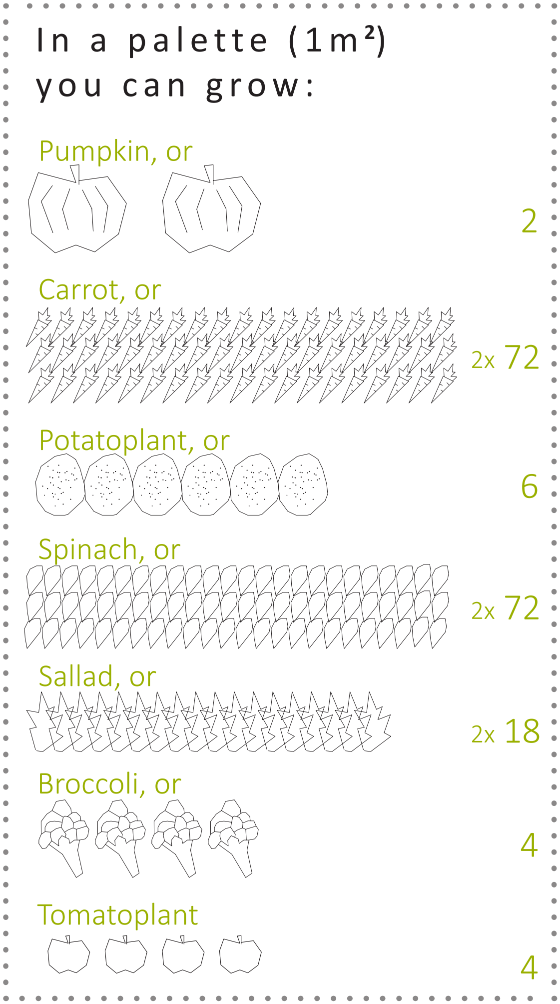


Image Source: Kihlström

A garden of $500m^2$ is enough to make a family self sufficient in vegetables.

1. In the master thesis "*Självförsörjande ekologisk odling av grönsaker på friland*" (*Self sustaining ecological farming of vegetables*) from 2010, Jenny Helsing at the University of Gävle provides figures that give an indication of both the yield and performance.



Calculations from the book “Odla i Pallkrage”.

compared to an ordinary palette of $1m^2$. During summer time, the growing can also take place in exterior allotment gardens, providing even more space. The image to the left show the amount of vegetables that can grow in a monocultural palette. Some vegetables can grow twice during one season, marked in the image.

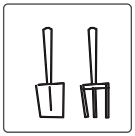
Go City Grow will not make urbanites self-sufficient in food, but give them fresh vegetables during certain seasons and inspire them to think differently by putting their hands in the soil.

Image Source: Kihlström

Exterior palettes provide fresh vegetables and herbs during the growing season.

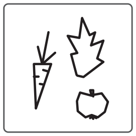
PROGRAM
ACTIVITIES

Growing Activities



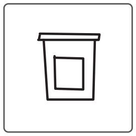
GROWING

Activities	Assets
MAKE SEEDLINGS PLANT FERTILIZE REMOVE WEEDS WATER PLANTS BRING SOIL IN	GROWING MATTER STORAGE WATER TAP WORKING BENCH



HARVESTING

Activities	Assets
HARVEST CLEAN PRODUCE STORE PRODUCE	SINK STORAGE WATER TAP WORKING BENCH



CANNING

Activities	Assets
CLEAN & CUT COOK PUT IN JARS SEAL JARS	SINK KITCHENETTE WATER TAP WORKING BENCH STORAGE

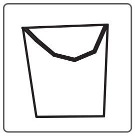
Other Activities

RELAXING

Activities	Assets
MAKE COFFEE COOK PLAY GAMES READ	TABLE / CHAIRS KITCHENETTE STORAGE

LEARNING

Activities	Assets
READ TALK LECTURES WORKSHOPS	TABLE / CHAIRS STORAGE BLACKBOARD



CLEANING

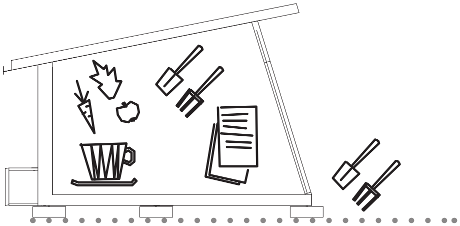
Activities	Assets
SWEEP THE FLOOR CLEAN WINDOWS CLEAN FURNITURE CLEAN DEVICES	SINK WATER TAP STORAGE

The program of the greenhouse includes *Growing, Harvesting, Canning, Relaxing, Learning* and *Cleaning*. This is a direct result of relevant field studies and interviews. All activities are listed together with the assets needed to perform the certain activities.

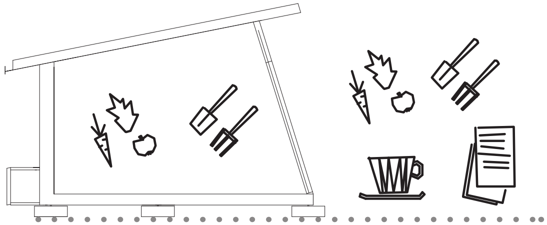
The amount of m^2 needed for each activity differs, according to the number of users. Therefore they are not defined at this stage, but rather decided by the need of the customer, ordering a certain amount of greenhouse modules.

PROGRAM

SEASONAL USE

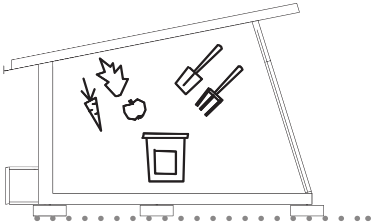


SPRING



SUMMER

FALL



WINTER

The greenhouse will be used differently depending on the seasons. The preparation for the growing season begins in spring, containing seedling and preparing the soil, as well as planting and harvesting. In summer, most of the activities take place outdoors. In the greenhouse, the natural growing season can be extended to the late fall, but there are still crops to harvest and conserve. In winter, the greenhouse can serve for growing certain crops such as green leaves, since the temperature will not go below zero degrees. The greenhouse will also serve as an area for storing crops or canned and conserved produce in winter.

PROGRAM
GROWING TOGETHER IN THE GREENHOUSE

Different phases in the greenhouse management[1]:

1. The handover of the empty greenhouse
   Presentation, introduction
2. Building knowledge through a course
   Self-organisation and start of a greenhouse community
   Arrangement of interior and equipment
3. Growing activity starts
4. Reflection and feedback concerning knowledge
5. Change, development
6. Stabilisation, phase of maturation

1. Adopted from Örneblad 1997, p.84.

The shared greenhouse is a space for social interaction and knowledge exchange. The space, the knowledge, the experience and the tools are shared in the greenhouse. Each grower has its own plot, its own soil and its own crops. Depending on the size of the community, the management will look different, and so will the sharing. Every grower could, e.g. get one module, and a common herb plot can be organized. The sharing will look different in every community.

The growing can be organized in a greenhouse group consisting of the growers in the community.


Image Source: Kihlström

Shared growing by tenants in Olofshöjd, Gothenburg.

PROGRAM

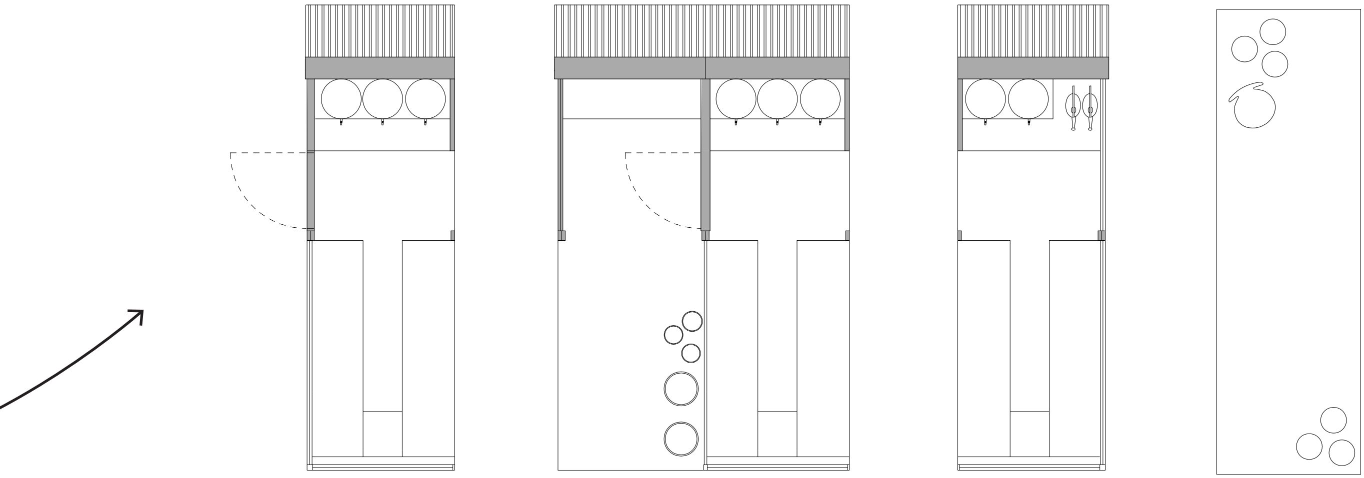
After discussing the growing space, activities, seasons and the way the greenhouse could be shared, we decided the program to be as follows.

Each growing module shall contain of maximum growing space possible, 6-9 water barrels, and storage area, either shelves, closets or benches. The passage area shall be held to a minimum. Each growing module shall contain of special assets such as kitchenette or window. The growing modules shall be adapted to standard-sized, common building materials.

A MODULAR CONCEPT

MODULARITY

The greenhouse is designed by adding modules. All modules have the same dimensions, except for the “extremities” that require a slightly different configuration. Different types of modules have been developed.

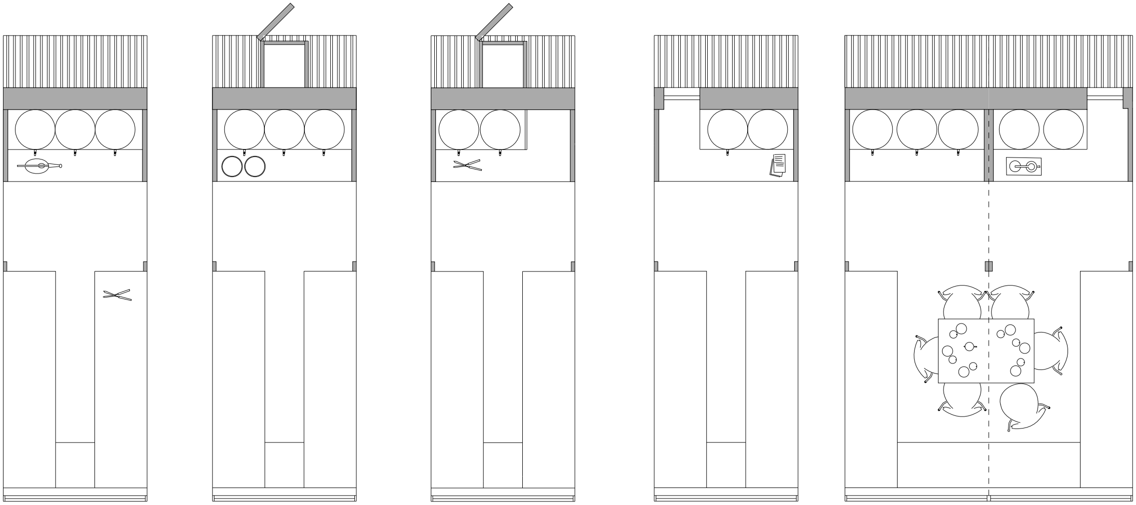


ENTRANCE SINGLE MODULE

ENTRANCE DOUBLE MODULE

EDGE MODULE

DECK MODULE



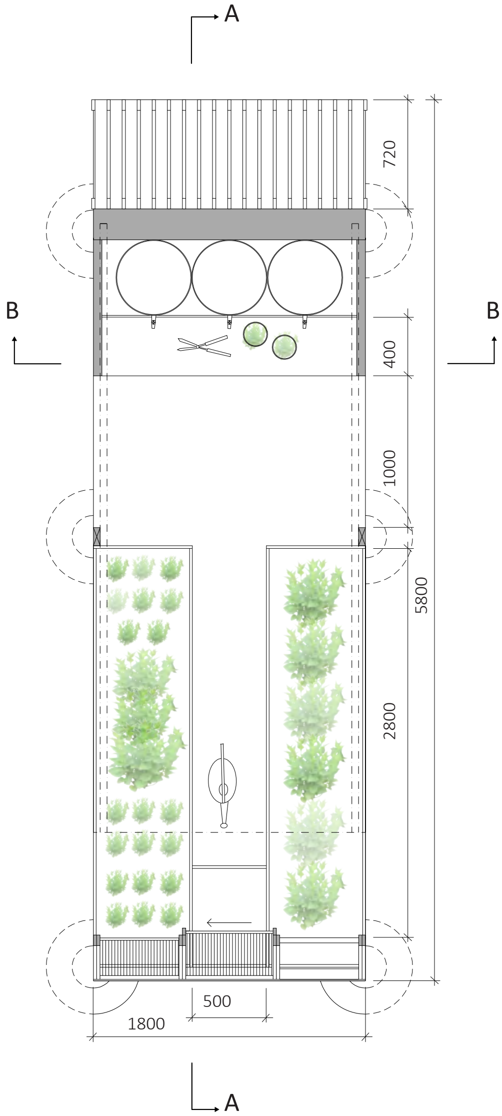
GROWING BEDS 9 BARRELS COUNTERTOP

GROWING BEDS 9 BARRELS STORAGE

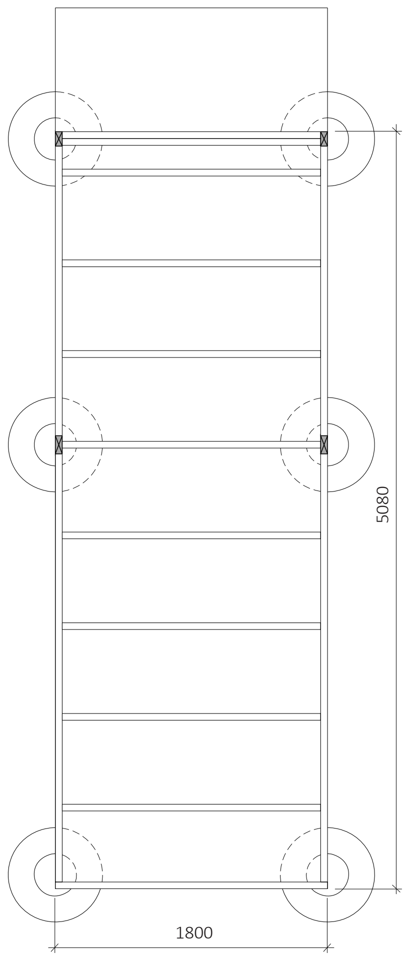
GROWING BEDS 6 BARRELS STORAGE

GROWING BEDS 6 BARRELS WINDOW

RELAXING 6 BARRELS WINDOW



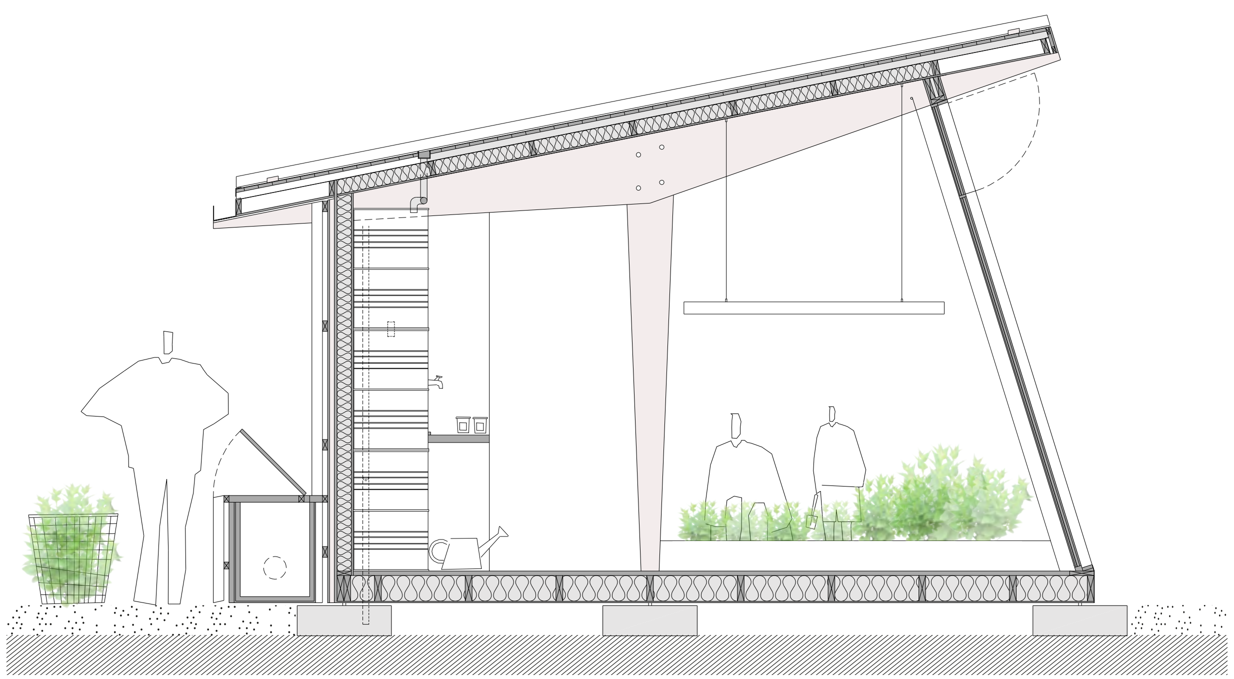
MODULE
PLAN 1:50



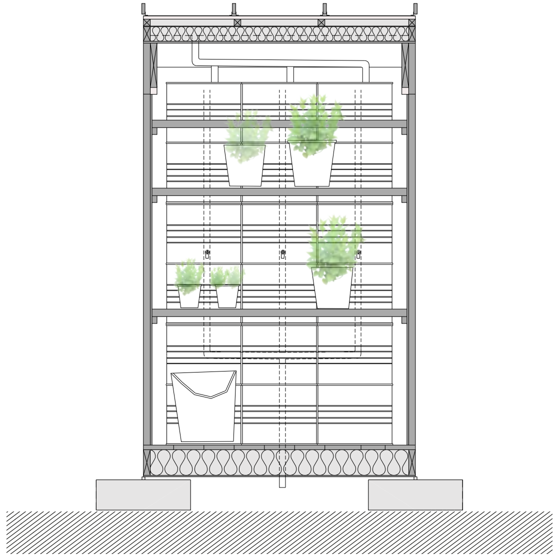
MODULE
FOUNDATION PLAN 1:50

THE STANDARD MODULE

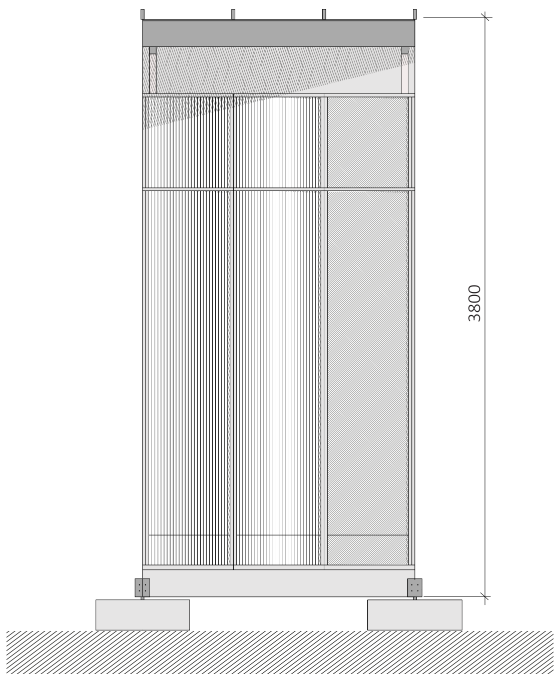
All measurements in mm



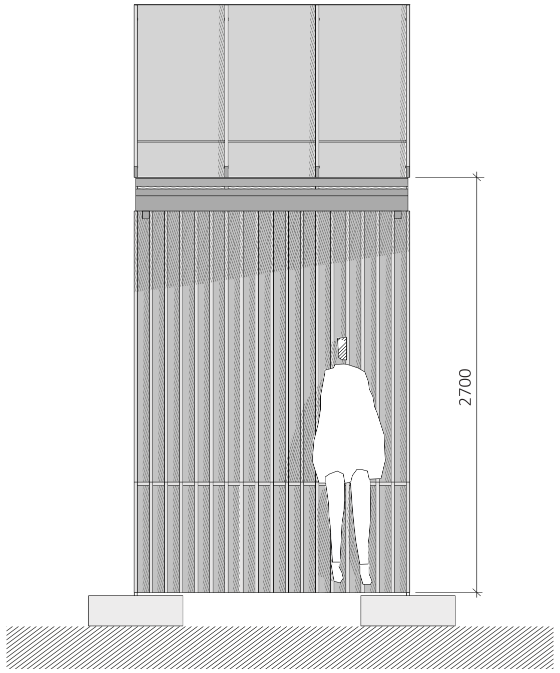
MODULE
A-A SECTION 1:50
SCALED FROM 1:20



MODULE
B-B SECTION 1:50
SCALED FROM 1:20

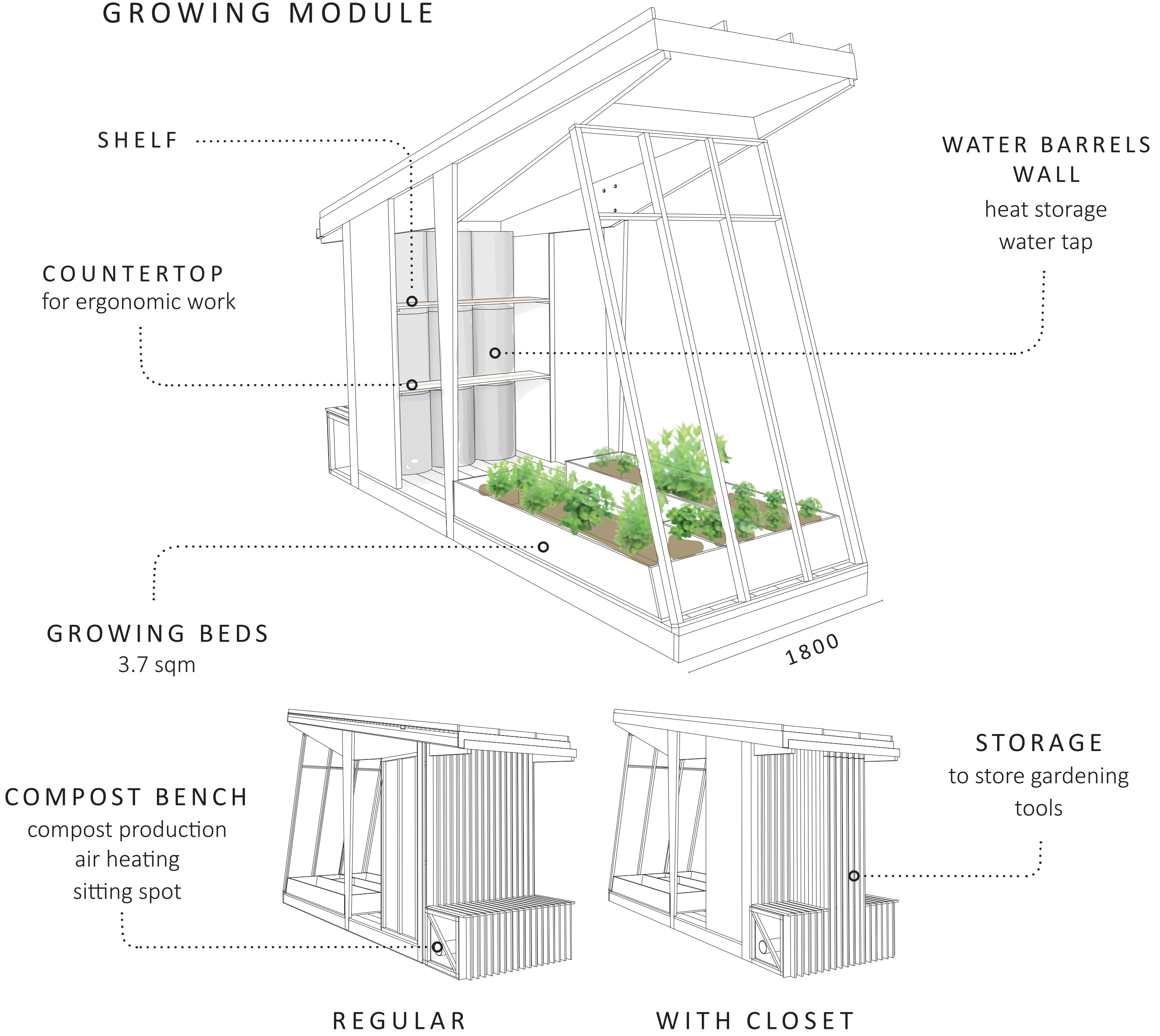


MODULE
SOUTH ELEVATION 1:50

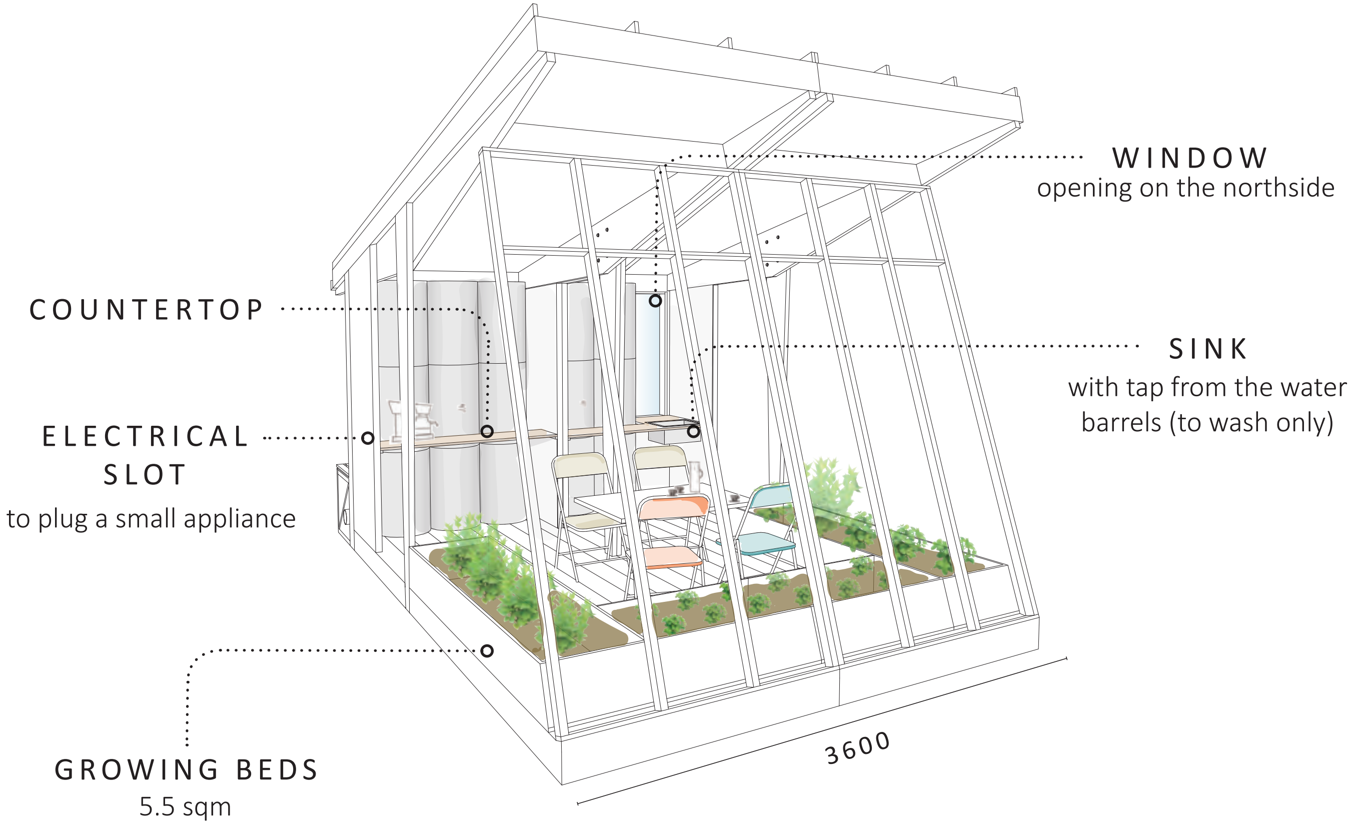


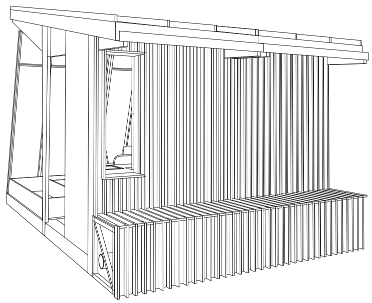
MODULE
NORTH ELEVATION 1:50

GROWING MODULE



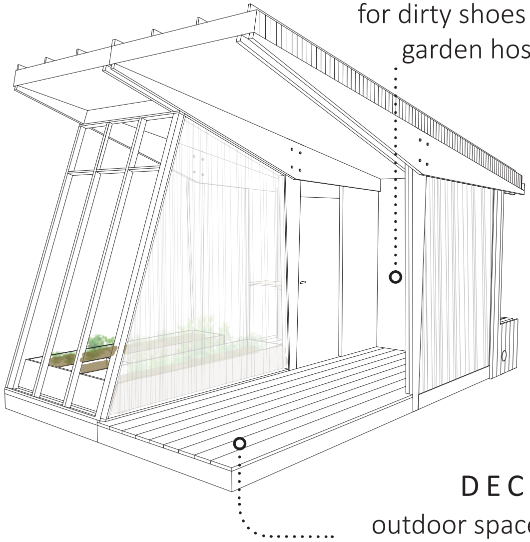
MEETING MODULE





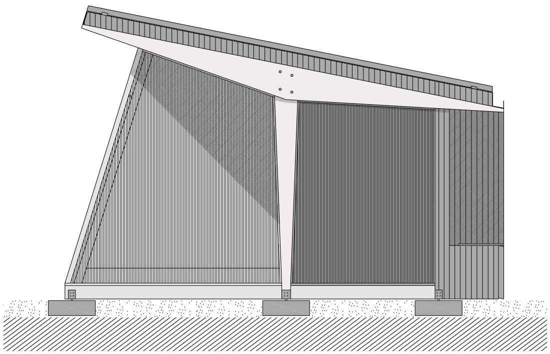
VIEW FROM THE NORTH SIDE

ENTRANCE MODULES

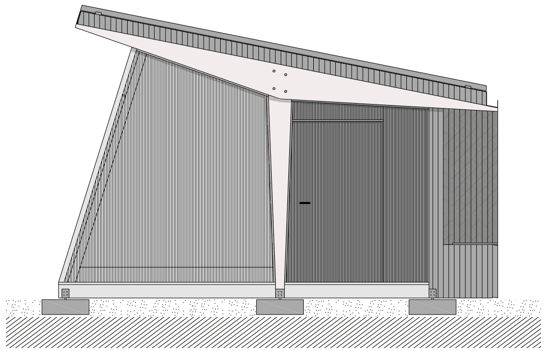


STORAGE
for dirty shoes or outfits, garden hose, etc.

DECK
outdoor space to relax when the weather is nice or to grow in pots

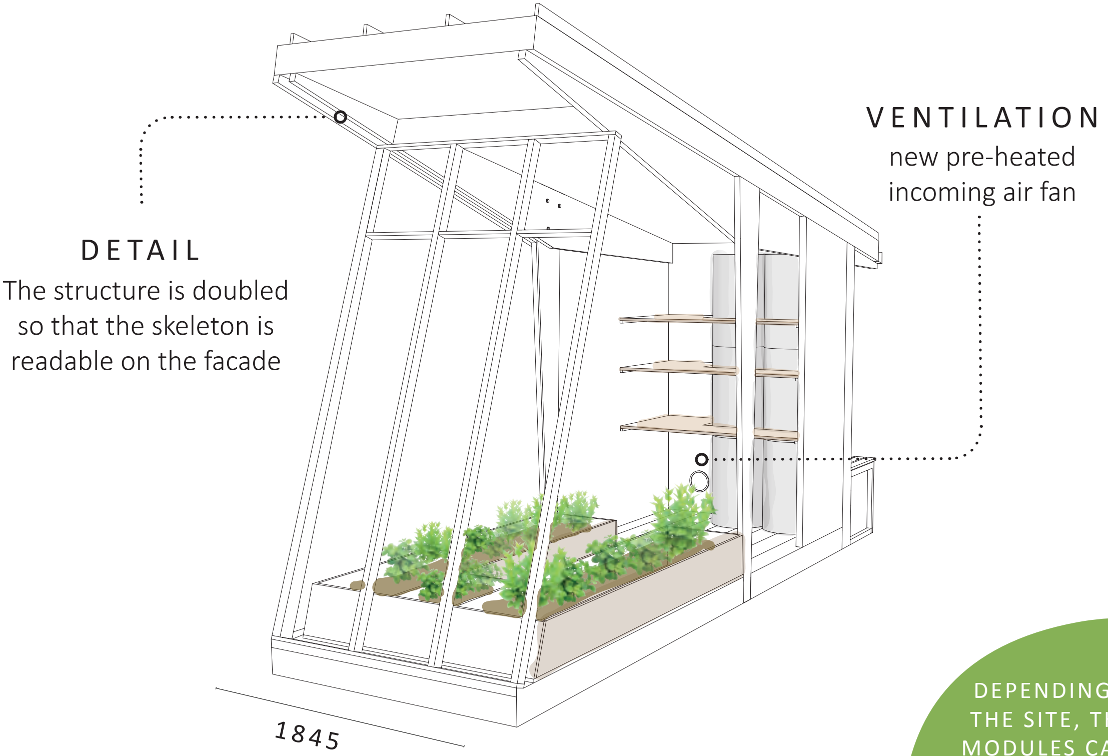


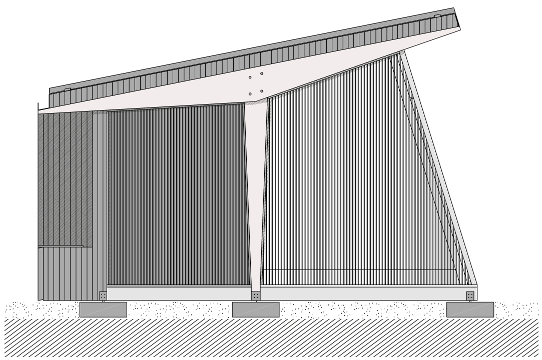
TWO-MODULES ENTRANCE WITH A COVERED DECK



ONE-MODULE ENTRANCE

SIDE MODULES





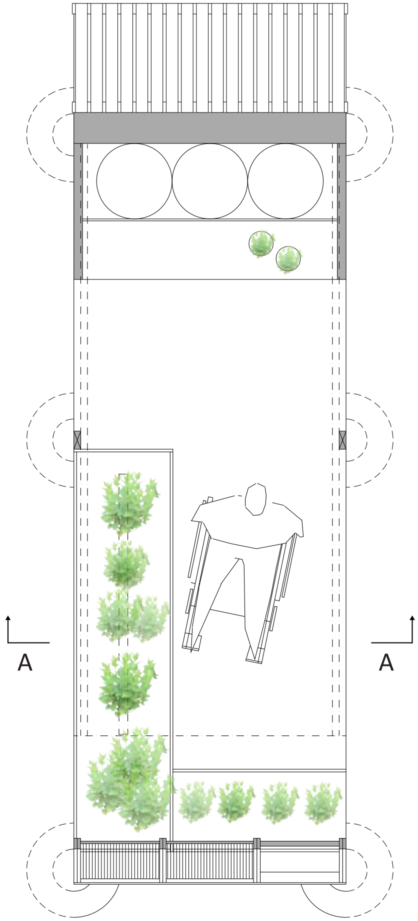
DEPENDING ON THE SITE, THESE MODULES CAN BE PLACED ON THE WEST OR EAST EDGES

ACCESSIBILITY

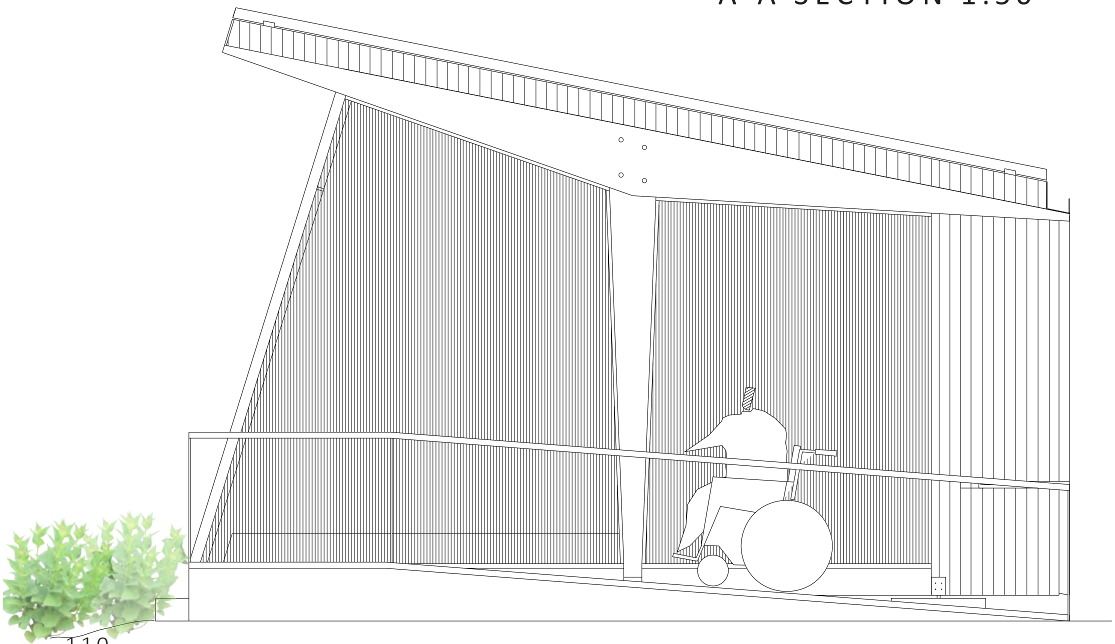
The basic design of the greenhouse is accessible. A person in a wheelchair can grow in the greenhouse with raised growing beds, as shown below.

The entrance of the greenhouse can be supplied with a ramp, depending on the needs and the surrounding landscape.

A-A SECTION 1:50



PLAN 1:50

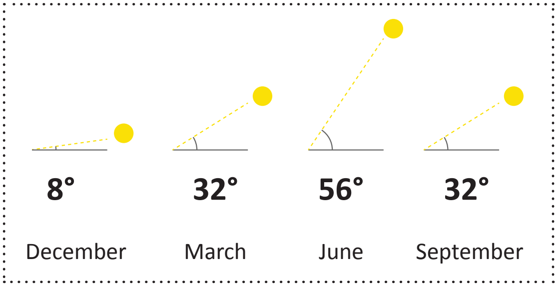


VIEW EAST ENTRANCE 1:50

A SMART BUILDING

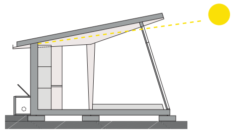
SHAPED BY THE LOCAL CONDITIONS

The shape of the greenhouse is adapted to the climate and location of Gothenburg. Following design principles of cold climate solar greenhouses[1], Go City Grow has only one glazed facade oriented towards the south and the glazing is inclined according to the altitude of the winter sun. The other facades are opaque and insulated to limitate heat losses. By the design itself, the growing period is extended and the greenhouse can keep a temperature above zero all year around.

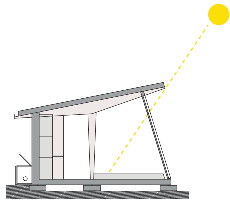


SUN ANGLES DURING THE YEAR IN GOTHENBURG
source: www. http://solarelectricityhandbook.com/

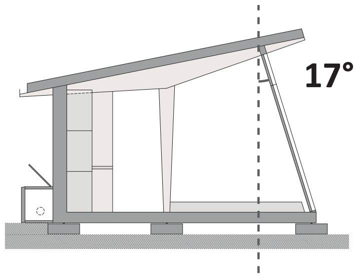
1 After studying the *Cold Climate Greenhouse Resource Guide* and reading many blogs or watching videos of personal experiences from farmers of the Mid-West of the U.S.A, it appears that greenhouses designed for cold climate usually have only one glazed facade and insulated roof and north wall. These greenhouses are often attached to the back of an existing house.



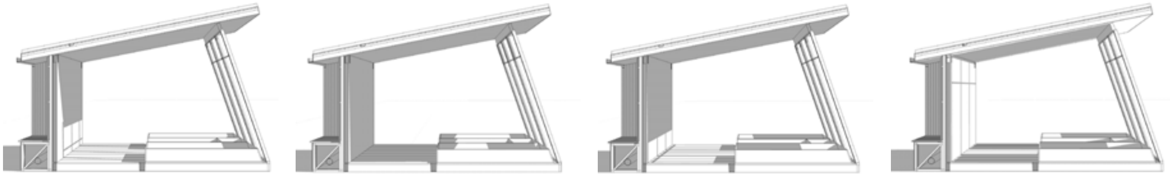
Winter sun: goes all the way to the back of the greenhouse and reaches the water barrels that capture solar heat more efficiently.



Summer sun: the roof extension of the greenhouse blocks the sun from radiating too far and the direct sun light is oriented toward the growing beds.



We decided upon a glazing inclined by 17° from the vertical, median angle between the sun angle of December and the one of March. The design is therefore optimized to get better solar heat during winter. This choice was also made for aesthetics reasons.



March June September December

ANALYSIS OF SHADOWS IN THE GREENHOUSE
MADE WITH A GEO-LOCALISATION TOOL IN GOOGLE SKETCHUP

Even if Go City Grow is inspired by cold climate solar greenhouses from the mid-west of the United States, the design can't follow all design principles as the climate is not the same in Gothenburg and for example in Winsconsin.

The two tables to the right show climate data about Gothenburg (Sweden) and Minneapolis (WN, USA). Striking is the difference of daylight hours in winter and fall and the average percentage of sunny daylight hours for the same period. It helps to understand how solar greenhouses in the US, even if the temperatures are much colder, can provide sufficient conditions to grow crops using the sun. In Gothenburg, with less sun, it might not be relevant to rely on the sun as a resource. We took these observations into account when deciding upon operation solutions.

WEATHER DATA FOR GOTHENBURG, SWEDEN

	J	F	M	A	M	J	J	A	S	O	N	D
Average Temp. °C	-1	-2	1	6	12	16	18	17	13	9	5	2
Average Prec. mm	51	34	29	39	34	54	86	84	75	65	62	57
Nr. of Wet Days	15	12	10	12	10	12	14	14	16	15	16	17
Average Daylight H/ Day	7	9	12	14	16	18	18	15	13	10	8	6
% of Sunny Daylight Hrs	22	30	42	48	54	54	54	53	48	35	21	15

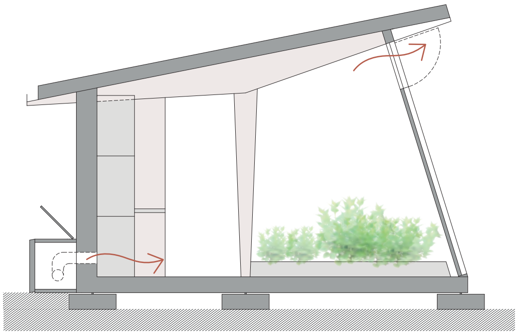
WEATHER DATA FOR MINNEAPOLIS, WISCONSIN, USA

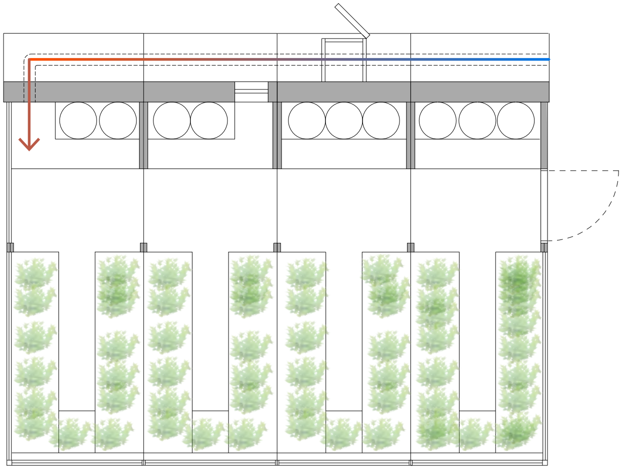
	J	F	M	A	M	J	J	A	S	O	N	D
Average Temp. °C	-11	-8	-1	8	15	20	23	21	16	9	1	-8
Average Prec. mm	24	22	49	62	86	103	90	92	69	56	39	27
Nr. of Wet Days	8	7	10	9	11	12	10	10	9	8	8	8
Average Daylight H/ Day	9	10	12	13	15	16	15	14	12	11	10	9
% of Sunny Daylight Hrs	48	59	54	55	56	60	67	64	62	61	45	44

Source: www.climatemps.com

OPERATION SOLUTIONS

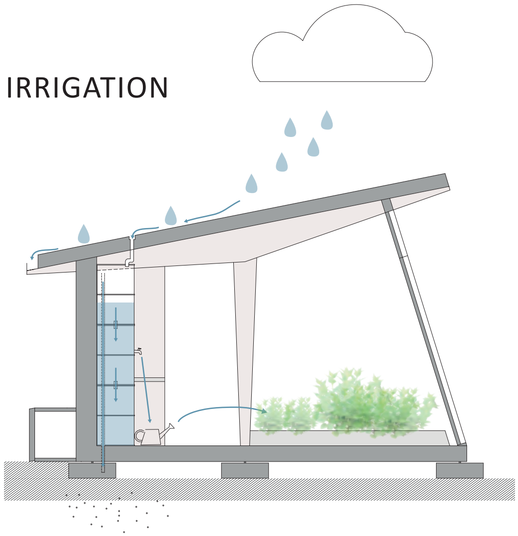
VENTILATION





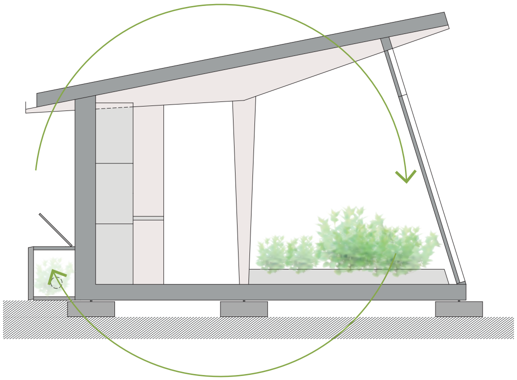
Natural ventilation
Openings in south facade
Pipe running through compost heating the air

IRRIGATION



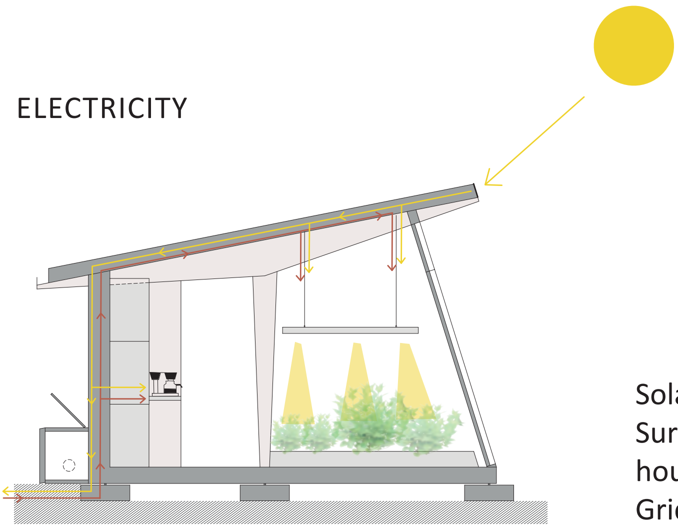
Rainwater collection for irrigation
Local drainage with gravel
Water as thermal mass

NUTRIENT SUPPLY



Compost for nutrition
Organic waste = worm compost
Takes care of households food waste

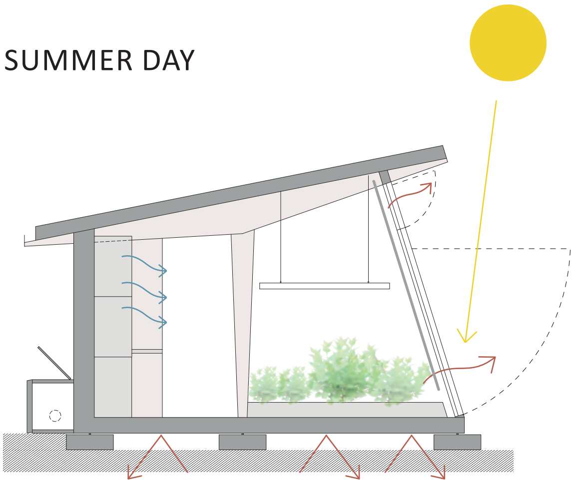
ELECTRICITY



Solar panels for electricity
Surplus electricity sent to surrounding houses
Grid provides electricity if needed

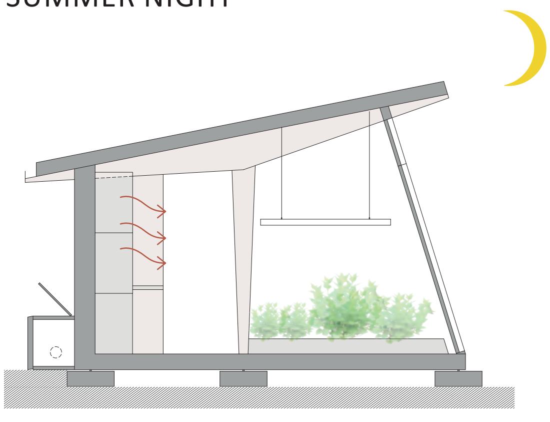
SUMMER VS. WINTER

SUMMER DAY



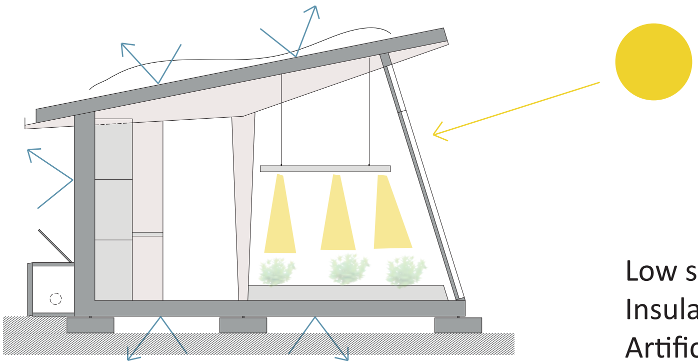
High sun
Natural ventilation
Insulation keeps heat from ground
Thermal mass regulates temperature
Curtain for shadow

SUMMER NIGHT



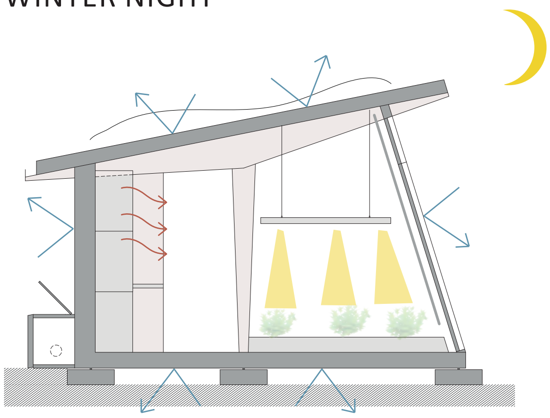
Thermal mass regulates temperature

WINTER DAY



Low sun
Insulation keeps cold out
Artificial light

WINTER NIGHT



Insulation keeps cold out
Curtain keep cold out
Thermal mass regulates temperature
Artificial light

TO HEAT OR NOT TO HEAT, THAT IS THE QUESTION

Along the design process, we have been questioning the purpose of the greenhouse; how should people use it and what kind of benefits would people gain from the greenhouse. If the ultimate aim of this object is to raise awareness about the food cycles and to change people's consumption habits concerning food, then the greenhouse should make them aware of the seasons and relate seasons to their food. In that case, the greenhouse should not be heated in winter.

Another reflection is to state that the ultimate purpose of the greenhouse is to bring people together around a hands-on activity and encourage them to share, learn from each other, as community gardens are known for. In this case, the greenhouse can be heated in winter because it can be a good space to relax outside of home without consuming, when you cannot relax outside.

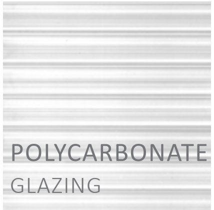
What is more important here: to design a sustainable building that, at the furthest extent possible, will save energy and have a low environmental impact, or does the aim rather stand in encouraging behavioural change and community building? These questions are important for the actual design and our belief is that the social benefits of such a greenhouse are the larger ones. Gardening is a meaningful hobby and sharing a space is the best way to bring people together. Growing vegetables at home can teach kids where their food comes from and influence their future lifestyles.

Designing an energy efficient and sustainable building is significant concerning the state of the world, but the vision of sustainablity in architecture is complex. We think that consuming energy to operate the greenhouse all year around , with stategies to lower the energy consumption, can be relevant as there are social benefits. We would like the users to decide if their greenhouse should be heated in winter or not, depending on the context. Therefore, Go City Grow provides the possibilities to connect to a heating system, but will keep its temperature above 0 degrees in any case, thanks to insulation and vernacular systems of regulating the temperature.

MATERIALS, DETAILS AND ASSEMBLY

MATERIALS

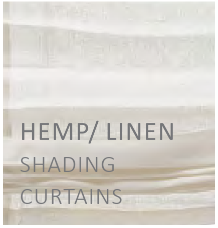
+ durable
+ improved greenhouse effect in winter and UV protection in summer
+ little insulation capacity if used as double layered
- heavy
- costly



+ UV resistant
+ insulating
+ light
+ easy to mount and seal
- lasts only 10 years
- high embodied energy
- made from petrol

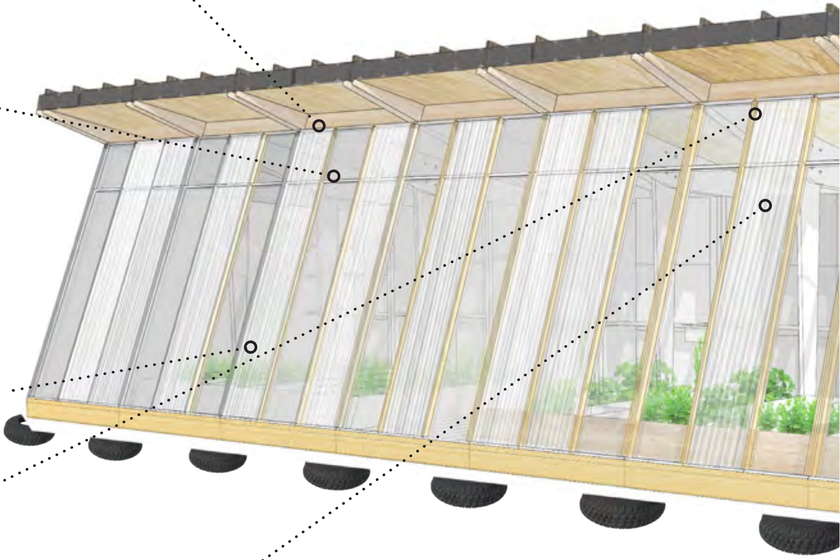
TIRES
FOUNDATIONS

+ cheap
+ re-used
+ can cushion the building and adjust to the terrain
- made from petrolean resource



+ natural material
+ very cheap
- not sourced locally
- will be altered quickly

+ cheap
+ re-used
+ can be re-used after disassembly
+ highest thermal resistance among thermal mass materials
+ can be combined with rainwater collection
+ easy to install
- made of plastic or metal



ASSESSMENT

Materials for the different parts in the building where assessed through criteria such as moisture behavior, cost etc.

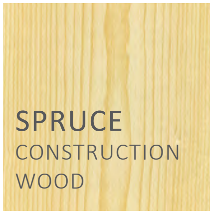
GLAZING
ROOF
FRAME
FOUNDATIONS
INSULATION
CLADDING (int, ext)

comparison between different materials

+ much lower embodied energy than steel
+ easiest way to make the profile shape out of wood
+ fire safe and resistant
+ can be sourced and manufactured in Sweden

+ low embodied energy
+ no chemical treatment
+ sourced in Sweden
+ re-usable after disassembly if panels are screwed in the structure
- takes a long time to build

+ supports agriculture
+ hemp grows very fast
+ naturally moisture resist-ant
+ biodegradable
+ very low embodied energy
+ “CO2 negative”
+ non-toxic



+ low embodied energy
+ made from a renewable resource
+ cost efficient (standard sizes)
+ easy to assemble
+ can be re-used after disposal if screwed

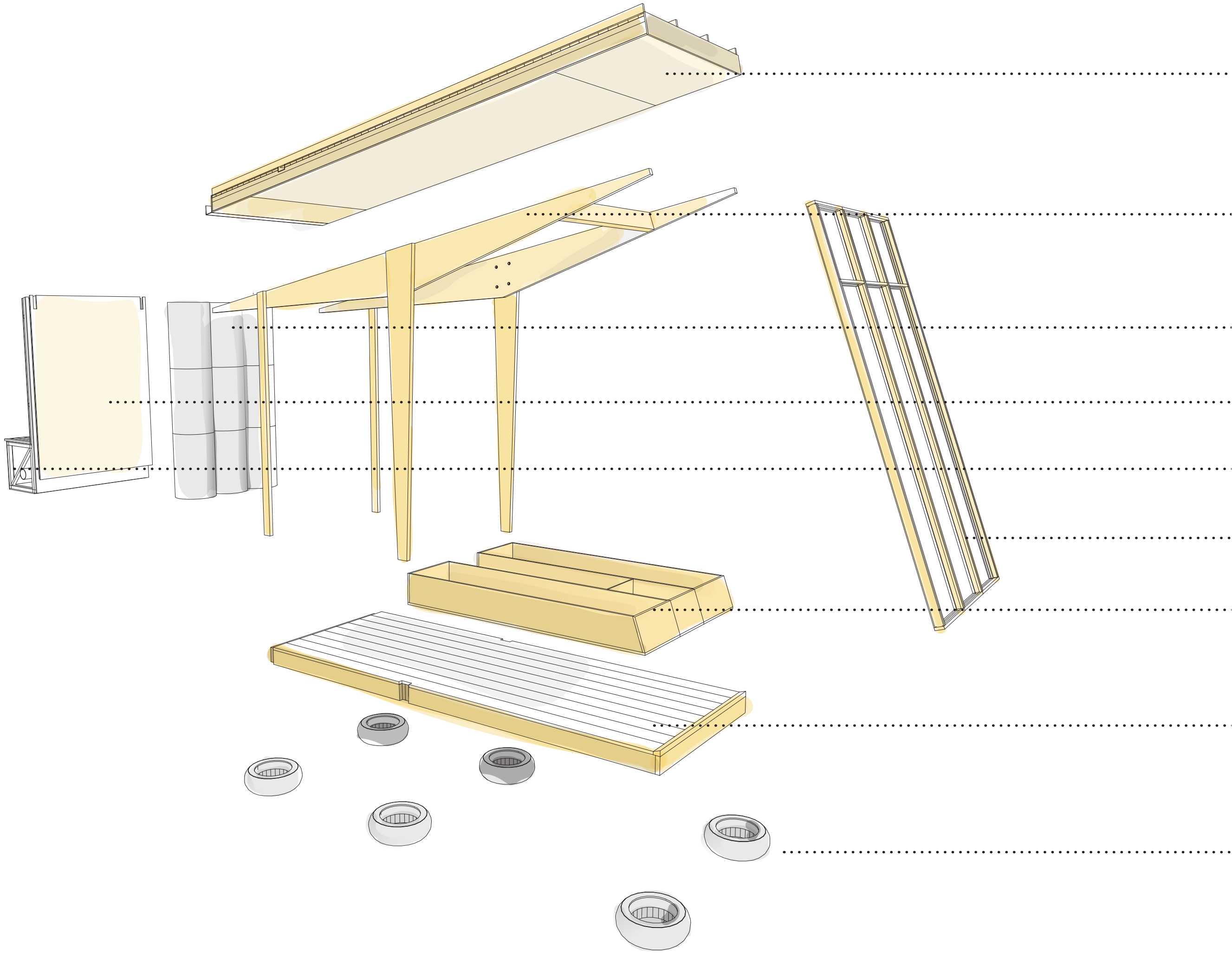
+ made of 95% wood
+ resins are moisture resistant
+ delivered in standard size sheets adapted to our module
- not locally sourced (America)
- binded with chemical resins

CRITERIA

moisture behavior
insulating capacity
environmental impact
cost
aesthetics

source
emissions
disposal

DETAILS



INSULATED ROOF P.131

TIMBER FRAME P.128

WATER BARRELS P.133

INSULATED NORTHERN FACADE P.130

AIR HEATING, COMPOST SUPPLY BENCH P.130

GLAZED SOUTHERN FACADE P.129

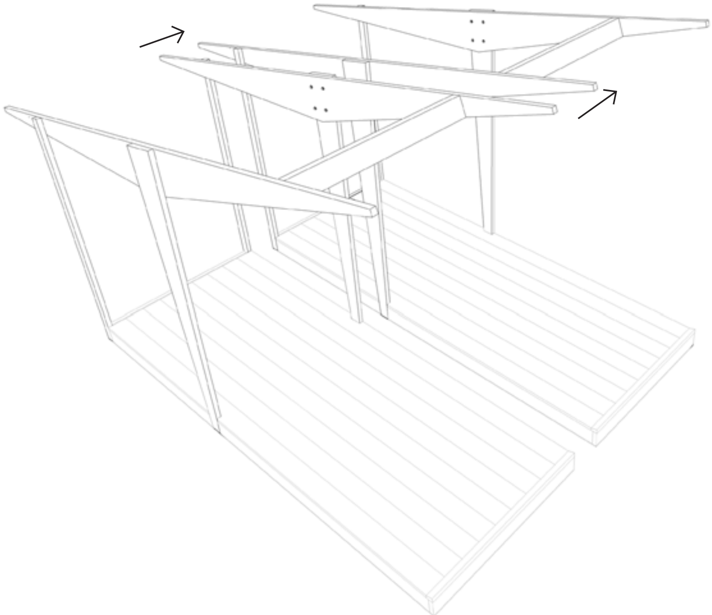
WOODEN FRAME GROWING BED P.134

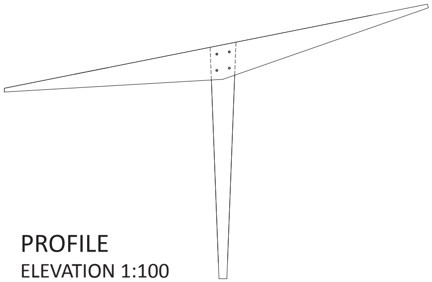
INSULATED FLOOR P.132

FOUNDATIONS P.132

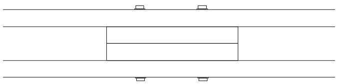
STRUCTURAL FRAME

Each module of the greenhouse has its own frame. It is designed like half-pilars and half-beams that are connected together when two modules are assembled.





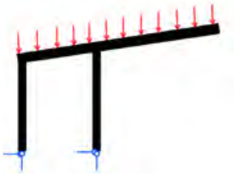
PROFILE
ELEVATION 1:100



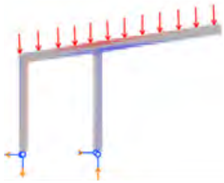
DETAIL
PLAN 1:20

LOAD BEARING SIMULATION

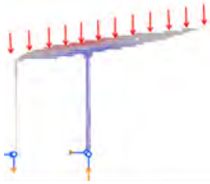
TO OPTIMIZE THE BEAM'S PROFILE
simulation made with ForcePad2



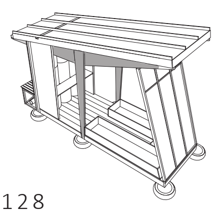
Application of force and contraints



Results of the simulation

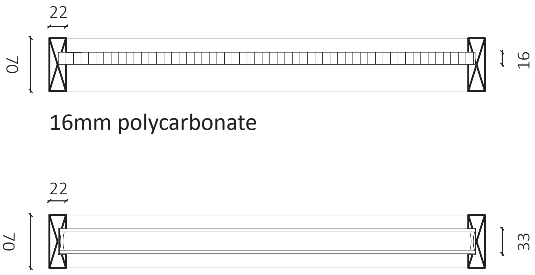


Proposed optimization of profile



GLAZED SOUTHERN FACADE

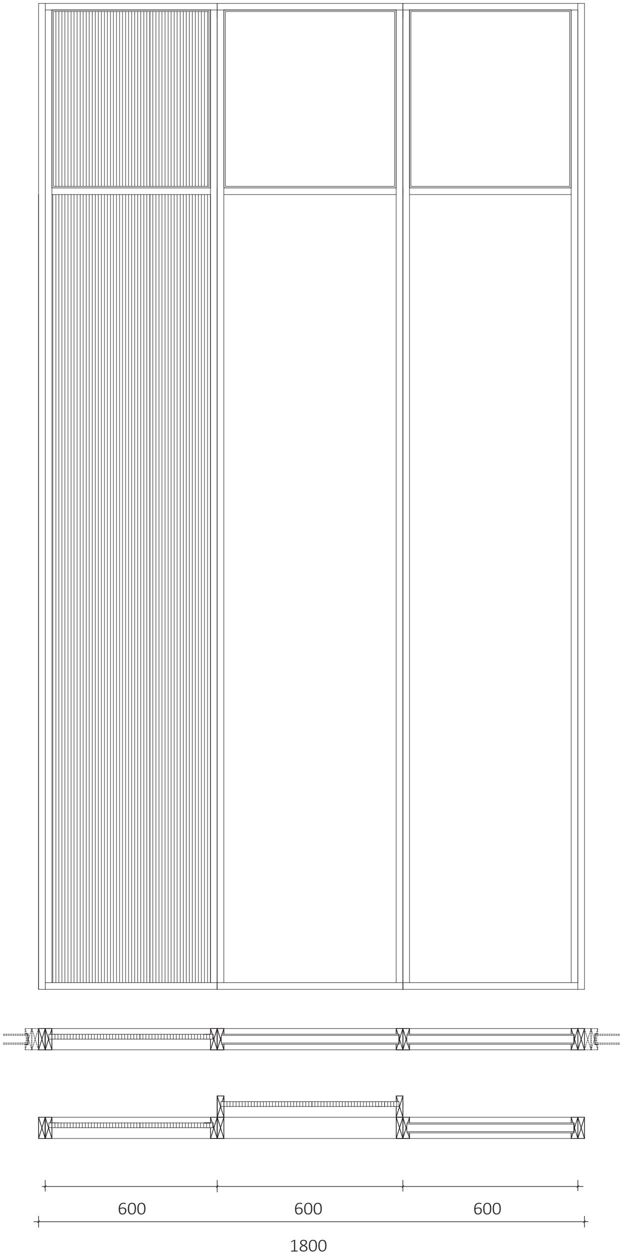
To balance the cost, create interesting rythms in patterns on the southern facade, one can choose between polycarbonate or glass panels. Each module contains three independant panels attached to the frame on top and the floor module at the bottom.



16mm polycarbonate

33mm double layered energy glass

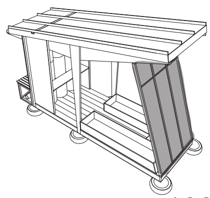
GLAZING FRAMES DETAIL
PLAN 1:10



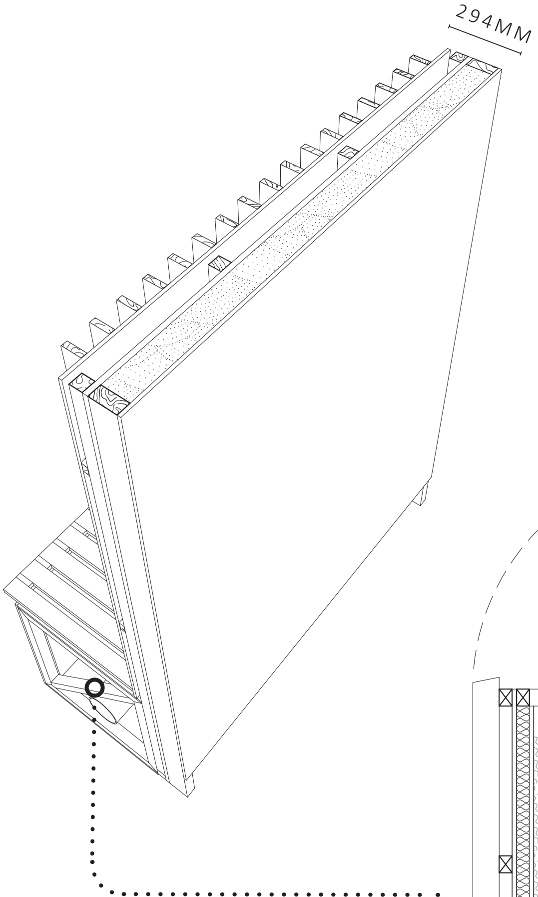
GLAZED FACADE OF ONE MODULE
PLANS AND ELEVATION 1:33

normal configuration

sliding door configuration

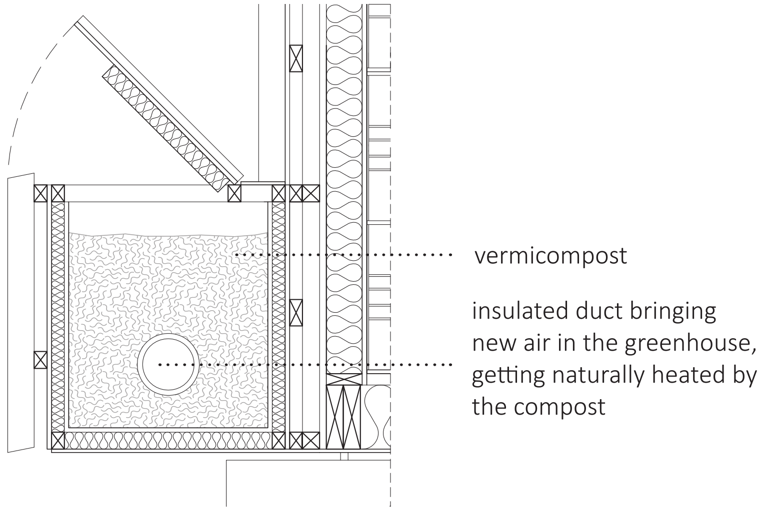


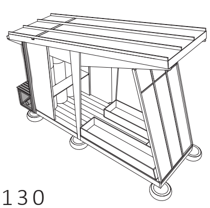
INSULATED NORTHERN WALL



WALL COMPOSITION

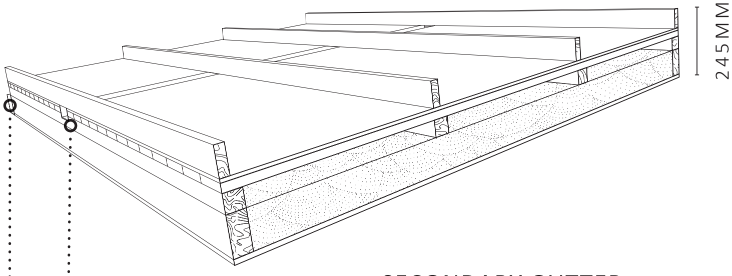
- 70 Exterior Finishing:
  Wooden panel 22*70
- 15 Black coated Plywood
- 22 Horizontal Lath 22*45
- 45 Vertical Stud 45*45
- 35 Asphalt Impregnated Fiber Board
- 95 Hemp Insulation + Pilars
- 12 White Coated OSB Panel





COMPOST BENCH DETAIL
SECTION 1:20

INSULATED ROOF



SECONDARY GUTTER
for rainwater collection
in the water barrels walls

INTEGRATED GUTTER

ROOF COMPOSITION

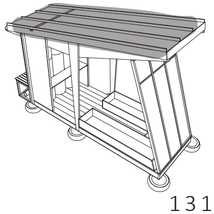
- 70 Decorative Panel
  Wooden panel 22x70
- Roofing Felt (Asphalt)
- 22 Horizontal Lath 22x45
- 45 Vertical Stud 45x45
  Hemp Insulation
- 95 Joists 95x45
  Hemp Insulation
- 12 White Coated OSB Panel

SOLAR PANELS

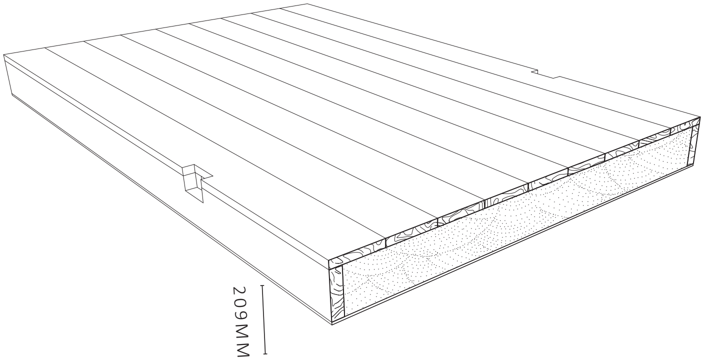
In winter, electricity is needed to power LED lamps 16h a day, and to power a small appliance. This represents, for one module, a consumption of ~1KWh per day. Solar cells on the edge of the roof could supply one tenth of this consumption minimum*. This is far from fully sustaining the greenhouse all year around in electricity, but can help reducing the bill and sustain the greenhouse in summertime at least.

*According to energymatters.com.au, powering 6 LED lamps of 10W each during 16h would require 0.915 kWh. 0,32sqm of solar cells could produce 0,1 KWh per day in bad weather conditions (2KWh in optimal conditions).

AVAILABLE SURFACE OF 0,32 SQM FOR SOLAR CELLS APPLICATION.
This surface could provide minimum 0,1KWh, maximum 2KWh/day/module. *



INSULATED FLOOR

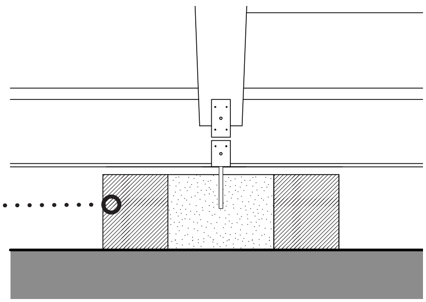


FLOOR COMPOSITION

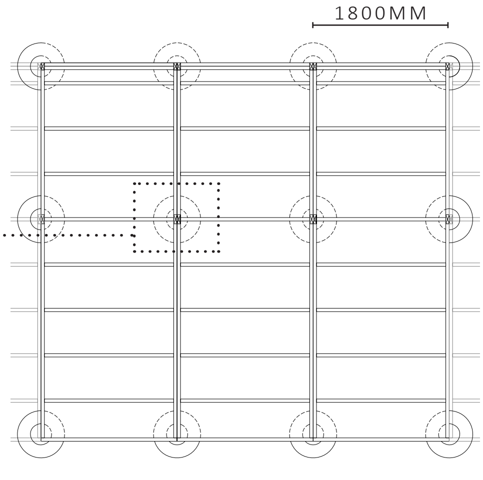
30 Hardwood Flooring
170 Joists + Hemp Insulation
9 Masonite
Impermeability layer

FOUNDATIONS

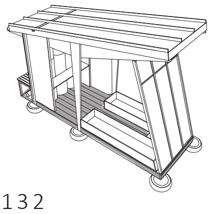
TIRE FILLED WITH CONCRETE:
∅600MM
HEIGHT:200MM



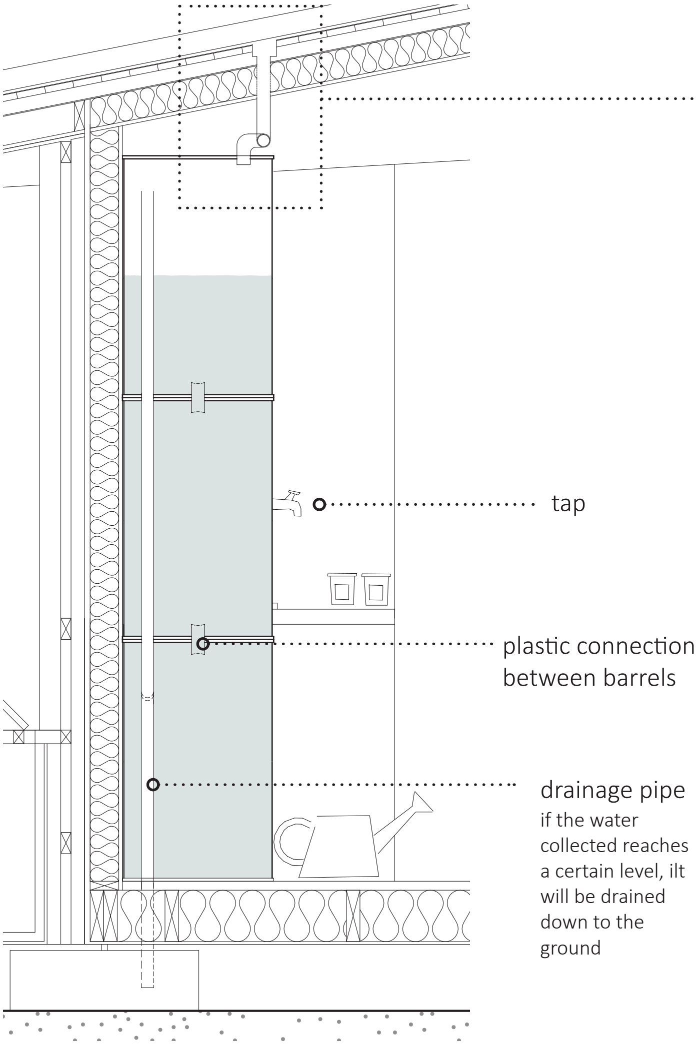
PILAR-FLOOR-FOUNDATION
CONNECTION DETAIL
SECTION 1:20



FOUNDATION PLAN:
FLOOR STRUCTURE AND PILARS ATTACHED TO TIRES
SCALE 1:100

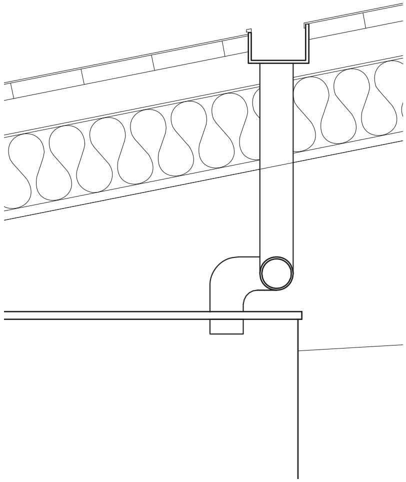


RAINWATER COLLECTION: WATER BARRELS

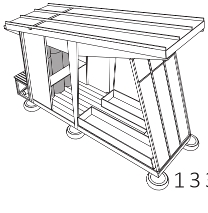


RAINWATER COLLECTION AND DRAINAGE SYSTEM IN WATER BARRELS
SECTION 1:25

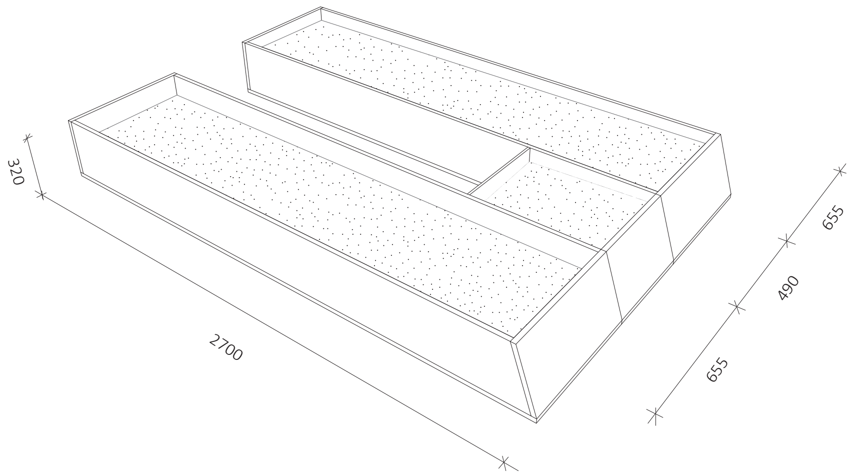
GUTTER FOR RAINWATER COLLECTION, CONNECTED TO THE BARRELS
SECTION 1:10



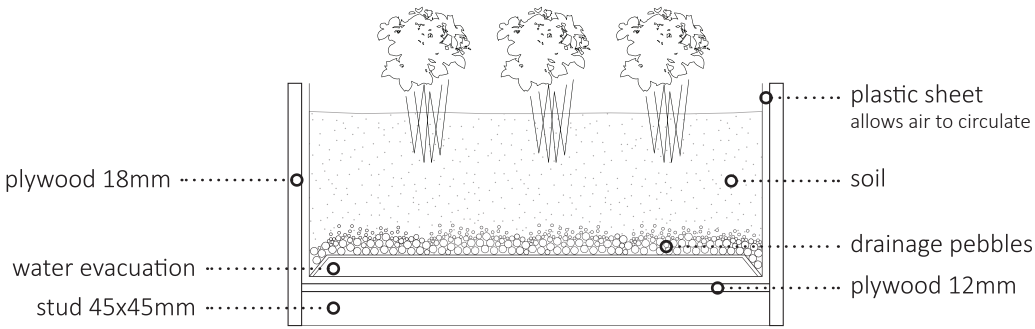
Water is collected from the roof because we want the system to be visible from the interior space, to make users aware that they use rainwater.



WOODEN FRAME GROWING BED

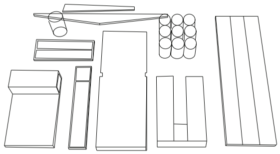


The growing beds are integrated in the design. Since water cannot be drained out of the greenhouse, there is a built-in system for water to be collected down in the bed. The growing bed works like a pot.

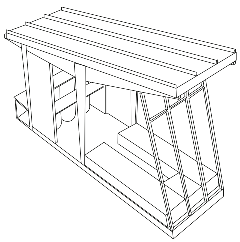


GROWING BED SCHEMATICAL SECTION

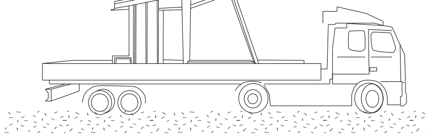
CONSTRUCTION & ASSEMBLY



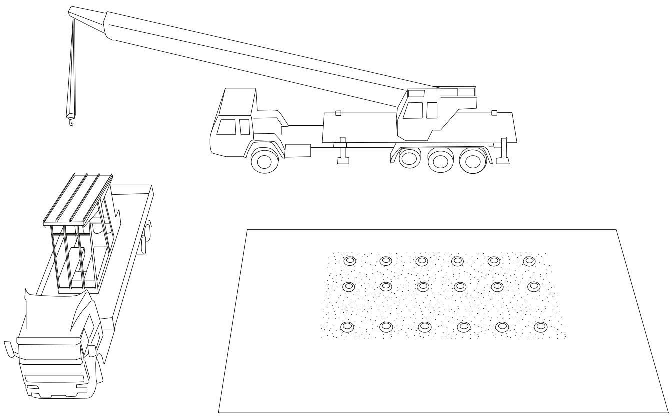
Elements (floor, roof, wall, glazing frames, growing beds modules) are built separately in a factory.



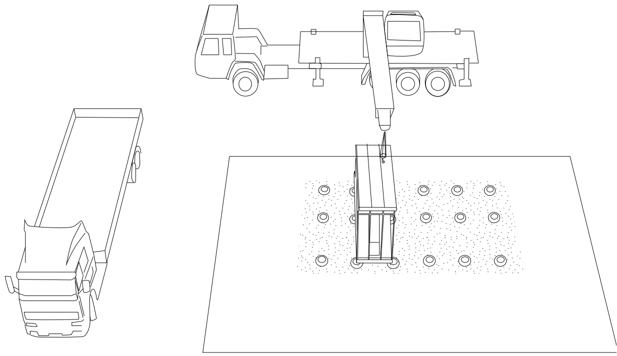
Elements are assembled and the greenhouse module is built



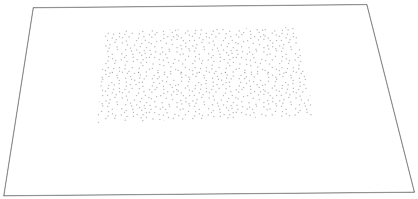
The modules are transported to the site by truck



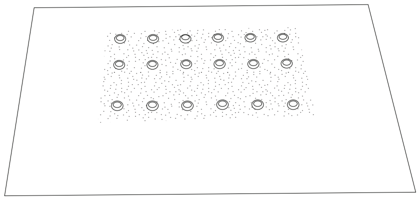
A crane takes the module...



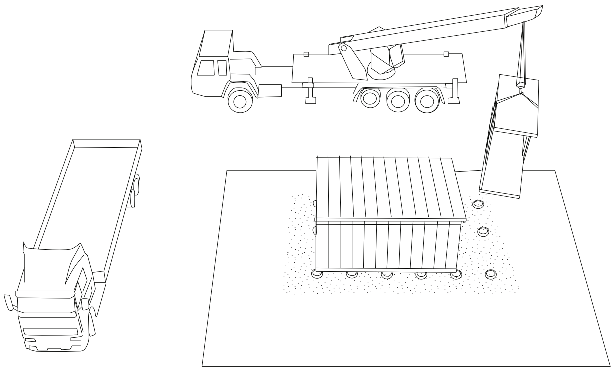
...and places it on its foundations.



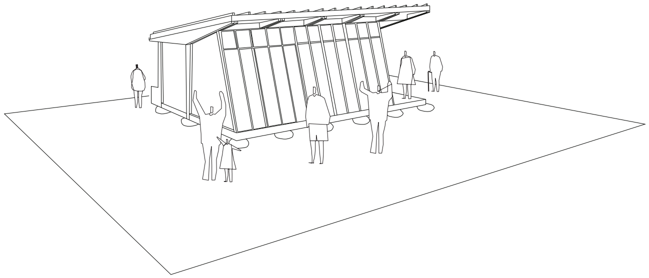
The site is prepared for the placement of foundations



Foundations are installed at the right location



Modules are placed, bolted together very fast. The crane is only needed for one or two days.



The greenhouse is built, people can enjoy it!

IMPLEMENTATION: HSB LIVING LAB

CAMPUS JOHANNEBERG, GÖTEBORG, SWEDEN

At the origin of this master's thesis is Sara Renström, PhD student at the department of Design and Human Factors at Chalmers University of Technology, working on innovative ways of using district heating in Gothenburg's dwellings.

In her work, she proposes new products that would make people have a more efficient and interactive use of their heating system: radiators, smart phone apps, but also greenhouses for all year round production, heated by the city's district heating. Sara contacted us in the fall 2013 because she knew that we had interest for designing spaces for food production as a master's thesis, and was looking for architecture master's thesis students interested in developing this concept of heated, shared greenhouse.

Sara Renström may have the chance to test her research in real conditions by implementing her products in HSB's Living Lab, a research and demonstration pavilion that will be built on Johanneberg's campus in 2015. We think that this Living Lab represents a tremendous opportunity for new energy and social systems to be tested, that is why we decided to integrate an implementation of our design in the Living Lab in our master's thesis.

WHAT IS HSB LIVING LAB?

HSB Living Lab will be a student housing building of a new kind, since it will also be the host of tests in scale 1 to 1 for Chalmers' on-going research at different departments. It will be built within the campus area of Chalmers University of Technology, in Gothenburg.

The house is planned as a three storeys building of 400 m2, that will stay on the campus for ten years. One part of the building will contain student apartments and one part will contain common areas, where offices, meeting rooms, show room for research results and laundry room will be situated.

Research on the building will be both in shorter and longer terms during the building's lifetime. HSB[1] wants the overall design to give an innovative feeling of home and a holistic idea of housing. The perspective of sustainability is central in the research, therefore the exhibition area is essential; an arena for raising awareness for sustainable solutions. Different research projects will be tested at the same time as students actually live there. The subjects are wide: from new materials to measurements linked to the behaviour in

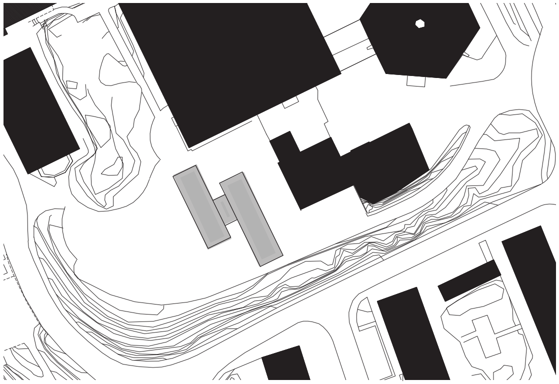
1. HSB is a Swedish housing company

the house. In HSB Living Lab, the tests are made in small, but real scale. The tested materials and methods for dwellings shall lead to increased quality on the building process and the dwellings in general (HSB, 2013).

The HSB Living Lab is a collaboration between HSB, Chalmers and Johanneberg Science Park. HSB aims to use the results from the research in the HSB production, both in new built dwellings and in their existing building stock. The Living Lab is also a way to increase collaboration with companies, researchers and students, as well as finding a model for temporary housing for young people and students. Sustainability is one of HSB's core values and the company wants to be at the forefront of the development of a sustainable housing sector (Johanneberg Science Park, 2014).

Currently, there is no final design for this Living Lab. Two master's students at MPDSD Program[1] made a proposal last semester, and their design is the proposal we based our implementation on.

Design Proposal for the Living Lab, Paul Balaÿ and Shea Hagy, MArch & MSc Design for Sustainable Development, Chalmers University of Technology, 2014.



Living Lab Site 1:2000 at Chalmers Campus Johanneberg, incl. proposal by Paul Balaÿ and Shea Hagy.

1. Shea Hagy, Paul Balaÿ, *Adaptable Design for the HSB Living Lab*, Master's Thesis at MPDSD Program, Chalmers University of Technology, 2014

A HEATED ALTERNATIVE OF GO CITY GROW IN THE LIVING LAB

We decided to propose an implementation of our greenhouse in the Living Lab because it is a very suitable case in different aspects. For us, designers of this greenhouse, it would be an opportunity to go from school to reality, as it was our dream in the beginning (see *Timeline for our Master's Thesis*, p.12). It would particularly be interesting to us to observe how people share, but also to test the performance of the building itself (materials, technical solutions, assembly process, etc).

Both social and energy systems could be tested, which are core aspects of both the living lab and our project. It would be a great place for observations since students are going to be the users: they are flexible, they can get direct financial benefits from growing vegetables at home, and it would increase the experience of sharing, a core concept of the Living Lab.

Implementing Go City Grow in the Living Lab would also be connected to other research areas like Sara Renström's work with the heating system, but also food waste related research for example. It can thrive the development of innovation by creating interactions within research.

As we discussed earlier about heating the greenhouses[1] or not, there is in the Living Lab an opportunity to test a heated alternative of our design in order to assess the benefits of heating in terms of production, socialization, etc. compared to the energy consumed.

Among energy sources available in the context of Gothenburg, district heating can be seen as a sustainable choice: since the system is already well settled, the connections are simple and the plants use a high percentage of sustainable resources to produce heat.

Solar energy to produce heat is not reliable in fall and winter in Gothenburg because the days of sunshine are too few. We have also thought of installing a boiler or biomass burning unit in the greenhouse. Considering cost and high maintenance, we do not consider this being suitable. District heating wouldn't require maintenance from the users, and can be easily controlled not to overheat, to be shut down when peaks of consumption happen (in winter) and would be combined with heat storage to save energy. Connections to the house's heating system and the city grid would be easily made, since the house would be built at the same time as the greenhouse.

1. see p. 112 of this booklet

Heating a greenhouse with district heating is not free of energy cost but it is a sustainable way of heating for the context of Göteborg if the house is newly built.

ABOUT DISTRICT HEATING IN GÖTEBORG

District heating is a heating system characterized by its scale of a town or city. Centralized heating plants provide heating for residential, commercial and office buildings. District heating is the major heating system in Gothenburg, settled in the city since 1952 and providing 90% of the houses of Gothenburg with heat and hot water. In Gothenburg district heating is produced by Göteborg Energi. The energy company produces heat in twelve plants and distributes it to the whole city and its suburbs[1]. Heat is produced in different ways: burning biomass, natural gas, household waste, but also by re-using waste heat from refineries and by electricity coming from renewable energy plants.

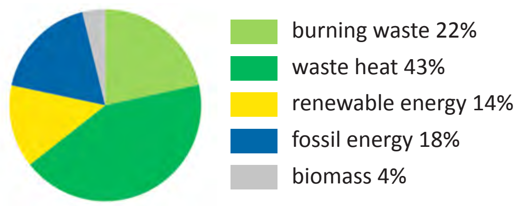


Diagram showing different types of resources used in Gothenburg
source:goteborgenergi.com

The technique is very simple: burning matter to produce heat that will heat huge amounts of pressurized water up to 100 degrees. This hot, pressurized water is then distributed to houses through a network of underground insulated pipes. The water used in the district heating system of Gothenburg is used in a closed loop. Once the hot water has heated the water of the house by a system of heat exchangers, the colder water goes back to the plants through a network of colder water pipes. The same water is heated again and again.

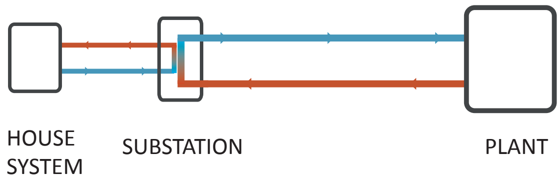


Diagram: from the plant to the house.

1. Information collected during an interview with G. Nilsson from Göteborg Energi, February 20th 2014.

LIVING LAB PROPOSAL

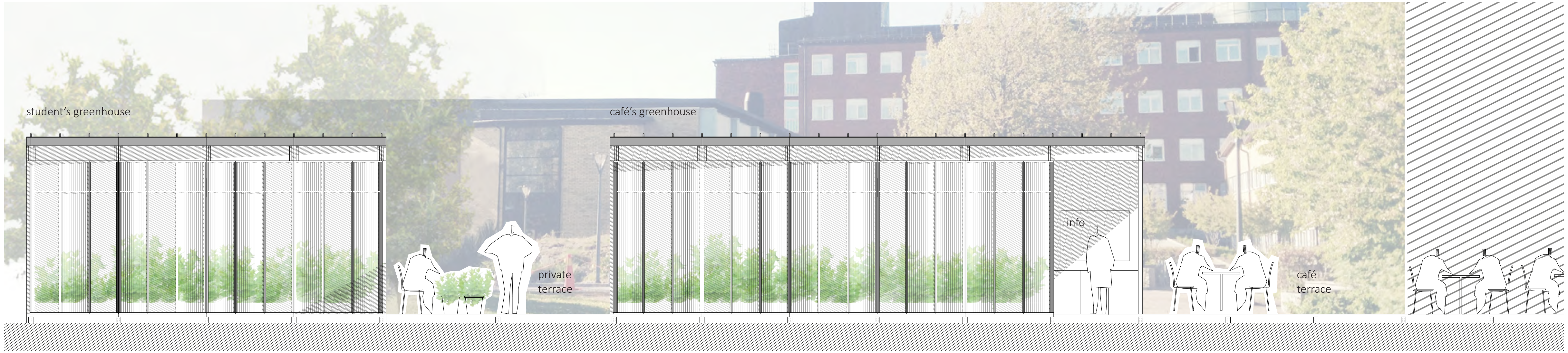
SITE PLAN
1:500

GREENHOUSES PLAN
1:100

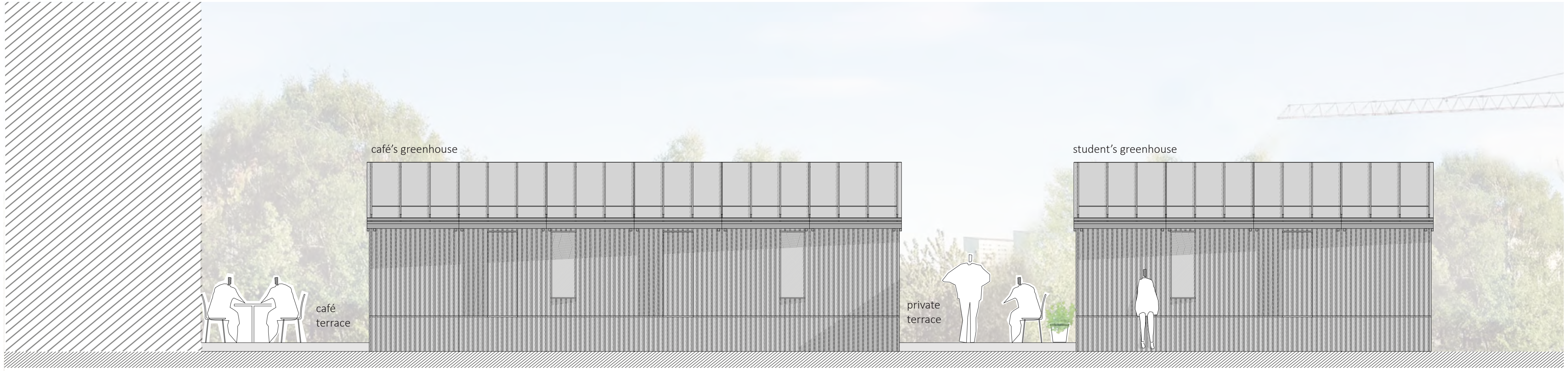
The Living Lab contains apartments for 20 students and different facilities such as common laundry room, storage, etc. To promote the research in the Living Lab, it also consists of an exhibition hall and a public café.

In this proposal for the Living Lab, the site has two greenhouses. One greenhouse belongs to the students, shared in a special way, explained more deeply further on. This greenhouse is for private use, for strengthening the feeling of community among the students. The second greenhouse belongs to the café. Here, herbs and salad are provided all year around and the café is selfsustaining in certain vegetables. This green living can inspire the visitors of the café to start their own growing.

Section A-A 1:100



South Elevation 1:100

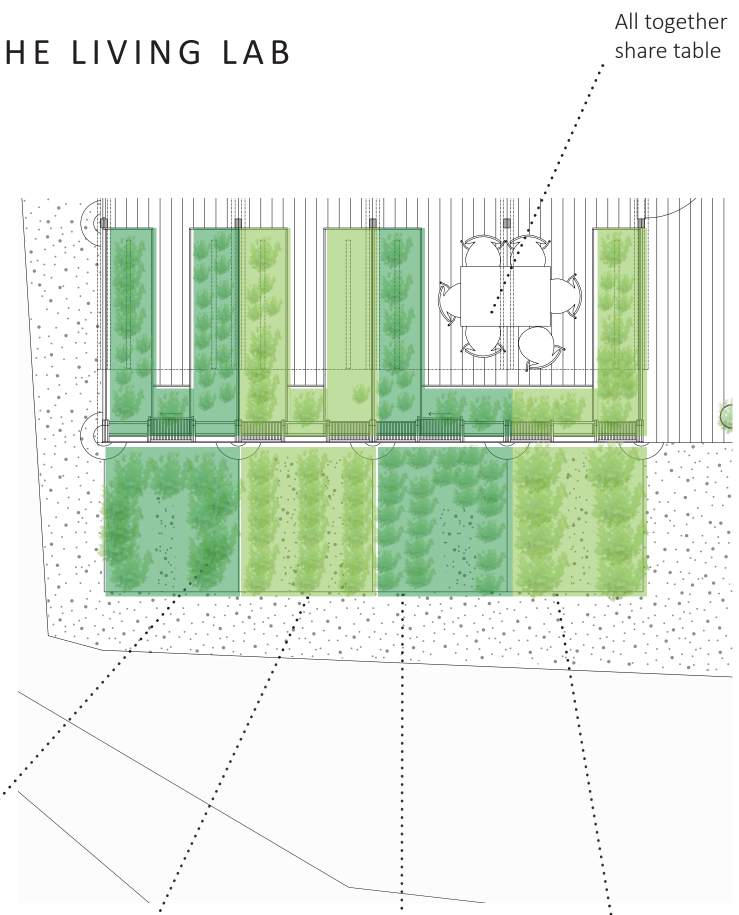


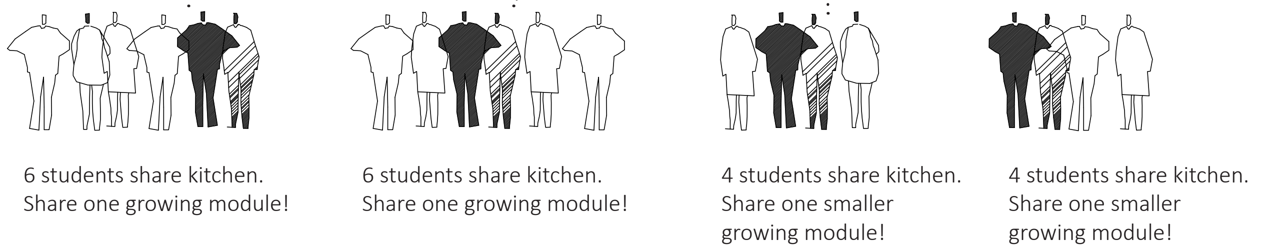
North Elevation 1:100

STUDENTS SHARE IN THE LIVING LAB

The students in the Living Lab have their own room and bathroom, and share kitchen with other students. There are 4 kitchens; 2 shared by 6 students, and 2 shared by 4 students. Each kitchen has one growing module in the greenhouse, and the students share their crops according to which kitchen they belong to. Each kitchen also shares an exterior garden where crops can grow in summer.

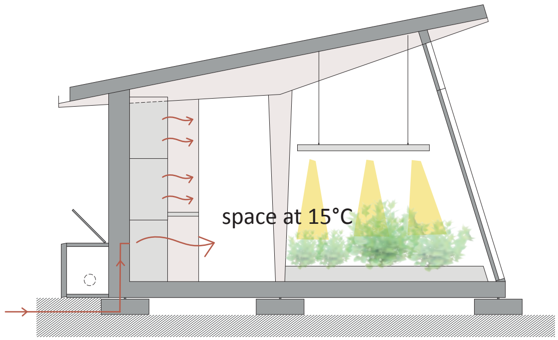
The greenhouse also hosts a table to gather for drinking coffee, learning from each other and socializing.



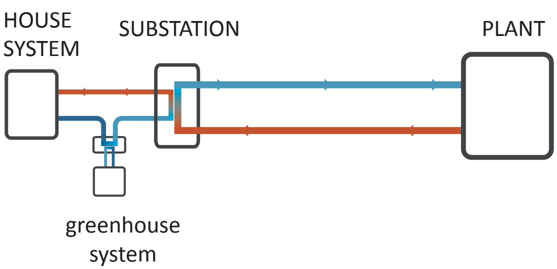


HEATING SYSTEM IN THE LIVING LAB GREENHOUSE

ALL-YEAR AROUND PRODUCTION ENABLED BY THE CONNECTION OF THE GREENHOUSE TO THE DISTRICT HEATING SYSTEM OF THE CITY.



hot air coming in



GREENHOUSE HEATING DIAGRAM

Air is heated by a heat exchanger outside the greenhouse. Hot air comes in through the former compost duct. The heating system is combined with the heat storage water barrels to save energy. Heating periods can be smartly defined and peak hours can be avoided.

LIVING LAB HEATING DIAGRAM

The greenhouse has its own heat exchanger connected to the house's heat exchanger. This heat exchanger should be close to the greenhouses and integrated in the design. Heating is delivered by hot air in the greenhouse: in that way, there is no need to change the design in order to make pipes run around the space.

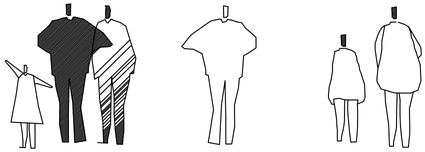
View towards the Living Lab and the two greenhouses.


CAFÉ

The students share their greenhouse

FURTHER IMPLEMENTATION

The greenhouse can be implemented in any area, as the two following exaples show.



MAJORNA, GÖTEBORG
VILLA SHARED BY 3 FAMILIES

GREENHOUSE SHARED BY 3 FAMILIES

PLAN
OF THE GREENHOUSE
1:100

ORGANIZATION:

Each family bought their own growing modules, and shared the cost for the entrance module. They share tools and can take care of each other’s plants when somebody is away. They organize shifts to clean the greenhouse.

5 MODULES:

4 GROWING MODULES

1 SIMPLE DECK MODULE

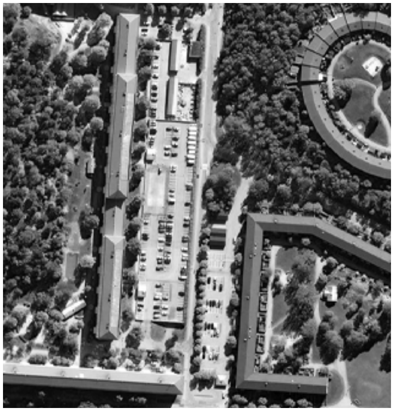
1 OUTDOOR STORAGE

TOTAL GROWING AREA: 14,8 SQM

TOTAL AREA: 37 SQM

GROWING AREA PER FAMILY: 3.7 AND 7.4 SQM

HAMMARKULLEN, GÖTEBORG
APARTMENT BLOCK FOR 20 FAMILIES
GREENHOUSE SHARED BY 10 FAMILIES



ORGANIZATION:

The housing company bought two greenhouses for the tenants, each one for ten families, sharing one growing module by two families. They share tools and can take care of each other's plants when somebody is away. They organize shifts to clean the greenhouse.

7 MODULES:

4 GROWING MODULES

1 ENTRANCE MODULE

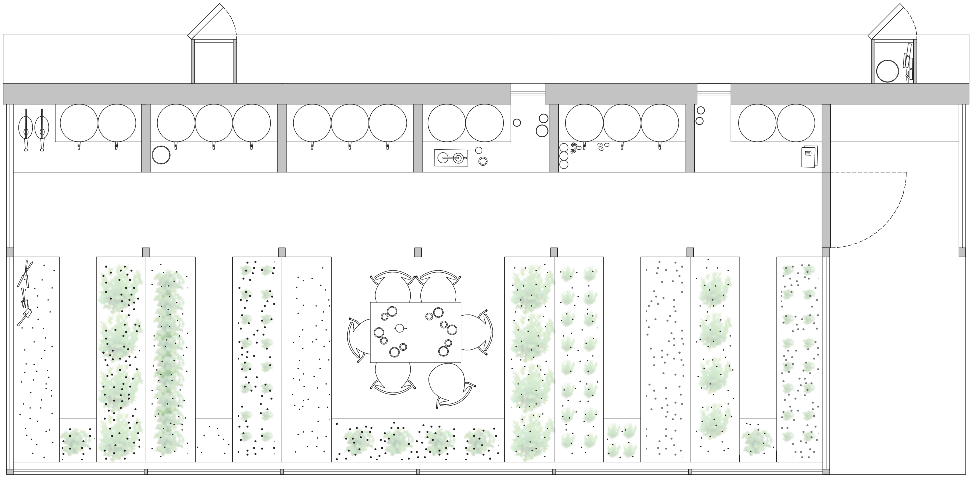
1 COFFEE MODULE

2 OUTDOOR STORAGE

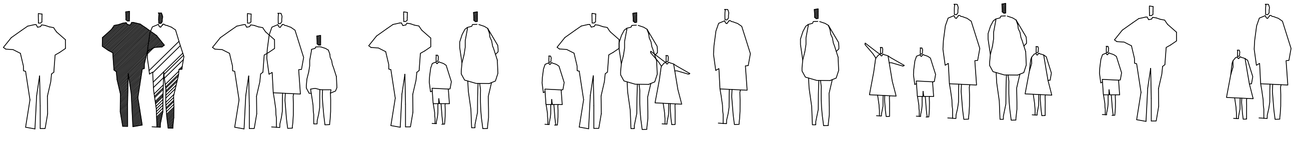
TOTAL GROWING AREA: 25 SQM

TOTAL AREA: 54 SQM

GROWING AREA PER FAMILY: 1,9 SQM



PLAN
OF THE GREENHOUSE
1:100



VIII. CONCLUSIONS AND REFLECTIONS

Our aim with this master's thesis was to create a space where urbanites can grow vegetables in a cold climate city such as Gothenburg, as well as providing space for learning and socializing. We wished to create a shared space for all year around production as a sustainable building. The thesis resulted in the project Go City Grow, a modular, adaptable and affordable greenhouse for community use.

We consider that we fulfilled these criteria and covered all aspects to consider when having a holistic approach in architectural design, and developed the design at a rather detailed level, even if the goal at the start of the thesis was to be able to produce construction drawings!

The all year round production shifted toward an "extension of the growing season", as it makes more sense to let communities decide on the growing period they wish to have in the greenhouse.

GO CITY GROW: GENERAL REFLECTIONS

SHARING

At the beginning of this thesis, our notion of a shared garden was a place where everything is shared, including the soil, the plants and the harvest. After researching about existing and well-functioning community gardens, we realised that sharing everything was not optimal. That's why the concept shifted toward a space where people can share the experience of growing, rather than sharing the plants and the harvest. The purpose of sharing is primarily, according to us, making people communicate, inspire and learn from each other, preferably without arguing whom the ripe tomatoes belong to.

Sharing has furthermore been a key in our thesis, as we, Charlotte and Lisa, have shared our time, our joy but also our downs during this master's thesis. We have learned from each other and helped each other. How great it is to do a shared master's thesis! Sharing is fun, and therefore we believe in creating spaces for shared activities.

WILL GO CITY GROW CHANGE GOTHENBURG'S FOOD SYSTEM?

One purpose of this master's thesis was to illustrate and test our vision of changing the food systems in the world. Since changing the food system was too great of a task for our master's thesis, we decided to go small in scale and impact as we mentioned earlier in this report, and decided to design Go City Grow.

One of the purposes of this greenhouse was to produce food all year around in order to decrease the amount of imported food. We are aware that all the food consumed in Gothenburg will not be produced by domestic farmers in the city center and that greenhouses as our Go City Grows, implemented in Gothenburg, would not have the capacity to sustain the whole town with food, but rather provide the city farmers with a part of their vegetables.

As discussed throughout this thesis, spaces such as shared greenhouses can raise awareness about food cycles, encouraging change in people's consumption and habits concerning food. By raising awareness and making people come closer to their food, the system will change through the demands of the consumers. The request for local food will also lead to an increased food production close to the cities, rather than in the city center.

An action like ours would not have a tremendous global impact, but for the development of local food in Gothenburg, it could be one important step. Many local actions need to happen, and communities need to be built around these actions.

SUSTAINABLE URBAN AGRICULTURE

The design we made is based on the research about greenhouses we have done, rather than experience in growing. While reading, we understood that the growing of plants is a science that we get to fully master only after being an experienced farmer. We don't know how plants would grow in our greenhouse, therefore we think that it would be useful to test it for real one day, in order to see what works and what doesn't.

DESIGNING A SUSTAINABLE BUILDING

Go City Grow is, according to us, a sustainable building in different ways. Due to carefully chosen materials, where re-usability, production manner, and emissions have been taken into consideration, the greenhouse can be seen as ecologically sustainable. The durability of the building, both the ageing of materials and aesthetic values will make the greenhouse last long. The energy saving arrangements extends the growing season and makes the greenhouse use less energy if it is heated. The visible loops of water, air and soil will raise awareness among the users, but also ecologically take care of local waste and resources. Also, growing plants changes people's behaviour, as the mentioned case study of Järnbrott shows.

In terms of energy efficiency, we preferred to reduce needs and provide the growers the essential resources (water and electricity) in order to lower the bill and lower the operating environmental impacts. We believe that this attitude should be further considered in the design practice in general because our habits demand more resources than what we actually need.

Throughout our design process, it clearly appeared that aiming for the design of a sustainable building with the approach we defined in chapter 4, even in a very small scale, was highly complex. We have tried to solve all issues and considerations in the design, but even after been very deep into details we haven't solved everything. The architectural design practice starts to require other types of knowledge, and it was exciting for us to learn so much with this project that we haven't learnt before, throughout our education.

Another aspect of sustainable design is how the building is implemented in the surrounding areas. By using tires as foundations, the building will not leave any traces if it would be removed in the future. Nevertheless, considerations regarding the wildlife and nature has to be done, e.g. attracting bees through planting specific species surrounding the greenhouse etc.

OPENING: GO CITY GROW HELPING HOUSING BLOCKS TO REDUCE THEIR ENERGY BILL

During a discussion with Fredrik Olsson from the architect firm Tailor Made, another possible use of Go City Grow was brought to the table. We imagine that the design could have other purposes than growing food and be a sustainable building independently: it could be integrated to the house's system. The greenhouse could help the surrounding housing blocks to clean the wastewater or produce extraenergy for the house itself. It could have a better use of the house's wasted resource, for example using heat from laundry rooms. Go City Grow could possibly make housing blocks reduce their energy bill if the concept and scale was slightly changed.

Tailor Made is a company designing and building "NaturHus", villas in greenhouses where waste-water is locally treated and cleaned and where the loops are closed. They have invented a way to naturally clean waste water from shower and toilets using plants.

Lisa's Urban Farming

AND, WHAT ABOUT US?

Our personal interest in local and good food grew during this project. Through constantly talking about our project, we like to believe that we have *planted a seed* in our friends and colleagues' minds. After researching about growing food in an urban context, we both started to grow food on our own. Both living in apartments, we realized also that what one can grow is limited, if we don't possess a balcony or a garden. We also realized that from the moment a seed is planted until the moment you can harvest the fruit, it takes several weeks and you have to be patient. It also made us reflect about the way we consume.

Charlotte's Urban Farming

REFERENCES

Afentoulidou, Galini and Pirri, Eva (2013) *Student Lab - experimental sustainable living.* Chalmers University of Technology, Gothenburg, Sweden (master's thesis).

"All eyes on the sharing economy", (2013). *The Economist (The sharing economy)*, 9th March 2013. www.economist.com/news/technology-quarterly/21572914-collaborative-consumption-technology-makes-it-easier-people-rent-items (14 April 2014)

Balaÿ, Paul & Hagy, Shea (2014) *Adaptable Design for the HSB Living Lab - flexible, co-created spaces in Student Housing*. Chalmers University of Technology, Gothenburg, Sweden (master's thesis).

Bergstrand, Karl-Johan & Schlüssler, Hartmut (2012) "Nya tekniker inom växthusbelysning." Alnarp, SLU (*LTJ-fakultetens faktablad*: 2012:26).

Botsman, Rachel & Rogers, Roo (2010) *What's Mine is Yours: The Rise of Collaborative Consumption*, HarperCollins.

Brophy, Vivienne & Owen Lewis J (2011) *A Green Vitruvius, Principles and practice of sustainable architectural design*, Earthscan.

Brown, Lester (2004) *Outgrowing the Earth, The Food Security Challenge in an Age of Falling Water Tables and Rising Temperatures,* Earth Policy Institute.

Brown, Lester (2009) *Plan B 4.0, mobilizing to save civilization*, Earth Policy Institute.

Christer Nordström Arkitekter. www.CNA.se

Carpenter, Novella & Rosenthal, Willow (2011) *The Essential Urban Farmer,* Penguin Books.

Christiansson, Samuel (2012) *Potentialen för spillvärmeuppvärmda växthus i Sverige ur ett hållbarhetsperspektiv*. Stockholm, KTH (TRIBA-CHB Rapport 2012:84).

Cockrall-King, Jennifer (2012) *Food and the City, Urban Agriculture and the new Food Revolution*, Prometheus Books.

Collaborative Consumption Hub. www.collaborativeconsumption.com (21 May 2014)

CSA Farms. www.csafarms.org

Dutreix, Armand (2010) *Bioclimatisme et performances énergétiques des bâtiments,* Eyrolles (in French).

F.A.O (2013) *Food Wastage Footprint: Impacts on Natural Resources,* Food and Agriculture Organization of the United Nations, Summary Report.

F.A.O (2001) *Feeding the cities*, Food and Agriculture Organization of the United Nations, Natural Resources and Environment Department.

Femenìas, Paula (2006) "Växthus del i socialt program som ska öka trivsel." *Husbyggaren*, nr 5, pp. 24-28.

Filosofiska rummet (2013) Delad glädje – om delandekulturens mekanismer och möjligheter. 2013 (Podradio) Sveriges Radio P1, www.sverigesradio.se/sida/avsnitt/288088?programid=793 (25 March 2014)

Garrett, Steve & Feenstra, Gail (1999) *Growing a community food system.* Pullman, WA: Western Rural Development center. Found June 2014 at: http://smallfarms.wsu.edu/wsu-pdfs/WREP0135.pdf

Gorgolewski, Mark, Komisar, June & Nasr, Joe (2011) *Carrot City, Creating places for urban agriculture*, The Monacelli Press.

Hailweil, Brian (2004*) Eat Here: Reclaiming Homegrown Pleasures in a Global Supermarket*, Worldwatch Insitute.
Hardin, Garrett (1968) “The Tragedy of the Commons.” http://www.princeton.edu/~achaney/tmve/wiki100k/docs/Tragedy_of_the_commons.html (25 March 2014)

Helsing, Jenny (2010) *Självförsörjande ekologisk odling av grönsaker på friland*, Gävle: Högskolan i Gävle

Hopkins, Robert (2008) *The Transition Handbook; from oil dependency to local recilience*, Transition Books.

Hopkins, Robert & Pinkerton, Tamzin (2009) *Local Food, How to Make it Happen in your Community,* Transition Books.

HSB (2013) Vad är HSB Living Lab? http://www.hsb.se/omhsb/var-verksamhet/hsb-living-lab - (24 January 2014)

Jean Pain Method. www.resilientcommunities.com

Johanneberg Science Park (2014) HSB Living Lab. http://www.johannebergsciencepark.com/en/what-we-do/arenas-collaboration/project-arena/hsb-living-lab (24 January 2014)

Jordbruksverket (2010) *Svenska matvanor och matpriser - prisutvecklingen under det senaste åren* (Rapport 2010:20)

Linde, Bella (2014) *Rätt ur jorden,* Ordfront.

Martinez Steve, Hand Michael, Da Pra Michelle, Pollack Susan, Ralston Katherine, Smith Travis, Vogel Stephen, Clark Shellye, Lohr Luanne, Low Sarah, and Newman Constance (2010) *Local Food Systems: concepts, impacts, and issues.* United States Department of Agriculture, Economic Research Service, Economic Research Report Number 97.
Mollison, Bill (1990) *Permaculture Two: Practical Design for Town and Country in Permanent Agriculture*, Tagari Books, Australia.

Mont, Oksana (2011) Collaborative Ways of Living and Consuming. http://medea.mah.se/2011/04/collaborative-ways-of-living-and-consuming/ (20 May 2014)

Närproducerat Tidaholm http://www.narproducerattidaholm.se

Nilsson, Ulla & Nimmermark, Sven (2013) *Restvärme för växthusproduktion*. Alnarp, SLU. (Rapportserie Landskap, trädgård, jordbruk. Rapport 2013:2)

Nordström, Christer (2014) Lecture at the Architecture School of Chalmers University of Technology, 12 February 2014.

Orru, Anna-Maria, Relan, David & Zetterquist, Johan *(2013) FoodPrints,* Research Catalog, FoAM Nordica.

Oxford Dictionaries (2014) English definition of photosynthesis. http://www.oxforddictionaries.com/definition/english/photosynthesis?q=photosynthesis (February 4th 2014)

Oxford Dictionaries (2014) English definition of monoculture. http://www.oxforddictionaries.com/definition/english/monoculture (April 28th 2014)

Oxford Dictionaries (2014) English definition of movement. http://www.oxforddictionaries.com/definition/english/movement (June 16th 2014)

Putnam, Robert (1995) *Bowling alone: America's Declining Social Capital.* In *Journal of Democracy* nr 6:1, Jqn 1995, p.65-78. http://xroads.virginia.edu/~HYPER/DETOC/assoc/bowling.html

Rich, Sarah (2012) *Urban Farms*, Abrams Publishers, USA.

Ringqvist, Jonas (2013) *Analysis of the agriculture and food supply in Tidaholm for Närproducerat Tidaholm,* document generously given to Charlotte and Lisa.

Robild, Eva (2004) *Odla i pallkrage*, Forma Books AB. p.34

Rothstein, Bo (2002), "Socialt kapital - ett genombrott för en ny samhällsvetenskaplig teori." Article from Sören Holmberg and Lennart Weibull (eds.) (2002) *Det våras för politiken*. Gothenburg.

Slow Food Movement. www.slowfood.com

Steel, Carolyn (2013) *Hungry city: how food shapes our lives*, Vintage Books, UK.

SusLab NWE (2014) http://suslab.eu (24 January 2014)

Teicher, Jordan (2014) "Americas new generation of farmers." *Slate*, 9 March 2014. http://www.slate.com/blogs/behold/2014/03/09/aliza_eliazarov_photographs_the_sustainable_farm_movement_in_the_united.html (4 April 2014)

Terra Madre Foundation (2006) *Terra Madre, 1,600 Food Communities*, Slow Food editors, Italy.

Thompson, Edward Jr., Harper, Alethea Marie, & Kraus, Sibella (2008) *Think Globally—Eat Locally: San Francisco Foodshed Assessment*, American Farmland Trust, USA.

U.S. Department of Agriculture, Agricultural Marketing Service (2013) *Farmers' Market Growth: 1994-2013*. Accessed June 2014 at: http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?template=TemplateS&navID=WholesaleandFarmersMarkets&leftNav=WholesaleandFarmersMarkets&page=WFMFarmersMarketGrowth&description=Farmers%20Market%20Growth&acct=frmrdirmkt

University of Minessota (2013) *Cold Climate Greenhouses Resource Guide*. http://www.extension.umn.edu/rsdp/community-and-local-food/production-resources/docs/cold-climate-greenhouse-resource.pdf

Viljoen André, Bohn, Karin, & Howe Joe (2005) *Continuous Productive Urban Landscapes, Designing Urban Agriculture for Sustainable Cities*, Architectural Press, UK.

Wang, Yong-Wei & Liang, Xi-Fen (2006) *Performance of underground heat storage system in a double-film-covered greenhouse. Zhejiang University of Science - April 2006* http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1447511/

World Climate and Temperature www.climatemps.com

Örneblad, Eva (1997) *Solhuset i Järnbrott - Grönrum och kreativa sociala processer på väg mot en bärkraftig arkitektur.* Chalmers University of Technology, Gothenburg, Sweden.

INTERVIEWS

Berggren, Karl-Johan. Alnarp (February14th, 2014).

Caspersson, Anki. Solhusen, Gårdsten (February 5th, 2014).

Edling, Sanna. HSB. Phone interview (March 10th, 2014).

Nilsson, Gunnar. Göteborg Energi (February 20th, 2014).

Olsson, Fredrik. Tailor Made Architecture, Gothenburg (April 9th, 2014).

Ringqvist, Jonas. Närproducerat Tidaholm, Bossgården Farm (November 17th, 2013).

Wennberg, Niklas. Stadsjord, Gothenburg (November 2013).

Wikström, Åke. Hållbar Hälsa, Svenshögen (February 7th, 2014).

FURTHER READING

BLOGS AND VIDEOS

Penn and Cord's Garden, Wild Mountain Gardening & Extreme Homesteading:
http://www.pennandcordsgarden.com

Blog about an experimental cold climate DIY greenhouse:
http://permaculturegreenhouse.com/

TED Talks:
Tim Jackson, *Prosperity Without Growth*
Carolyn Steel, *How Food Shapes Our Cities*

"The Power of Community, How Cuba survived Peak Oil", 53'
http://www.youtube.com/watch?v=76F4z4DRafA

URBAN FARMS

Greensgrow Fram, Philadpelphia, PN, USA
ReVISION Urban farm, Boston, USA
Edible Schoolyard NYC, Brooklyn, NY, USA
Brooklyn Grange, Queens, NY, USA
Growing Power Fram, Milwaukee, WI, USA

LOCAL FOOD ACTIONS AROUND THE WORLD

USA:
Grow Pittsbug Community: http://www.growpittsburgh.org
Commercial rooftop greenhouse in New-York producing basil: http://gothamgreens.com/

SWE:
Stadsjord, Göteborg, SWE
Närproducerat Tidaholm: http://www.narproducerattidaholm.se/

FRANCE:
Passage 56, Paris, FR: junkspace converted in community garden.
Nourriture à Partager: actions for spontaneous urban farming and free food.

LOW-TECH HEATING SYSTEMS

Website with ideas, tools, and examples of how to get energy from the sun
http://www.builditsolar.com:

Video about a greenhouse heated in an alternative way
http://cookingupastory.com/sustainable-energy-thermal-banking-greenhouse-design

ABC's of In-ground Heating & Alternate Fuels, John W. Bartok, Jr., Emeritus Extension:
http://www.newenglandvfc.org/pdf_proceedings/2009/ABCIgHAF.pdf

Geodome Heating System explanation:
http://www.youtube.com/watch?v=ALstV3cdXRc

GREENHOUSE DESIGN

Greenhouse Energy Conservation Checklist, John Bartok.
http://hrt.msu.edu/Energy/Notebook/pdf/Sec3/Greenhouse_Energy_Conservation_Checklist_by_Bartok.pdf

General Design Principles: orientation, glazing, passive solar heating, active solar heating, passive ventilation sytems, insulation, etc.
http://www.agrisk.umn.edu/cache/ARL01480.htm#basic
http://www.wvu.edu/~agexten/hortcult/greenhou/building.htm

The Garden Goddess Greenhouse Project:
http://www.gardengoddessenterprises.com/greenhouse.html

The Solar Cold Climate Greenhouse:
http://www.mwt.net/~roald/solargh.html

***The "Green" Greenhouse:**
http://people.umass.edu/~caffery/greenhouse/index.html
Example of a "Green" Greenhouse where they explain all the characteristics of the design: Frame, Glazing,Heating System, Ventilation, etc. Very Detailed. Plans available PDF.

GEODESIC DOME CONSTRUCTION

How to build a geodesic dome:
http://www.byexample.net/projects/current/dome_construction/index.html:

IMAGE CREDITS

All photos not listed below are taken by the authors.

p.10	Charlotte and Lisa - Agnes Hammar, 2013
p.30	Local Food Ring - Hopkins, Local Food, 2009, p.16
p.74	Solar Air Collectors (1) and (2). www.cna.se
p.76	Biomass Burning Systems (1) and (2). Jody Rader, Cold Climate Greenhouse Resource Guide
p.77	Jean Pain's compost heap. www.integralpermanence.org
p.78	Water Barrels Wall. source: permaculturemidwest.com, author unknown.
p.79	Subterranean heating storage. Chuck Waibel, Cold Climate Greenhouse Resource Guide
p.80	LED Lamp from a chinese supplier. www.growlight.cn
p.81	Passive composting. www.greenspire.se
	Vermicompost. www. msucares.com
p.82	Hydroponic. www.urbanacupunctureblog.wordpress.com
p.83	Aquaponics. Ryan Griffis, Urbana, USA
p.85	Multiline - www.byggmax.se
	EuroSerre - www.willabgarden.se
	Växthus utan bygglov - www.swedengreenhouse.se
p.86	GrowUp London - www.growup.org.uk
p.87	Globe Hedron - www.conceptualdevices.com
p.89	Charlotte and Lisa - Shahrzad Jazi, 2014
p.141	Living Lab - Shea Hagy and Paul Balay, Master's Thesis, Chalmers, 2013
p.154	Majorna - www.eniro.se
p.155	Hammarkullen - www.eniro.se

GRAPHICS

All graphics are done by the authors.

APPENDIX

Go City Grow Model




SUMMARY

This thesis develops the design of a shared greenhouse concept for residential areas of Gothenburg's city center. Based on a background research gathered in the present report, this greenhouse concept has been approached as a sustainable building that enables extension of the growing season in a cold climate like Gothenburg.

Go City Grow represents an opportunity for urbanites to reconnect with their food and therefore a potential trigger for food systems change. By growing together, people share experiences, knowledge and fun, but also resources. Go City Grow can make people's everyday habits change, and contribute to the development of a more resilient Gothenburg.