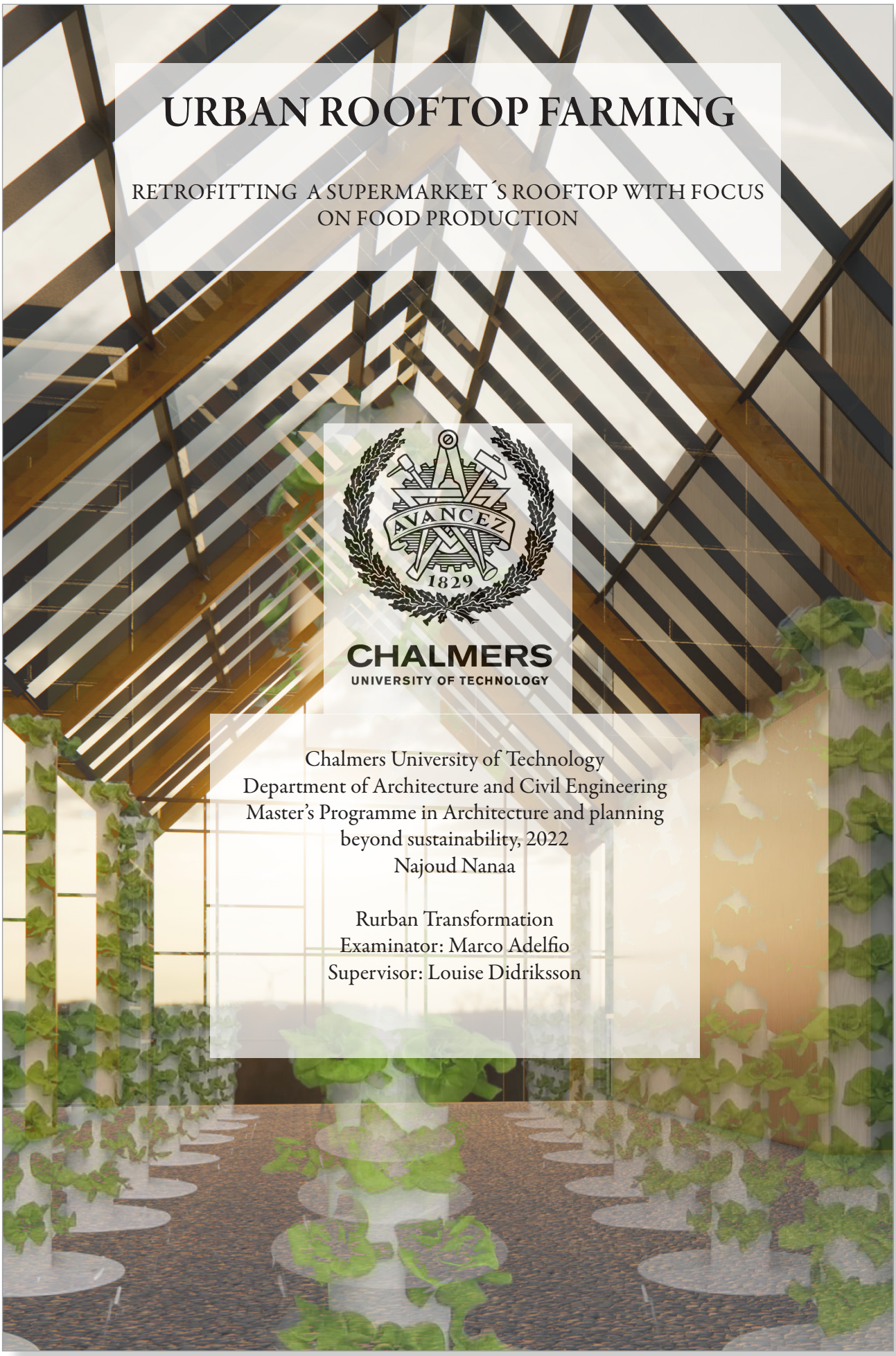

URBAN ROOFTOP FARMING

RETROFITTING A SUPERMARKET´S ROOFTOP WITH FOCUS ON FOOD PRODUCTION

CHALMERS
UNIVERSITY OF TECHNOLOGY

Chalmers University of Technology
Department of Architecture and Civil Engineering
Master's Programme in Architecture and planning
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Master's thesis in Architecture
Social-ecological urbanism
Masters thesis preparation course
History, theory and method, dealing with Inequalities
Sustainable architectural design
Design systems
Planning and design for sustainable development in a local context
Sustainable development and the design professions

CHALMERS UNIVERSITY OF TECHNOLOGY
Bachelor of Architecture

ABSTRACT

Climate change, urbanization, and a scarcity of resources are just a few factors that indicate a major structural change in our urban design. This has raised the question about the future of food production, where we rely on global imports and rural resources.

Sweden's overall supply of imported fresh fruit and vegetables is significantly high, accounting for more than 70%. Most imported products consist of products not produced in Sweden, products only produced during seasonal or not available in adequate quantities in Sweden (FAO, n.d.). Imported greens are accompanied by several undesirable side effects, like excess packaging, transportation, cooling, and warehousing.

Urban rooftop farming could become a viable alternative to imported vegetables and fruits in Sweden in order to deliver more resilient, sustainable, and safe food production.

The vegetables and fruits can be grown directly where they are sold, at the supermarket! That said, supermarkets can become some sort of flag for the democratization of urban rooftop farming, in a sense that we are not talking about hyper-stores or an exclusive place for rich people; it is for everyone!

These roof typologies can become a catalyst for urban farming that improves local food production and makes it more efficient to afford healthy and sustainable food for all people. This is accompanied as well as by several social and environmental benefits.

The thesis focuses on the spatial qualities and programming of a specific supermarket´s roof in the most beneficial ways. The project investigates how to optimize the added roof topology by focusing on technical solutions and design principles. The roof farming focuses on aeroponic system, a farming type of vertical farming, to make the food production more sustainable, with a high yield per sq m, and diverse. This project showcase what great potential a retrofitted green rooftop can have and how we need to plan and build with sustainability as a driving force.

The thesis is carried out as research by design project. Investigating the opportunities of adding a rooftop farm on a supermarket. The research consists of literature studies, references, site visits, and digital model analysis in order to create a relationship between the analysis and proposal.

Keywords: urban farming, food production, vertical farming, aeroponic system, indoor farming, unused rooftop, and greenhouse

TABLE OF CONTENT

1. INTRODUCTION

AIM & PURPOSE

The main aim is to investigate how to make food production more sustainable and efficient through rooftop urban farming connected to specific commercial activity. Rooftop farming will supply supermarkets with fresh, locally grown crops. The result will be a design proposal for a specific supermarket's roof in Gothenburg, with a focus on the spatial perspective and programming the chosen roof in the most beneficial ways.

THESIS QUESTIONS

How can a rooftop of a supermarket be retrofitted with a focus on food production?

DELIMITATIONS

The main focus point will be on the spatial qualities and programming the chosen roof in the most beneficial ways. The spatial qualities and construction of the green rooftop will be explored through digital models.

The second focus point will be on getting more knowledge on vertical farming and a closer look into the aeroponic system.

The aim is to complement the food production mainly imported food. So, it is not substituting the food production. It is also about having a smaller circle of production, which is closer to the consumer. However, this thesis will not investigate how many crops the Aeroponic system will produce.

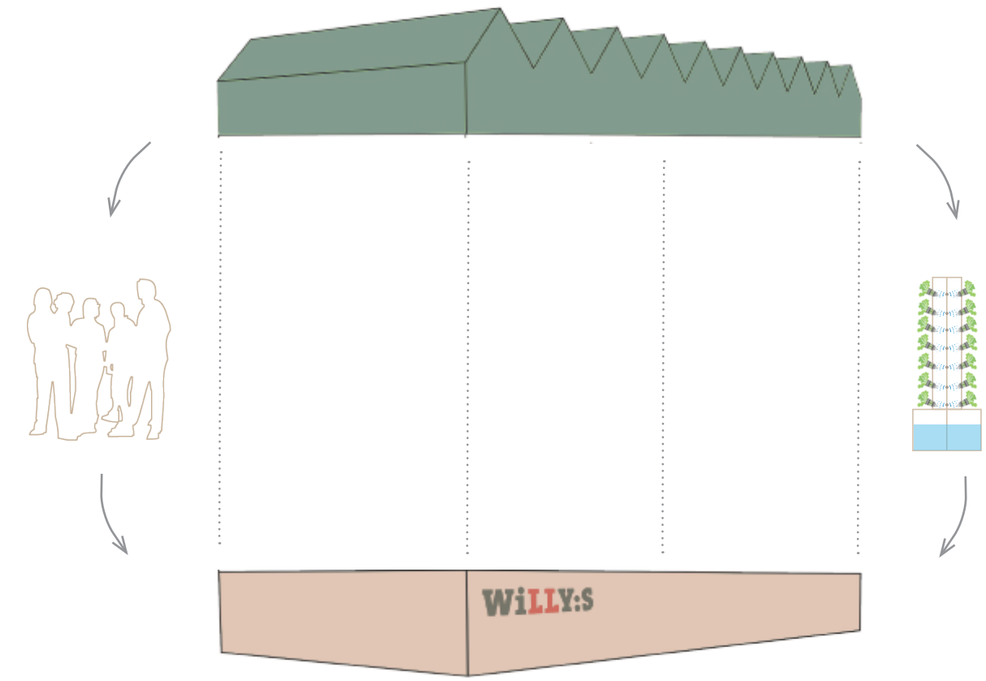
The focus will not be on making a business model or proposing who will work at the rooftop farm.

The addition of the greenhouse and other functions within it do require additional engineering considerations. However, the purpose of this thesis is not to investigate the new loads or wind loads that are generated by the new structure on the existing building's structure.

METHOD

This thesis will be research by design project investigating the opportunities of adding a rooftop farming on a supermarket. The research will consist of literature studies, references, site visits and digital model studies

CONCEPT



2. BACKGROUND AND RESEARCH

FOOD PRODUCTION IN SWEDEN

Sweden imports about twice as much agricultural products and food as its export. Both imports and exports normally increase every year (Jordbruksverket, 2022). However, we import a large number of products that compete directly with Swedish production. Certain kinds of fruits and vegetables, meat, and dairy products are examples (Jordbruksverket, 2022)

Sweden's overall supply of imported fresh fruit and vegetables is significantly high, accounting for more than 70 percent. Imports account for nearly all fresh fruits supplies, accounting for around 95 percent. Most imported fruits are centered on products that are not produced in Sweden, such as tropical fruits and citrus to mention a few, and products that are only produced seasonally - such as berries and deciduous fruits. Whereas imports of fresh vegetables account for about 60 percent of the market supply. Imported vegetables consist of products that are not produced or not available in adequate amounts in Sweden. Vegetable such as cucumber, tomatoes, cabbage, iceberg lettuce, cauliflower, paprika, eggplants and mushrooms are imported all year round (FAO, n.d.)

Greenhouse gases such as carbon dioxide, methane and nitrous oxide are significant for our soil because they create a pleasant climate so that plants, animals and humans can live here. But the use of fossil energy has led to excessive emissions of greenhouse gases, which has contributed to higher average temperatures on earth and global warming. The Swedish Board of Agriculture "Jordbruksverket" and the Swedish Environmental Protection Agency "Naturvårdsverket" estimate that emissions from Swedish agriculture could be reduced by about 20–25 percent by 2045 if various types of improvements in agriculture are implemented on a large scale (SLU, 2021)

Sweden currently has a 50 percent self-sufficiency rate. This implies that we right now only generate enough food for half residents within the country's borders. It is possible to increase the production to the point where there is enough food for all residents. In addition, instead of importing food with higher emissions, we could export climate-smart food (Lantbrukarnas Riksförbund, 2019)

UN SUSTAINABLE DEVELOPMENT GOALS (SDG´S)

From the seventeen UN sustainable development goals, eight goals could be applied to urban rooftop farming. Down below, each icon is accompanied by a description of the aspects to which the goal relates

- Space for social and community functions
- Making neighborhood more inclusive by adding an innovative program

- Water collection (for instance for irrigation, reuse as “gray” water)

- Adaption to climate
- Climate mitigation
- Making the existing building more sustainable

- Reduce energy consumption (through “post” insulation)
- Generating renewable energy

- Urban farming
- Utilizing of sustainable construction methods (for instance circular construction and use of sustainable material)

- Create local business
- Cost reduction in the final products

- Space for additional greenery

- Achieve food security
- Promote local sustainable agricultural

GOTHENBURG´S LAND AND WATER RESOURCES

“Gothenburg should be a pioneering country for sustainable growth, clean water and biodiversity in an urban environment. When the city growing, it must be done in an ecologically, socially and economically sustainable way “(Göteborgs Stad, 2018).

There is considerable competition for property in the municipality of Gothenburg, and there is a high demand for land for new building. Because a big portion of the land is used, and is therefore planned in detail. Many people who want to live and work in Gothenburg, and the population is expected to increase (Miljöförvaltningen, 2019)

Increasing self-sufficiency through cultivation must be seen from a holistic perspective, where all aspects of the framework of Urban Cultivation are essential (Fastighetskontoret, GöteborgsStad, 2017). Growing commercially and on the basis of economic incentives creates the conditions for long-term, sustainability, and welcoming a diversity of commercial ambitions, from micro-income to full-time employment, is important for expanding the potential for increased self-sufficiency.

Creating relationships and mutual trust between producers and customers, often known as relationship food, is an important part of developing a food culture. The concept is frequently seen in the debate about food production and describes the movement that has emerge among consumers who choose something other than what is available in the large chains and instead make their purchases through, for example, REKO rings (Miljöförvaltningen, 2019)

According to the report from The Environmental Management “Miljöförvaltningen” (2019), drinking water is a resource that can be seen as our most important resource. A safe and long-term sustainable water supply is an important part of society.

WHY ROOF?

How much food could we produce if we started farming on rooftops? We can simply set up greenhouses on each flat rooftop available to create a city that is entirely self-sufficient in greens. However, certain adjustments and reconstructions should be considered.

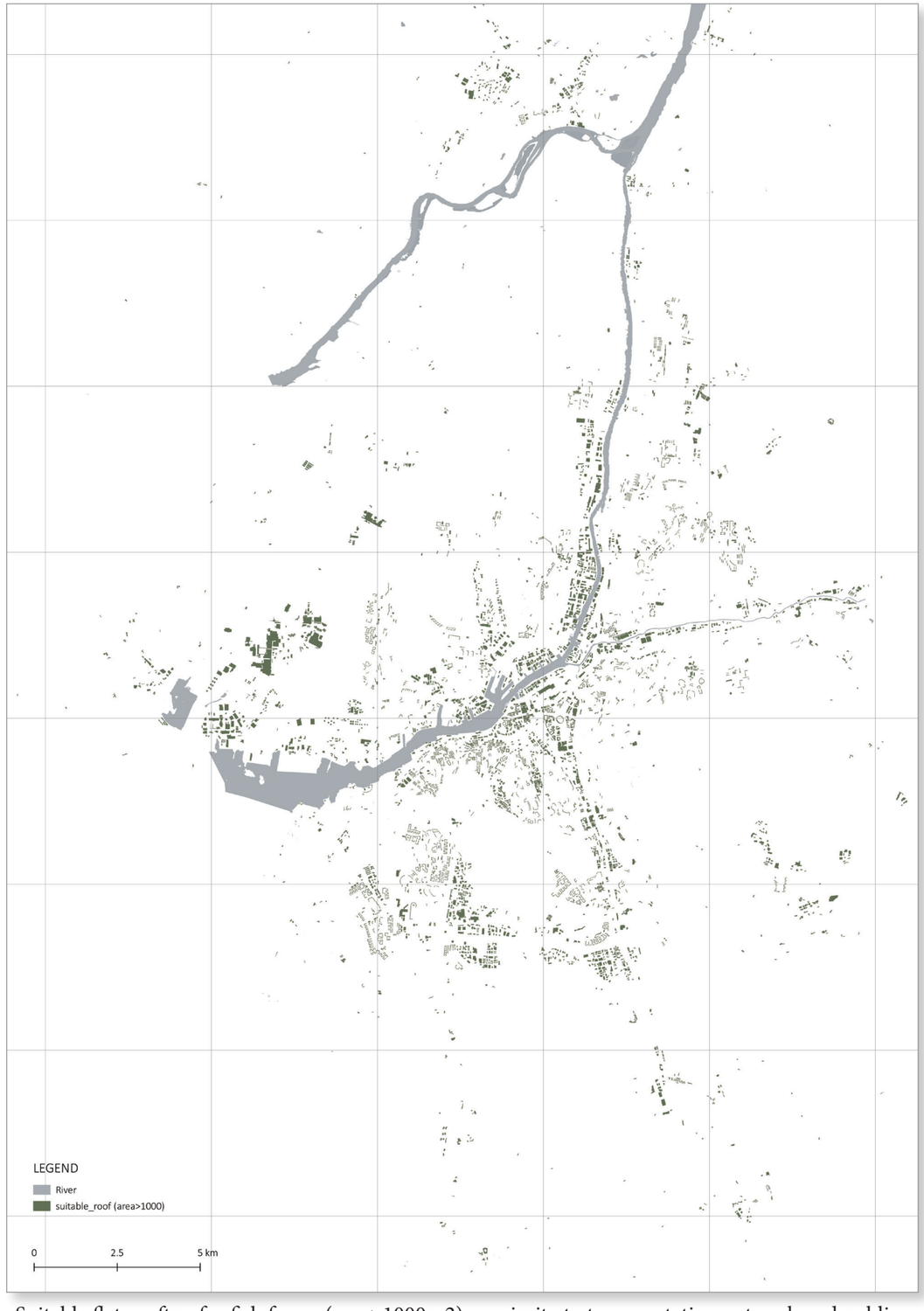
The city's flat rooftops remain unprogrammed, underutilized, and inaccessible to inhabitants. Building greenhouses on rooftops does not necessitate the acquisition of new land; it is already existing and ready for use.

When food production is brought closer to customers, transportation is reduced, and greens are fresher and more nutrient than they can be when they arrive on the shop shelf. The crops are kept fresher for longer, resulting in less food spoilage.
The residual heat from the underneath structure will help warm up the greenhouses, which will be especially beneficial during Sweden's colder months. The greenhouse can be connected to the district heating and ventilation systems of the buildings where it is housed.

The greenhouse rooftops allow natural light to reach the crops, which is critical for productivity. However, during winter, when there is a shortage of sunlight, artificial lighting will function as a supplement to ensure that the crops get adequate light every day.

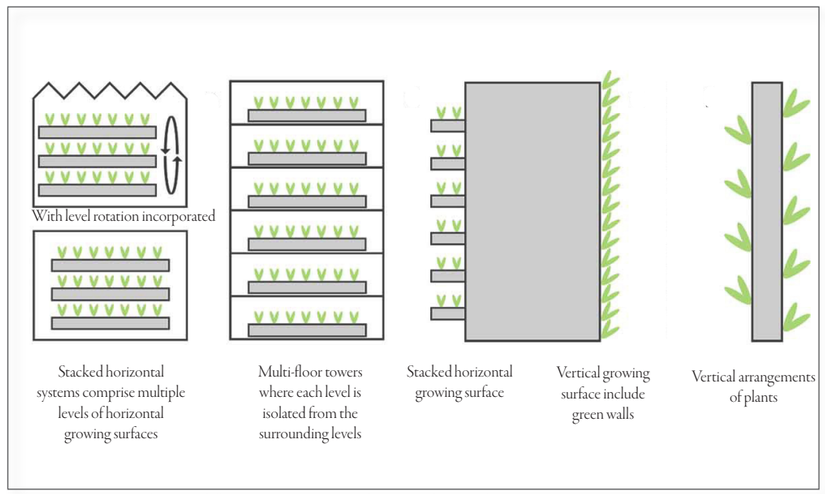
Farming nowadays accounts for at least 70% of world freshwater consumption (The World Bank, 2020). Collecting rainwater from rooftops and recycling it would not only simplify communal rainwater management systems but would also save fresh water.

To the right, a mapping of the suitable flat rooftop for fish farms in Gothenburg. Where one could see that rooftops have the potential to play a crucial role in solutions cities are searching for, which is in this case the future of food production



Suitable flat rooftop for fish farms (area>1000m2) proximity to transportation network and public transportation stops (Chen, 2021)

VERTICAL FARMING



Representation of vertical farming types (Beacham et al., 2019)

Globalization and urbanization have created pressure on agricultural land. That necessitates new methods for food production where we can maximize the crop yield per square meter of land.

The notion of Vertical Farming is gathering momentum to boost agricultural output per unit area of land. This approach tries to minimize pressure on conventional agricultural land by farming upwards rather than outwards and, by using soil-free growth technologies, is especially inspiring for application in urban environments. On the other hand, Vertical Farming comprises a wide range of growing systems with varying sizes, technology, users, locations, and aims. (Beacham et al., 2019)

The main distinction between vertical farming and conventional farming is the diversity of products that may be produced at the same time. Mono-culture refers to the practice of producing only one crop at a time in, which is almost the case in conventional farming. However, plants in Vertical Farming may grow all year, contrary to conventional farming, which can only be done during specific seasons. (Kalantari et al., 2018)

BENEFITS OF VERTICAL FARMING

Reduced carbon footprint: Local production is becoming more important, as urbanization takes place, towards a sustainable society through minimizing transportation. The demand for local produce already exists and it is in everyone's best interests to eliminate the non-value-adding phases of the food value chain.

Reduced food waste: Local production reduces the time spent on storage and transportation, the two processes that cause the majority of food spoilage

Reduction of water demand: Globally, the agriculture industry consumes over 70% of all freshwater annually (world bank,2020). High water usage can be harmful to communities with limited natural water resources. When compared to traditional agriculture operations, vertical farming can save up to 99% on water (Kalantari et al., 2018). In addition, circulating the water provides the exact amount of water required by the plants, ensuring that no water escapes the premises, contaminating the local ecosystem or causing eutrophication in rivers.

Land use: As the world's population and need for food have grown, finding arable land has become increasingly challenging. Arable land is scarce, and when new land is discovered that is conducive to food production, the existing ecosystem is frequently destroyed. According to Kalantari et al. (2018), depending on the crops grown and farm height, vertical farming can improve agricultural yield by up to 100 times. When agriculture is moved indoors to build vertical farms, there will be a 20-times decrease in land use. In fact, to feed a 100,000-person, each individual would require 1sq m of space, therefore a vertical farm would have to be 100m × 100m x 10 levels, with the top level acting like a basic greenhouse (Kalantari et al., 2018).

Lightweight system: It is easier with a lighter load on existing structures than wet soil. Vertical Farming is ideal when adding a new structure on top of an existing structure.

Resilience: The stacking of various growing surfaces provides additional benefits for vertical farming. For instance, crops could be produced year-round, crop rotation is unnecessary since the system is soil-free. As well as, many crops could be grown simultaneously. Furthermore, growing inside a controlled environment eliminates the danger of unpredictable external factors such as weather conditions, climate change, and natural catastrophes.

Pesticides free: The controlled vertical farming environments prevent pests and germs from destroying the crops which minimize the need of using pesticides. As a result, these closed vertical farming environments are void of any hazardous pests. Therefore, the entire process of vertical farming is carried out in an organic manner.

Improved food security: Vertical farming could significantly help to fulfill the essential food demands of the local community. The number of consumers in cities

is quite significant, and there is more low-income residents in this community who have little or no access to fresh food. In the case that an existing multi-story buildings are retrofitted with greenhouses, they will be able to provide enough food for the whole city's inhabitants. As stated by Kalantari et al. (2018), a vertical farm that takes 1 square block of city land and has 30 stories (approximately 3 million square feet) could offer 2000 calories for each person per day and, thus, can meet the needs of 10,000 residents.

Create local businesses: Food production in city centers is anticipated to boost economic growth and create new jobs in the area. As stated by Kalantari et al. (2018), working on these vertical farms comprise the design and management of the entire farm structure. Managing seed production, transplanting seedlings in vertical farming, managing resources such as light and water, managing waste, pollination techniques, cultivation, managing energy, distribution control, quality control, and maintaining IT personnel, and a variety of other occupations are available in these vertical farms.

Cost reduction: Vertical farms have a lot of cost-cutting aspects. Reduced transportation, fertilizer, water, and pesticide needs, along with increased output, will result in cheaper operational costs (Dahlberg & Lindén, 2019)

Education: Vertical farming acts as a link between the producer and the consumer. If the food we consumed is grown in cities, there will be opportunities to educate people about all of the processes involved. This is accomplished by arranging visits or excursions to vertical farming locations and offering information on food production, its concepts, and practices. Coordination between schools and vertical farms can help introduce the understanding of nature into the educational system. As a result, a vertical farm becomes a platform for innovative ideas, as well as a space for teaching and learning.

More productivity per unit of area: The main distinction between vertical farms and conventional farming is the range of crops that could be produced at one time. Conventional farming can only grow one crop at a time, which is known as monoculture, whereas vertical farms could produce numerous types of crops simultaneously on separate levels. However, unlike conventional farming, which can only be carried out at certain times of the year, plants inside vertical farming can grow all year round (Kalantari et al., 2018).

Resilient to climate change: The number of natural disasters has increased dramatically in recent decades (Ritchie & Roser, 2018). During the summer of 2018, severe droughts in both Sweden and the nations from which Sweden imports greens resulted in a shortage of the crop. It emphasizes the significance of adopting agricultural systems that can adapt to climate change to ensure that food is always available to the population. Since vertical farming plants are cultivated indoors, the

CHALLENGES OF VERTICAL FARMING

The vertical farms should aim to follow the guidelines of the UN Sustainable Development Goals and the Gothenburg Environmental Management "Miljöförvaltningen", which has been presented in previous chapters. In addition, vertical farms should strive to use renewable energy in accordance with the guideline of circular economy presented by Ellen Macarthur Foundation (2019). Indoor farming solutions frequently necessitate large amounts of energy for lighting and warmth. Renewable energy has been highlighted as a requirement for vertical farms to grow crops on a long-term basis (Ellen Macarthur Foundation, 2019).

Vertical farming is a technically hard and expensive crop production approach that combines protected horticulture systems such as greenhouses and controlled environment facilities in combination with multiple levels of growth surface. Vertical farming, as a result, necessitates a multidisciplinary technological approach to factors such as growing system, crop nutrition, lighting, energy efficiency, structure, and site selection (Beacham et al., 2019)

There is a need for huge investment in finding more sustainable methods of nutrient solution production and their delivery systems. This investment contributes to overcoming this circularity gap and ensuring that urban agricultural solutions are indeed regenerative at scale. Another investment is needed for platforms for growing crops and growth equipment, which would drastically increase costs. When compared to conventional farming methods, the high investment appears to be a disadvantage (Kalantari et al., 2018)

According to Kalantari et al. (2018), The initial costs of establishing, equipping, and running a vertical farm are undeniably considerable. This entails increased costs and maintenance, which may be a skeptical move to taking the lead in food production from an economic standpoint.

AEROPONIC SYSTEM

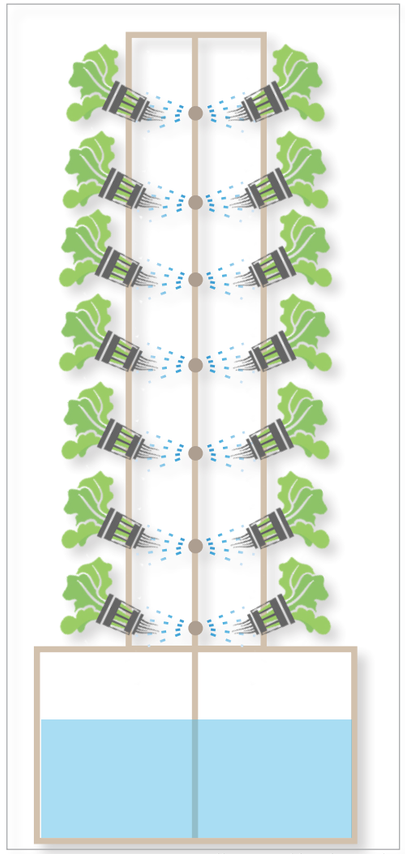
Aeroponics is the science of growing plants with the assistance of artificial support and without the need for soil or a substrate culture. In a nutshell, It is a growth technology of air-water culture cultivation in which plant roots are hung inside a closed container and openly exposed to the air in order to capture water nutrient-enriched mist via atomizers. The crown and leaves of the plant are extended above the moist zone. The artificial structure of the system separates the plant's root and canopy. The system uses pressure nozzles or foggers to spray nutrient-rich spray into the air to maintain hyper-growth under regulated conditions (Lakhiar et al., 2018).

When compared to other plant-growing systems, aeroponics utilizes a little amount of water. The system keeps labor costs down, utilizes 98 percent less water, 100 percent fewer pesticides and herbicides, 60 percent less fertilizer, and 45 percent to 75 percent more plant production than other plant growing systems (Lakhiar et al., 2018). Plant nutrients are supplied in a closed loop. As a result, consumption is limited to simply the amounts absorbed by the plants, resulting in significant water savings (Gopinath et al., 2017). In addition, there are few of Swedish nutrient solutions supplier that provide a locally produced nutrient solution.

Many vegetable crops are commercially grown in aeroponic systems, including potato, tomato, yams, lettuce, and some other leafy vegetables (Gopinath et al., 2017)

The mature plant can be simply removed at any time without causing damage to other surrounding plants. As a consequence of soil-free roots, soil-borne microorganisms, and adulteration from foreign plant species pollutants, the diseases were unable to spread quickly. Plant diseases could spread from plant to plant in other soil-less systems due to nutrient distribution in the growing chamber. The plant receives 100% of the available oxygen and carbon dioxide to the leaves, stems, and roots, resulting in rapid growth and shortened rooting time (Lakhiar et al., 2018)

On the contrary, an aeroponic system has a few disadvantages, including the high cost of the system, the need for regular root chamber cleaning, and the technical knowledge required to name a few (Lakhiar et al., 2018).



Aeroponic tower section illustrated by the author

Greenhouse Farm True Garden, Phoenix Arizona by Agrotonomy

Greenhouse Farm Scissortail Farms, Tulsa, Oklahoma by Agrotonomy

REFERENCES

UCHI

Primary functions: A Restaurant with an aeroponic greenhouse on the rooftop
Location: Denver, Colorado
Completed: fall 2018

US firm Tres Birds Workshop has built a greenhouse with soil-free growing towers for Uchi, a Japanese restaurant in Denver, Colorado. It's one of the country's largest rooftop aeroponic gardens. There are currently 23 different kinds of greens being grown. This project was part of a one-square-block renovation project in Denver's Curtis Park neighborhood (Tres birds, n.d.).

”Companies are trucking produce from 1,500 miles away into Colorado. Here we can grow more efficiently and much more close to our city centers, where restaurants and grocery stores and urban life is thriving,” said Sally Herbert, CEO of Altius Farms (Denver CBS local, 2019).

The building has a rectangular shape and is built on relatively solid brick and concrete foundation. Up above, a totally glazed volume is crowned with a multi-gable roof, giving the structure a distinctive appearance. This greenhouse is a 650-square-meter (7,000-square-foot) above the kitchen supplying the chef with the freshest organic greens available all year round (McKnight, 2019).

The plants, which include herbs, lettuce, and edible flowers, are misted with nutrient-rich water on a regular basis. Sensors that help control heating and cooling, as well as the opening of roof and side vents, keep an eye on the greenhouse's conditions. A number of local supermarkets and restaurants rely on this urban farm for leafy greens (McKnight, 2019).

Urban Denver Building by Tres Birds Houses (McKnight, 2019)

Urban Denver Building by Tres Birds Houses (McKnight, 2019)

Above-ground planters in the complex. Photo is by James Florio (McKnight, 2021)

SKY VEGETABLES

Primary functions: a greenhouse on top of a residential building
Location: Bronx, NYC
Completed: 2011

A hydroponic rooftop garden is placed on top of an 8-story building in the Bronx, north of Manhattan, that houses lower-income apartments. 6 individuals work full- or part-time to maintain the technical aspects of the greenhouse, including sun shading, ventilation, and nutritional levels. The goal was to involve the local community and pique their interest in urban agriculture. Since these employees, who live in the underneath building, work at this farm they get to pay a lower rent (Franzén, 2019).

Sky Vegetables utilizes hydroponic farming techniques, which are a sort of vertical farming, to produce more greens with less water than open-field agriculture. In a recirculating system, rainwater is recycled and used to irrigate crops (Sky Vegetables, n.d.).

The Bronx farm is located on top of a LEED Platinum-certified building. It has already distributions in a number of local and national retailers. Arugula, bok choy, butterhead lettuce, ruby chard, and herbs were cultivated in the Bronx greenhouse. Presently, the greenhouse provides local basil all year. The vegetables are sold at a local NYC market, and the customers like it (Sky Vegetables, n.d.).

The fundamental construction is made of aluminum frame and glass. To maintain an optimal temperature, fans and white fabric for sun shading are automatically controlled (Franzén, 2019).

Employees had no room for food preparation or packing, causing them to have to walk down to the ground level to eat since there was no space for them to take breaks or change clothes. This has resulted in preventing the business from running smoothly (Franzén, 2019).

Rooftop greenhouse farm, Sky Vegetables, in NYC (Skyvegetables, n.d.)

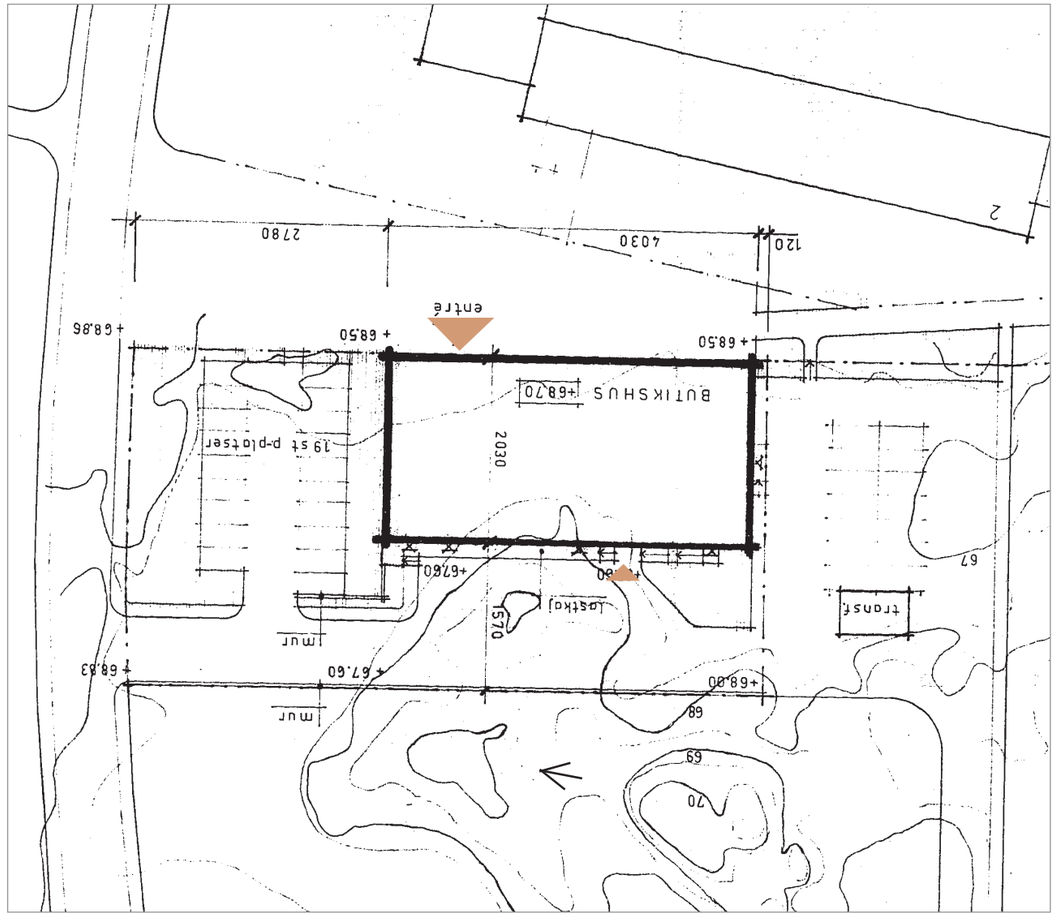
Inside perspective of rooftop greenhouse farm, Sky Vegetables, in NYC (Skyvegetables, n.d.)

4. APPLICATION ON SITE

CHOSEN LOCATION

EXISTING BUILDING

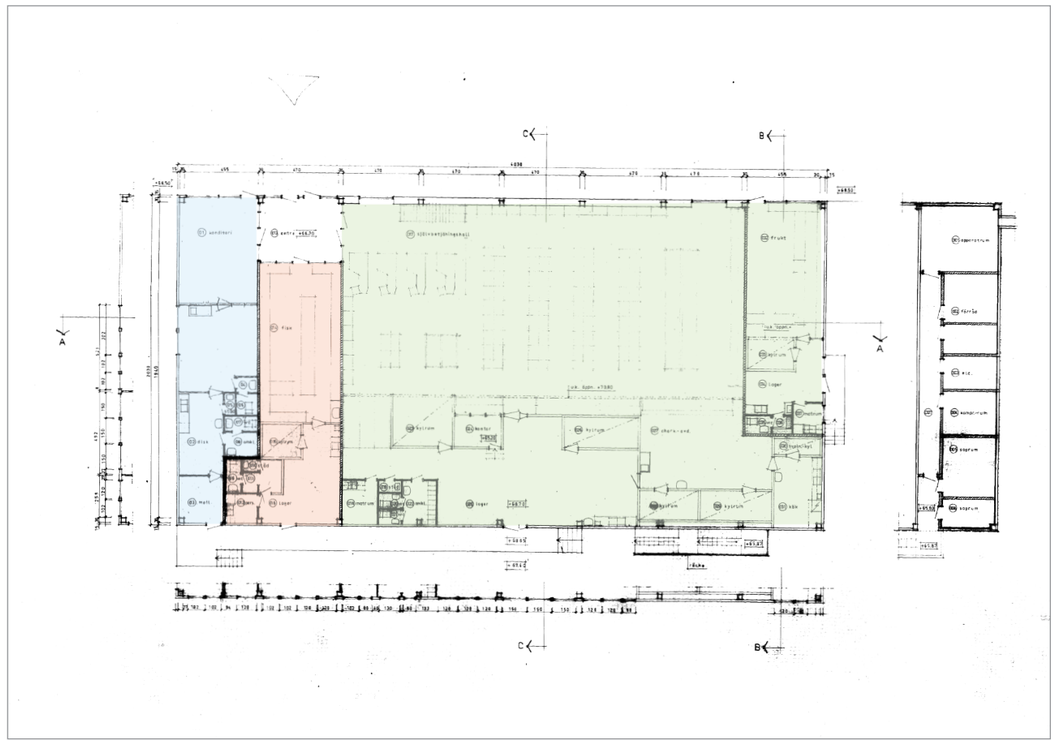
The building of interest called Kaverös Centrum. It is a one-story building, and it holds a Willys (supermarket), pizzeria and kiosk. The building is surrounded by a one-story parking garage on the west side and parking plots both on the south and north side, and a 4-stories residential building on the east side. The arrow shows the main entrance while the small one shows the staff entrance.



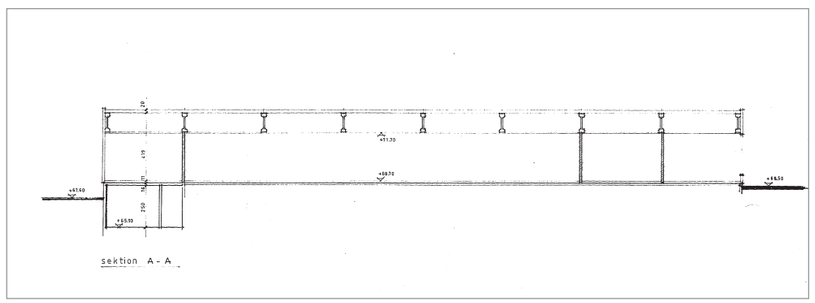

KAVERÅS CENTRUM
PIZZA · SALLAD · KEBAB
PASTA · HAMBURGARE · GRILLRÄTTER
LUNCH
LUNCH
LUNCH


WiLLY:S
Hemma


WILLYS
KAVERÅS CENTRUM



Willys Pizzeria Kiosk



STAKEHOLDERS

Primarily, the supermarket would gain the most benefits from crop yield on the rooftop since most crops would be sold on the supermarket's shelves. Willys focus on sustainability is completely in line with what a rooftop farm stands for, such as more control and lower environmental impact, to mention a few. According to the sustainability manager at Willys stores, Willys generally experience an increased demand for locally produced food. If these produced greens are good and fresh, they are only available in that particular store, which makes customers loyal (The sustainability manager at Willys stores, personal communication, 13 June 2022).

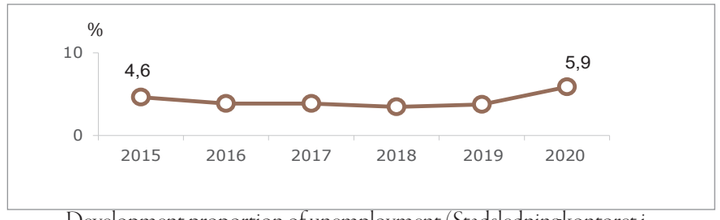
On the other hand, Willy's is a centrally managed chain that does not own its premises, so in that case, the landlord must be involved in the design process for the rooftop farm, which is Riksbyggen in this case.

In addition, the building of interest, Kaverös Centrum holds a pizzeria and kiosk. The pizzeria could be provided with some greens grown on the rooftops, such as an arugula. Meanwhile, the kiosk has a good potential to be developed into a Salad bar with outdoor seating.

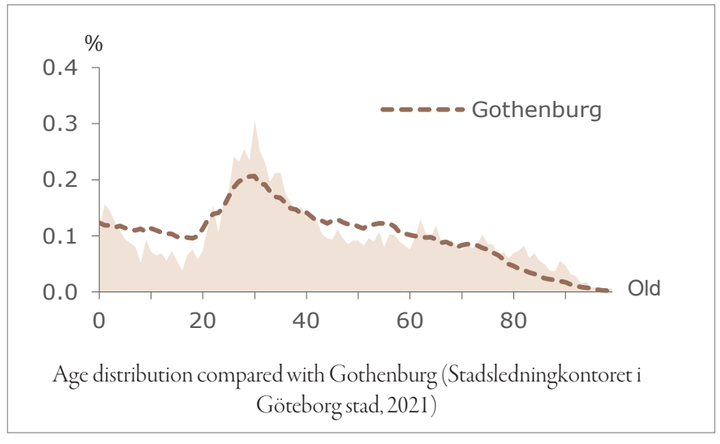
The age distribution of Kaverös demonstrates that the major residents belong to the age group 30–40 years old, which accounts for 26,3% of the residents in the Kaverös area. The following age group is 45–64 years old, which accounts for 19,1% of the residents in the Kaverös area (Stadsledningkontoret i Göteborg stad, 2021)

However, the report from the city management office in the city of Gothenburg (Stadsledningkontoret i Göteborg stad, 2021) indicates that 44.5% is a one person per household, meaning almost half of the residents there live alone in cramped spaces. This means a need for a communal shared space where the residents could host their gatherings and parties.

The report (Stadsledningkontoret i Göteborg stad, 2021) shows that the highest unemployment group in the area accounts for the age group of 30–40 years old. The newly added rooftop typologies would create local businesses and hopefully get residents interested in starting up with the reimplementation of this project in other locations



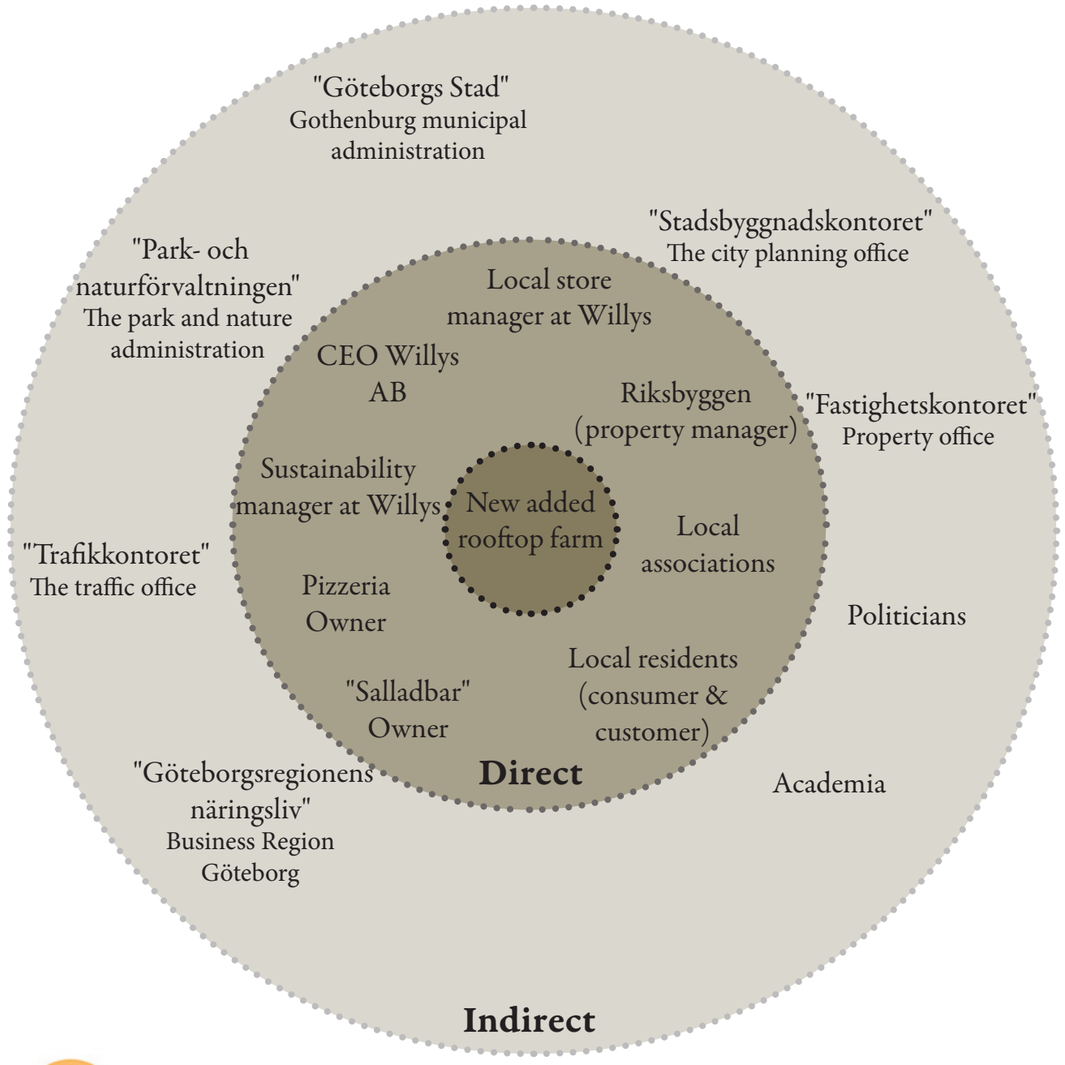
Development proportion of unemployment (Stadsledningkontoret i Göteborg stad, 2021)



Age distribution compared with Gothenburg (Stadsledningkontoret i Göteborg stad, 2021)

SUSTAINABLE CITIES AND COMMUNITIES

DECENT WORK AND ECONOMIC GROWTH

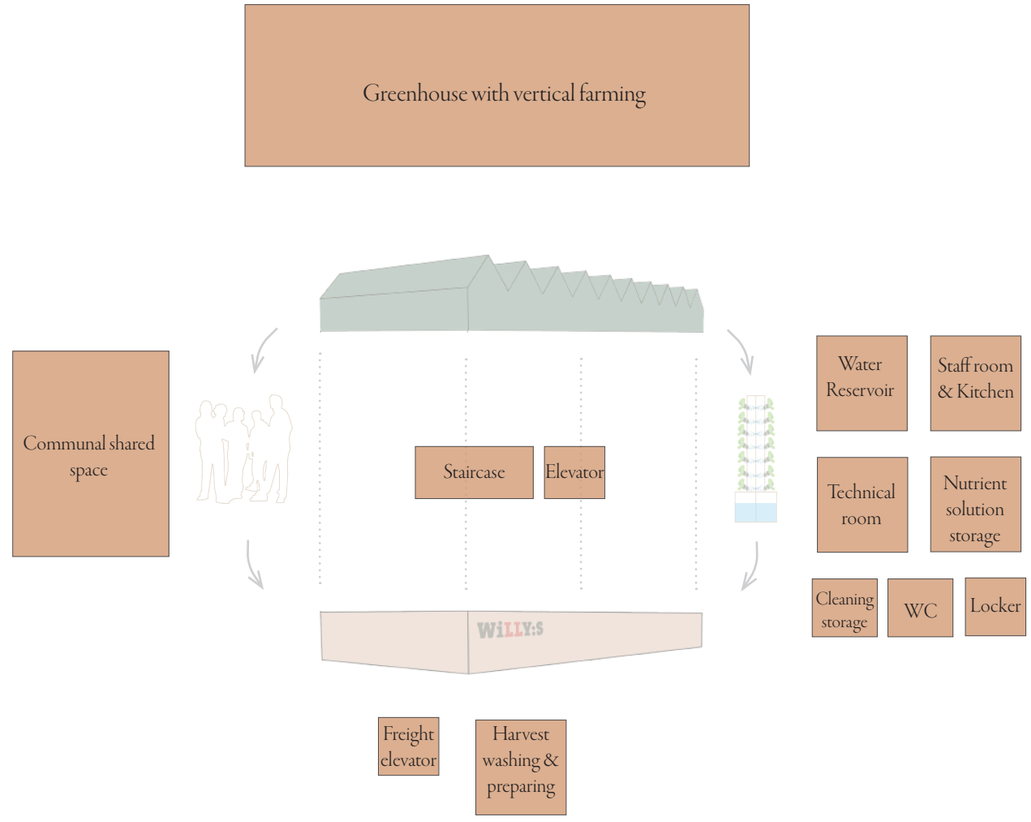


SUSTAINABLE CITIES AND COMMUNITIES

DECENT WORK AND ECONOMIC GROWTH

3. SYSTEMS AND STRUCTURE

PROGRAM



GREENHOUSE STRUCTURE

Greenhouses provide a sheltered and controlled environment for crops, extending the growing season by maintaining proper temperature and humidity throughout the year. Crops are protected from unexpected adversities, rodents, and insects to prevent crop failure. As a result, the production could remove seasonality and provide a consistent food supply all year. These have all been proclaimed as one viable solution for increasing food security production in urban fabrics with high densities of population, where more people demand more food, and their needs cannot be fulfilled.

The suggested greenhouse is a modular system that consists of a thin and light wood construction of frames and beams. Rainwater could be harvested from the greenhouse roof into the gutters on each side of the greenhouse structure. The water then flows into downspouts attached to PVC pipes. These pipelines transport the rainwater to water tanks where it is collected.

Extra LED lighting can be hung from the beams to provide the proper amount of daylight all year. It is highly recommended to allow the solar cells to have the same slope as the roof. The installation will thereafter be simple and cost-effective (Energimyndigheten, 2021). The optimal results are obtained if the solar cells are mounted in a southern direction with a roof slope of 40-45 degrees. (Solexperter, n.d.)

INDOOR CLIMATE AND VENTILATION

It's difficult to keep a greenhouse's temperature, humidity, and air movement consistent. To avoid producing micro-climates, it must be monitored and maintained at a constant level depending on the crops planted. Monitoring apps and climate control technologies are used to do this.

Plants' transpiration rate can be controlled by regulating temperature and humidity. If humidity levels are not managed, condensation will accumulate on crops and walls. Condensation areas would create a breeding environment for infections and mildew, which can harm the crops (Autogrow Team, n.d)

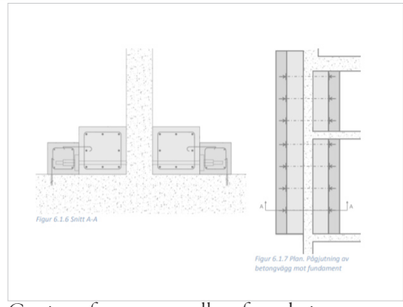
A Horizontal Airflow (HAF) fan, extraction fan, roof vents, side vents, wet walls, shade cloths, radiant heating, and fogging are just a few of the ways that can regulate the greenhouse environment (Autogrow Team, n.d). The proposed ventilation system is side and roof vents accompanied by extraction fans.

CONSTRUCTION´S REINFORCEMENT OPPORTUNITIES

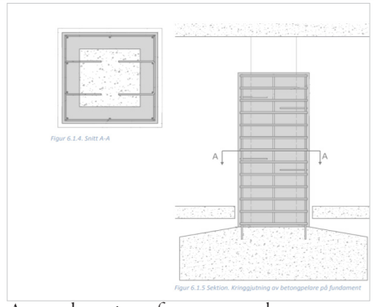
The construction reinforcement approach will be a more and more common methods to use in the future. Especially in the central parts of larger cities with high land prices. The new loads that occur on the existing building during adding new structure are horizontal loads and lack of stability, increased earth pressure and the need for basic reinforcement as well as cracking of columns due to increased vertical loads (Strömholm & Balkåsen, 2018)

On the right, a figures of different constructions reinforcement methods presented by Strömholm and Balkåsen (2018) The majority of all reinforcement measures addressed in this study consist of steel or concrete. Improvements can be achieved by looking at the overall picture of each specific reinforcement method as well as increased cooperation and dialogue between the various partner involved.

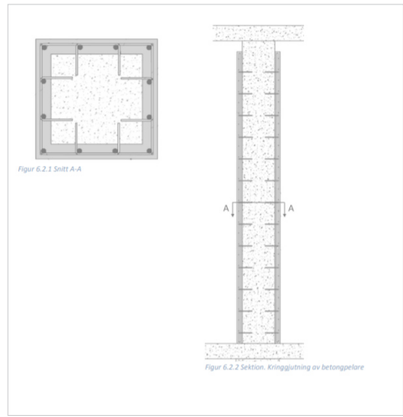
To sum up, there are a variety of construction reinforcement possibilities, and each project has unique conditions. However, the purpose of this thesis is not to investigate what the proper construction reinforcement method is. Thus, it is possible to carry out the additional loads from the greenhouse and other functions within it on the rooftop. However, some modifications and costs should be taken into consideration.



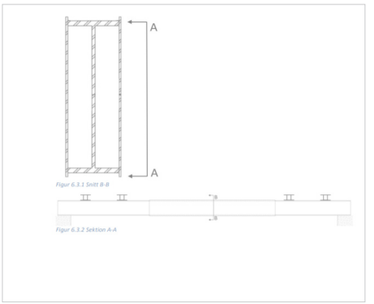
Casting of concrete wall on foundation



Around-casting of concrete column on foundation



Around-casting of concrete column



Beam reinforcement, a beam is reinforced with the underlying beam

Different constructions reinforcement methods presented by Strömholm & Balkåsen (2018)

SUSTAINABLE CITIES AND COMMUNITIES

CLIMATE ACTION

RENEWABLE ENERGY

LIGHT

Renewable energy sources are required for environmentally sustainable vertical farms, hence access to renewable energy is critical. Vertical farm implementation could be limited in areas where renewable energy is scarce. Sweden has the prerequisites to produce sustainable crops, with over 50% renewable energy compared to 7% in the United States, confirming a better prognosis for vertical farming in Sweden. Furthermore, renewable energy can provide a competitive advantage over traditional farming practices that rely heavily on fossil fuels (Dahlberg & Lindén, 2019).

The decision of adding the new structure on the top was to make use of natural light for vertical farming and in order to be less reliant on artificial lighting during the growth seasons when the sun condition is good. However, since the project is implemented in Sweden, where the winter season is long and dark, artificial lighting, such as LED, is required. The LED can be switched on and off as frequently as the plants require. It is the preferred solution since it is simple to manufacture and is an excellent choice for artificial lighting for plants.

RESIDUAL HEAT

The decision of placing the greenhouse on rooftop is to make use of an unused space, but also the fact that the greenhouse can use the heat that otherwise only leaked from the roof of the underlying building. Especially in the case of a supermarket, the refrigeration system and freezer room generate excess heat that could be captured and heat up the above greenhouse structure.

This heat is described by Mohamed Hage, CEO of Lufa Farms a rooftop-built greenhouse in Montreal, contribute a significant part of Lufa Farm's power needs. He claims that their greenhouse in Montreal uses 50 percent less heat energy than a similar land-based greenhouse would have done. But this gain is not one-sided. In return, the greenhouse insulates the underlying building, which helps to reduce its power requirements by up to 25 percent. Differences in construction technology standards between Sweden and Canada can, however, mean completely different conditions in Sweden (Schwartz, 2017)

CHOICE OF MATERIAL

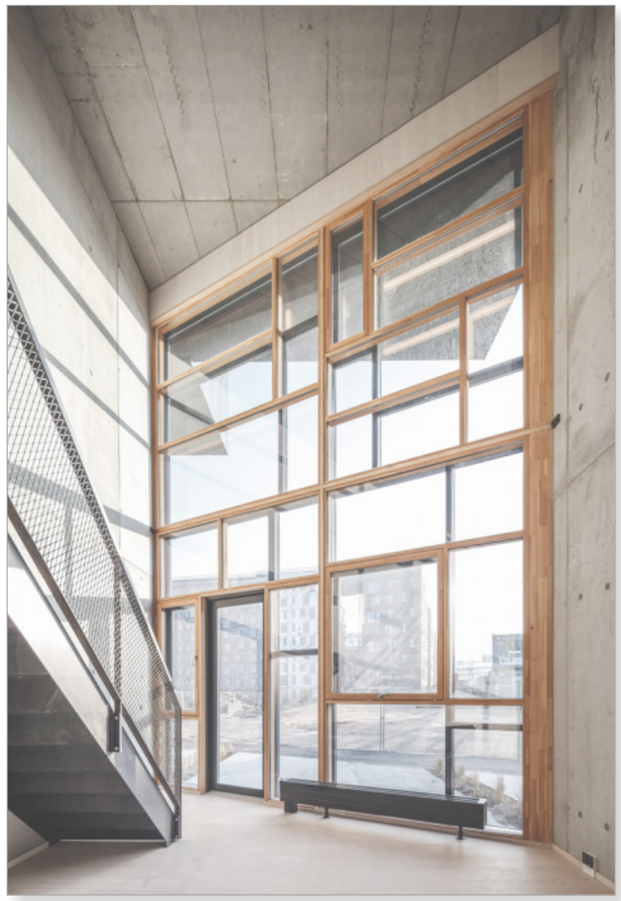
Using materials with a low carbon footprint was a design principle that was used to raise the sustainability profile of the project.

Figure 5 from Upcycle Studios shows that 75% of the windows come from abandoned houses in North Jutland, Denmark. In addition, 1400 tons of upcycled concrete are cast from highly durable concrete waste from the Copenhagen Metro construction (Lendager Group, n.d. (a))

In Copenhagen Towers in Ørestad, Figure 6, an upcycled concrete floor covering 1000m2 was designed by Lendager Group. The recycled concrete is visible on the new floor, giving it a varied and nearly stone-like texture (Lendager Group, n.d. (b))

The proposed beams and frames of the greenhouse structure were made of wood. The glass panels for the greenhouse would be made of reused glass from leftover windows. And the floor covering would be made of an upcycled concrete floor.

Upcycle concrete floor,Copenhagen Towers in Ørestad by Lendager group



Upcycle studios, Ørestad in Denmark by Lendager group

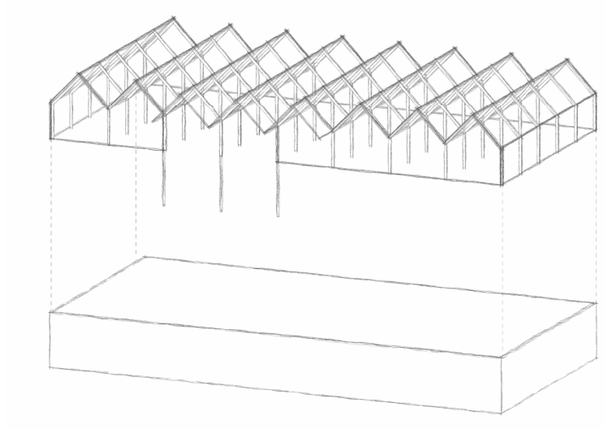
RESPONSIBLE CONSUMPTION AND PRODUCTION

CLIMATE ACTION

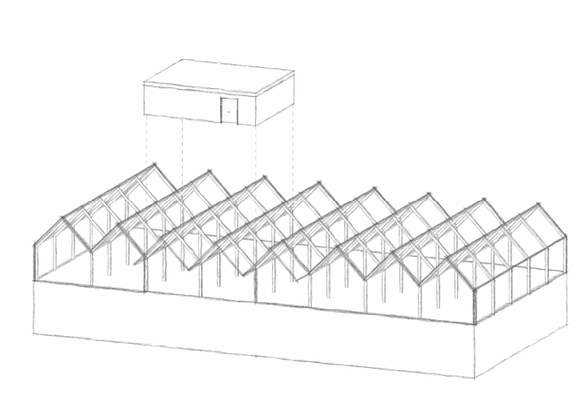
5. DESIGN PRPOSAL

DESIGN PROCESS

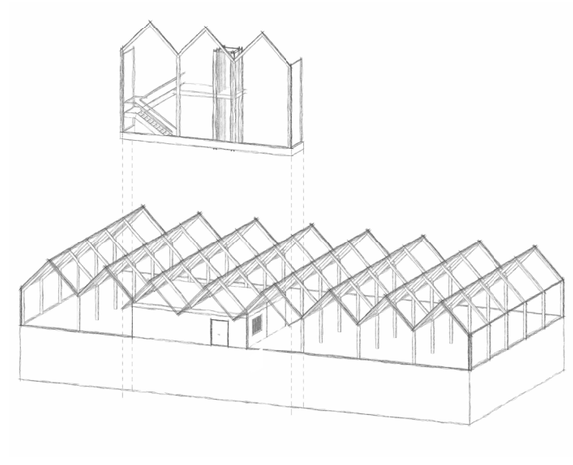
A series of interventions and decisions have been made during the sketch process on the design proposal. All have been based on the background and research that have already been presented, as well as the References.



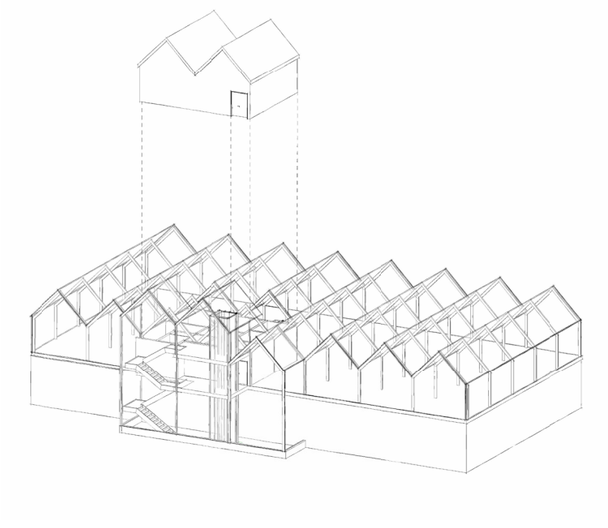
ADDING THE GREENHOUSE STRUCTURE



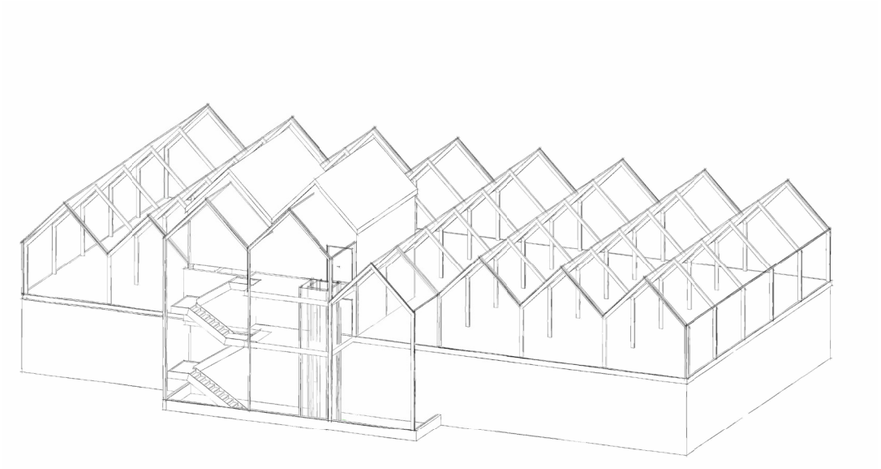
ADDING OTHER FUNCTIONS



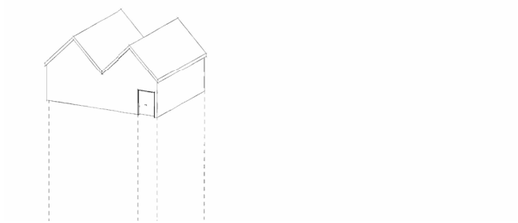
ACCESSIBILITY



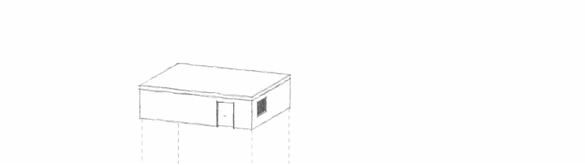
SHARED SPACE



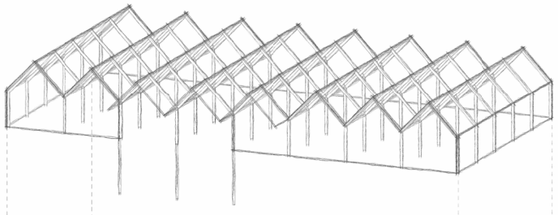
ACTIVITIES & FUNCTIONS



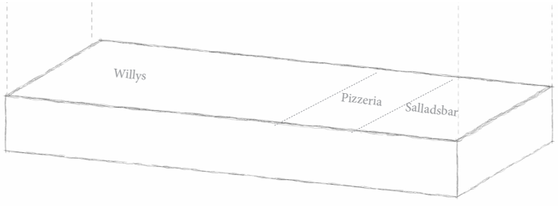
Shared Space
Local organizations & local residents



Administrative Functions
For running the rooftop farm

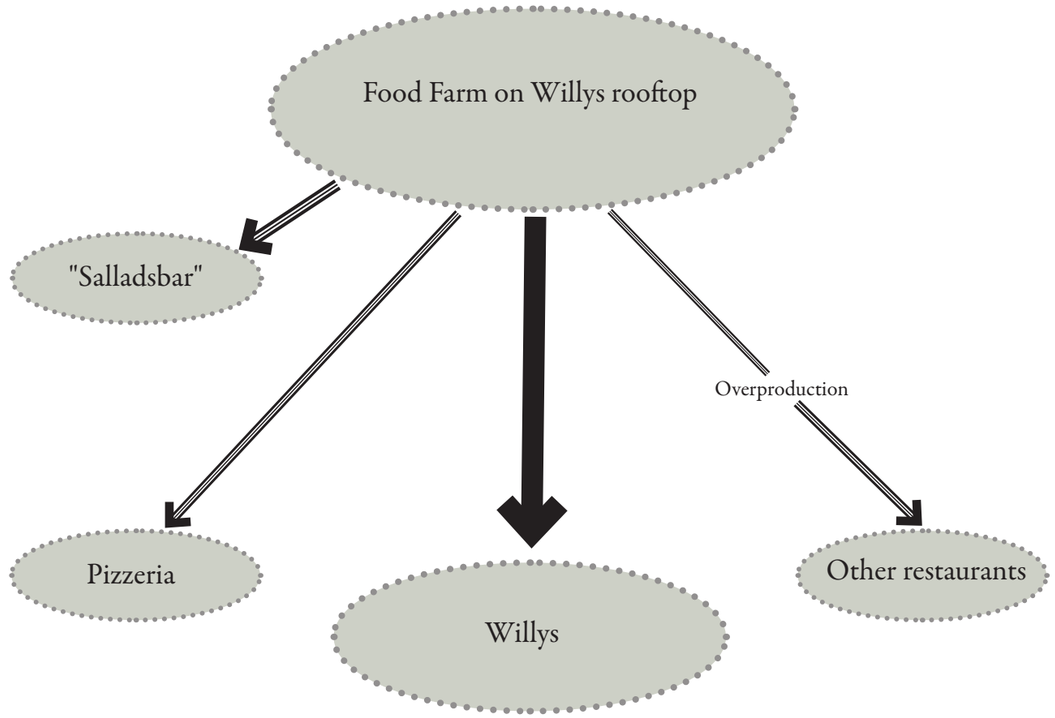


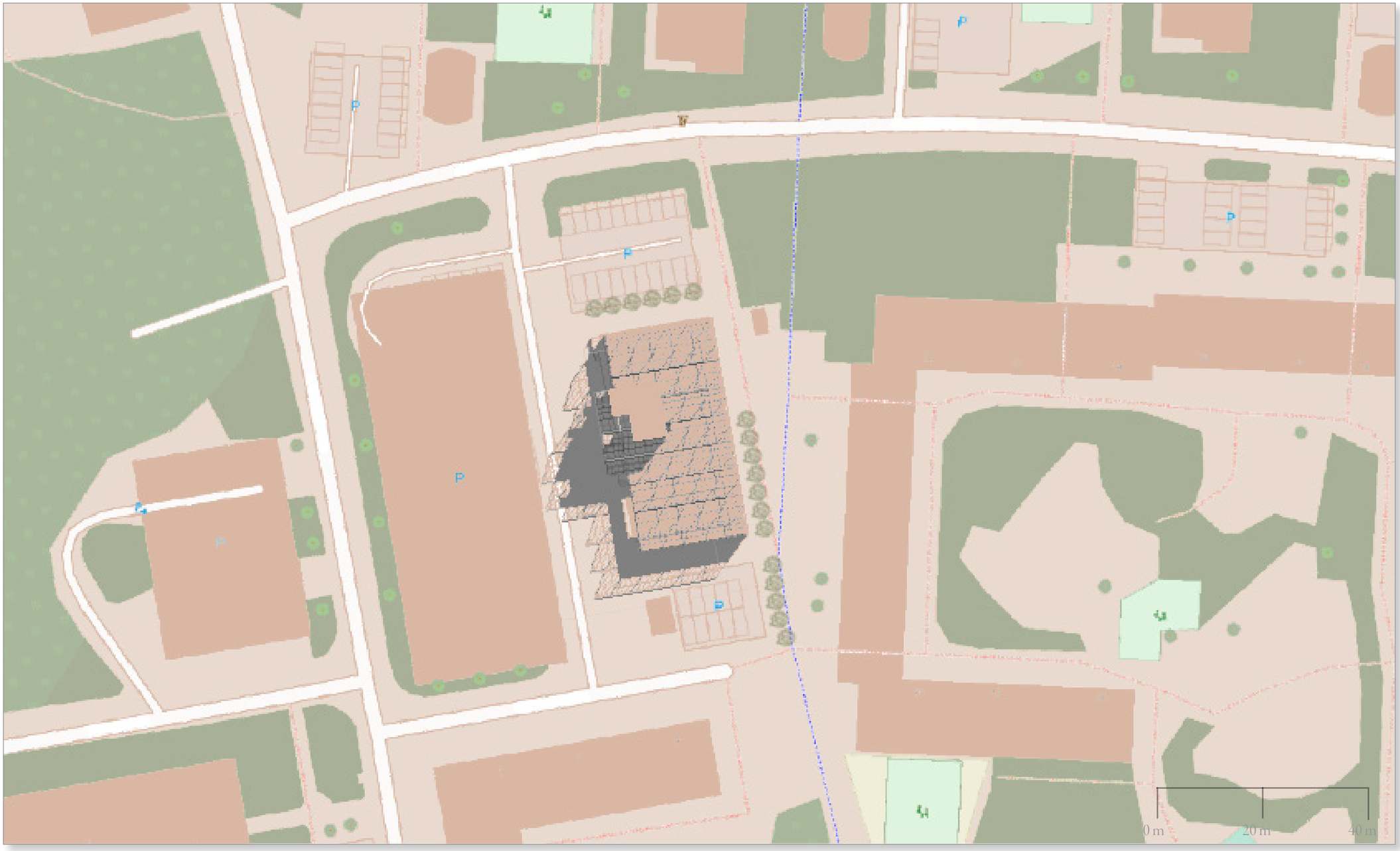
Greenhouse for food farming
Holding the aeroponic towers for food production

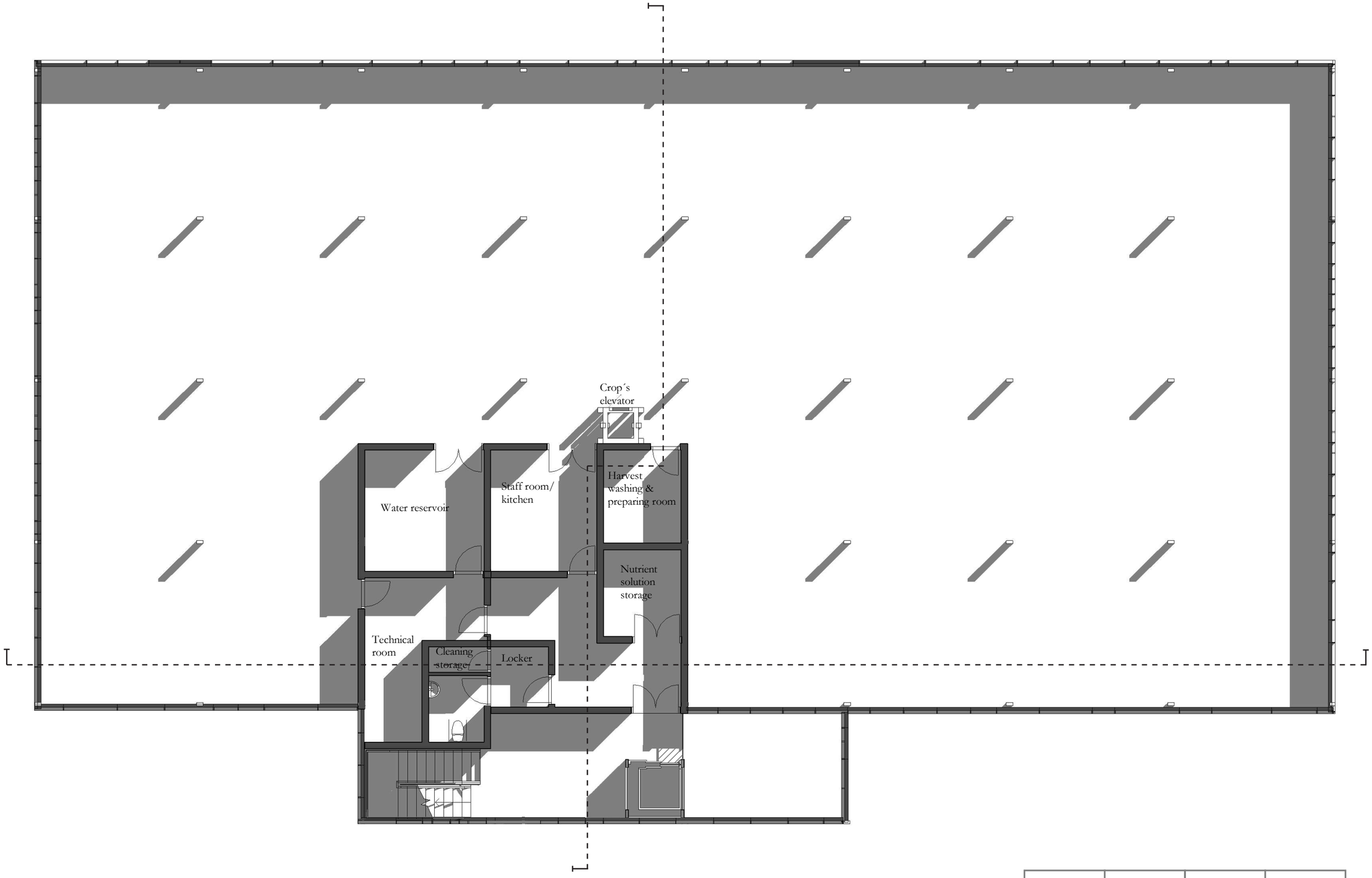


Willys, Pizzeria and Salladsbar
Are gaining the most benefits from crop yield on the rooftop

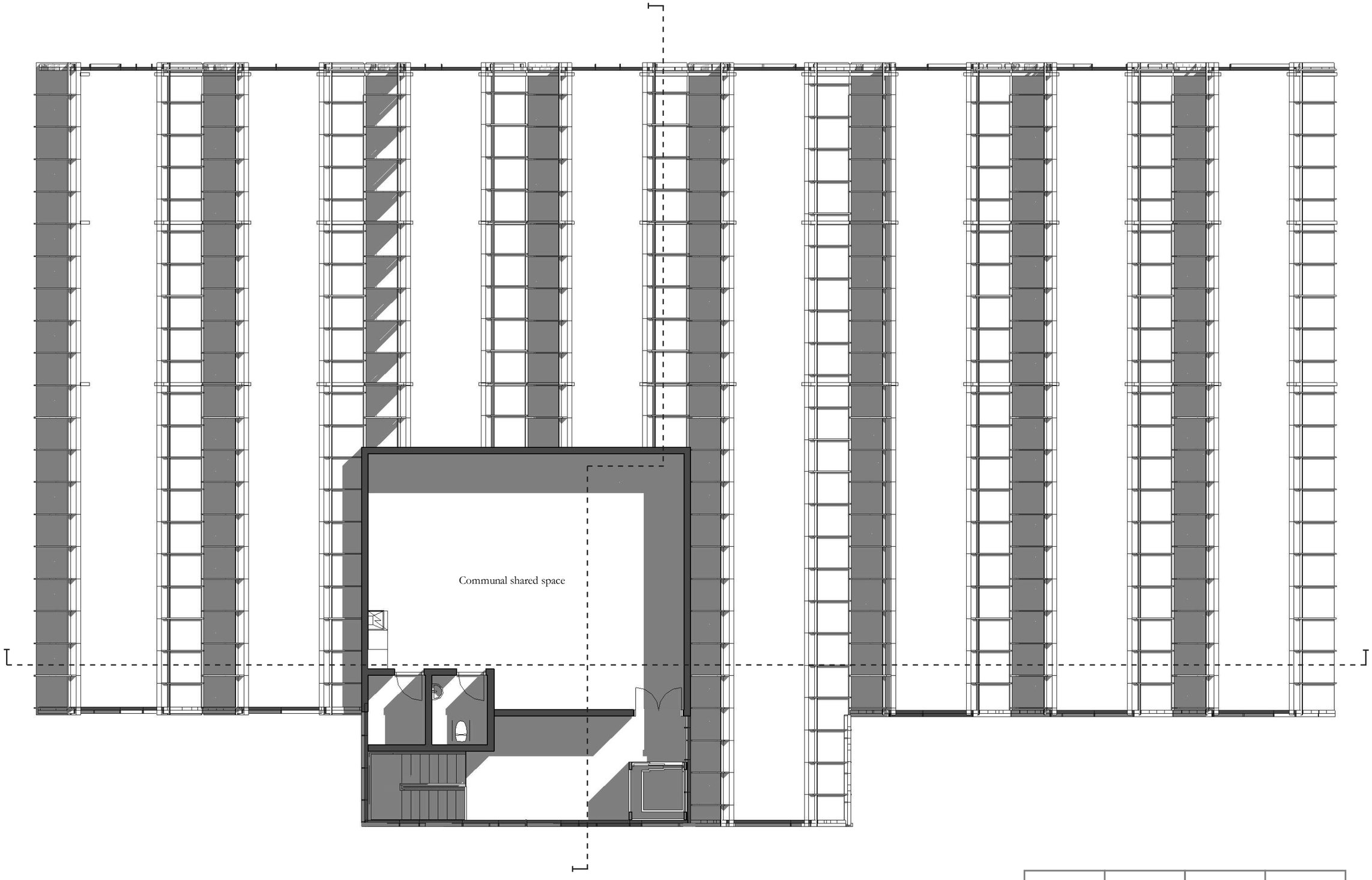
GREEN FLOW



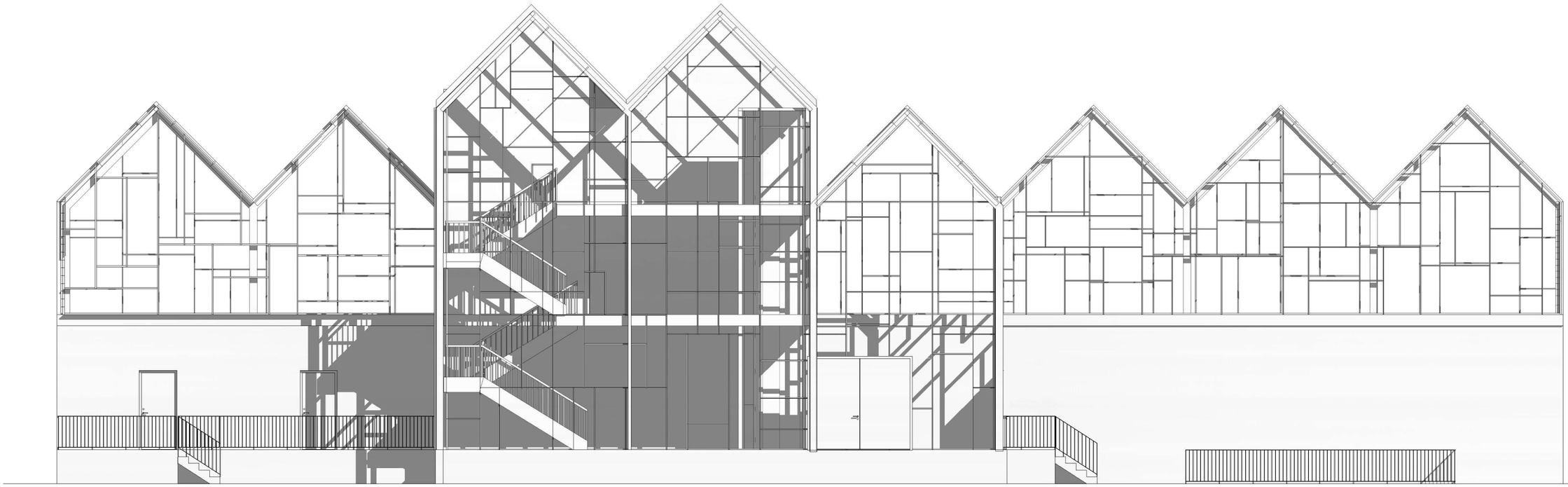

P
P
P
P
P
P
P
0 m
20 m
40 m


Crop´s elevator
Water reservoir
Staff room/ kitchen
Harvest washing & preparing room
Nutrient solution storage
Technical room
Cleaning storage
Locker
0 m
5 m
10 m

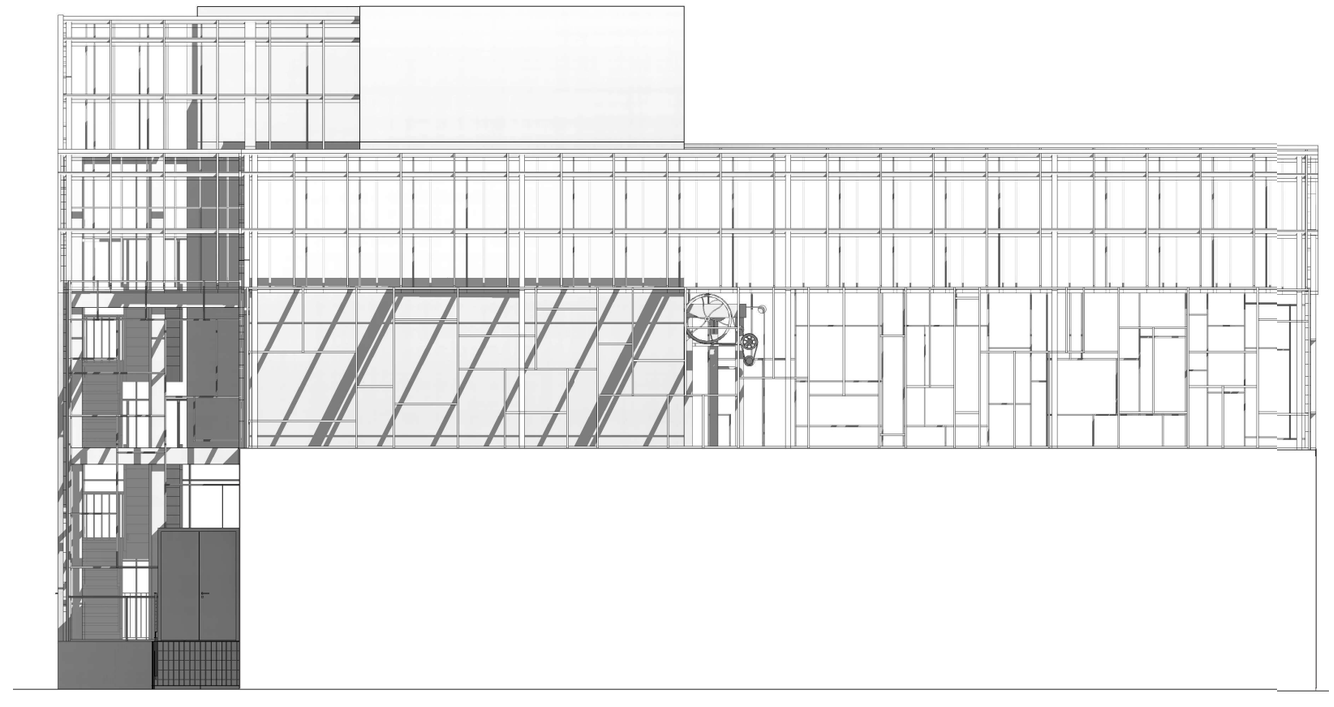
Level 1



Level 2

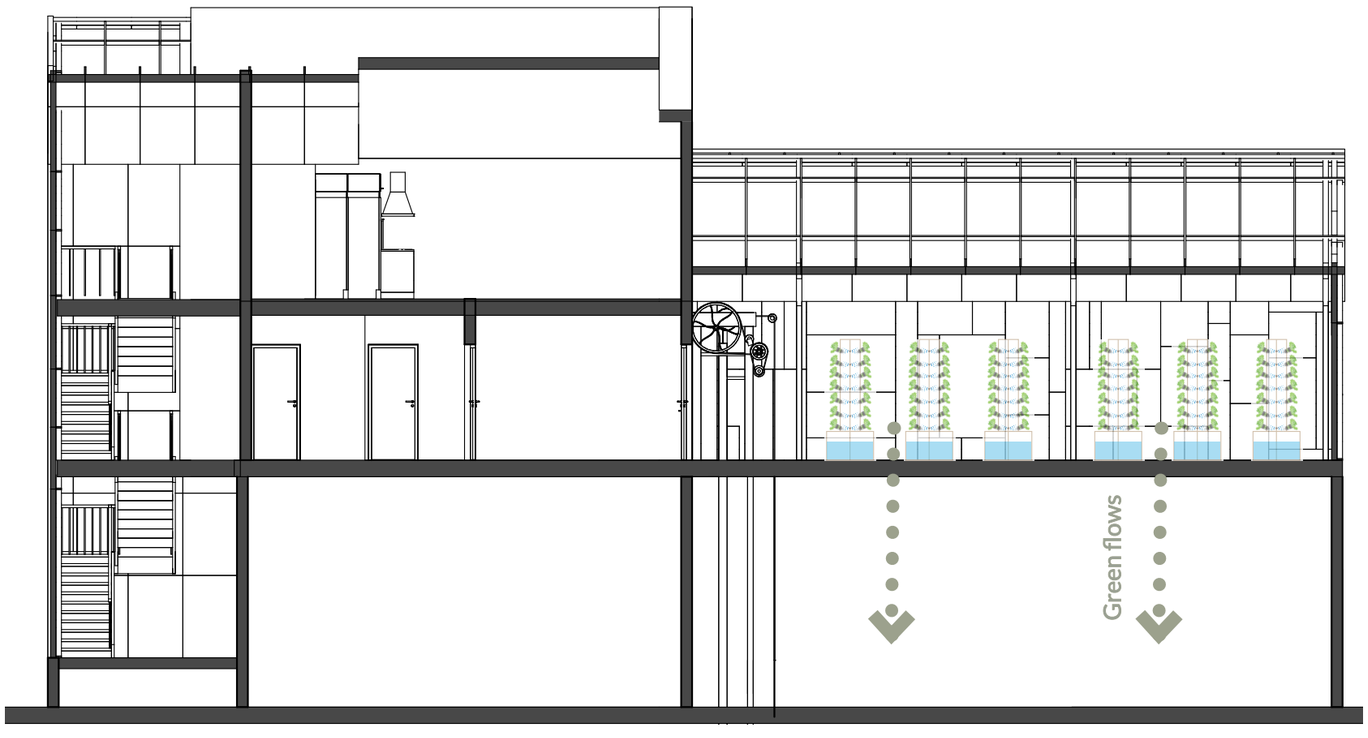


West elevation- main entrance for the roof



South elevation


Communal shared space
Technical room
Nutrient-solution storage
Salladsbar
Pizzeria
Willys
Green flows


Green flows

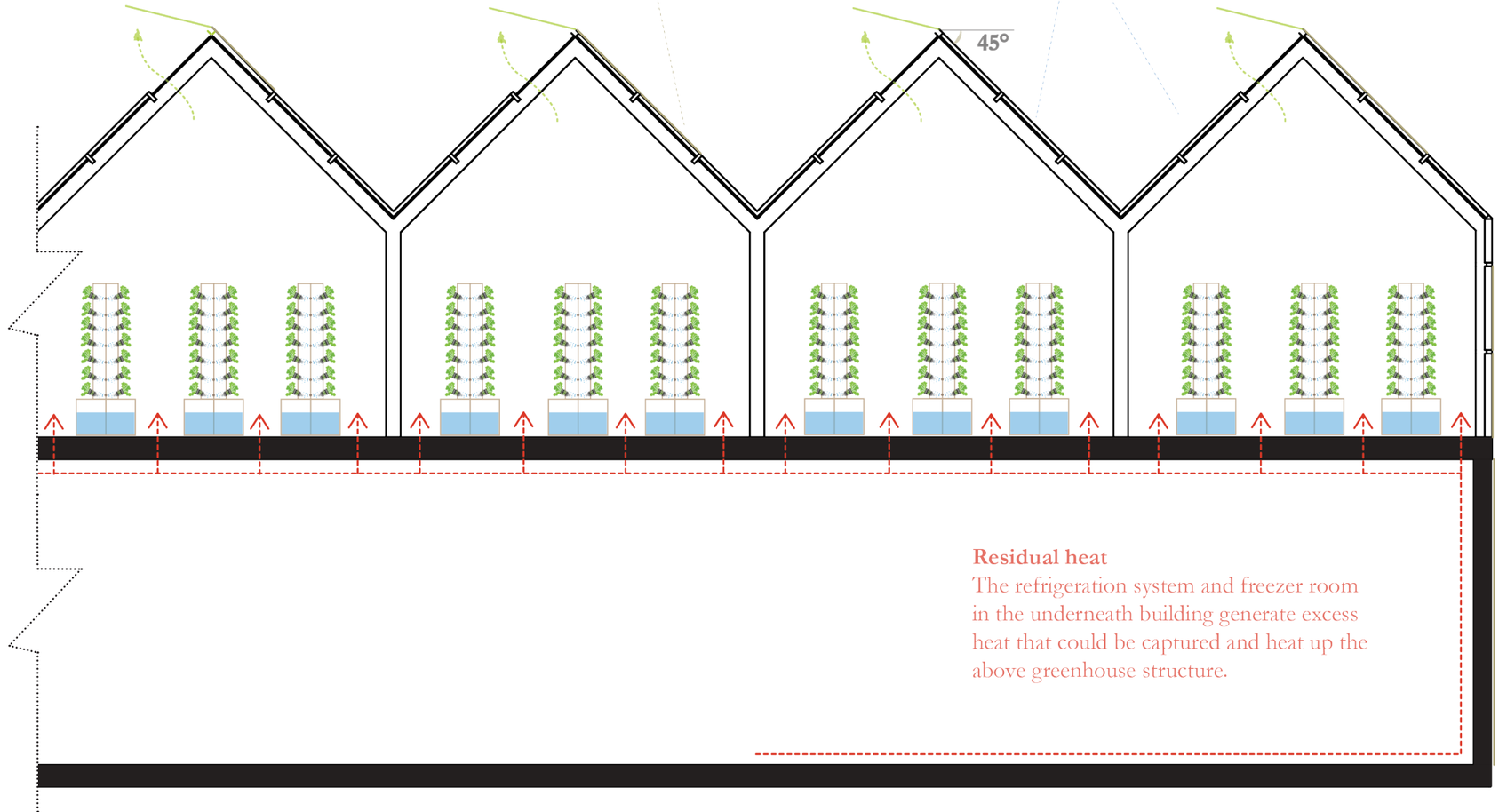

0 m
5 m
10 m


0 m
5 m
10 m

Ventilation windows towards the north
Sensors for carbon dioxide and humidity can be used in general for monitoring and controlling the indoor environment of the greenhouse.

Solar panels facing south
Generate electricity for pumps and LED lighting. Thin-film solar cells are easier to install on buildings due to their lightness, flexibility and the fact that they do not require heavy.

Reused glass from leftover windows
The choice of insulating glass or single glass is governed by carefully considered analyzes of cultivation period, crops etc.



Residual heat
The refrigeration system and freezer room in the underneath building generate excess heat that could be captured and heat up the above greenhouse structure.

RESPONSIBLE CONSUMPTION AND PRODUCTION

AFFORDABLE AND CLEAN ENERGY

CLIMATE ACTION

SCENES OF LIFE

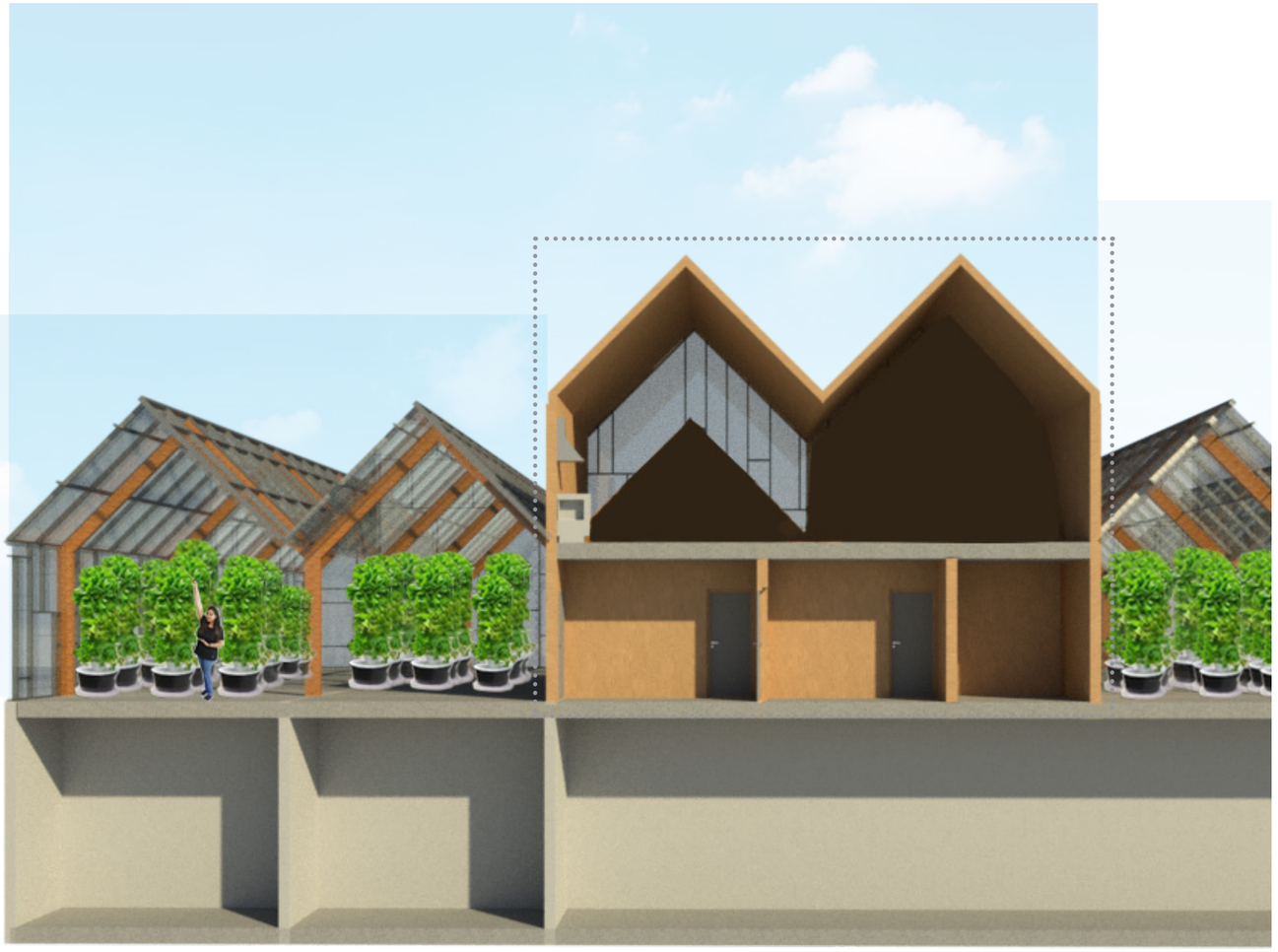
The previous analysis of the context shows that there is a need for a shared space in the area. The flexible design of the added shared space made it easy to adapt to different functions.

The shared space could hold cooking courses, catering, and educational courses for food production. It could function as a meeting space where locals gathered for meetings arranged by the home owner association and tenants' association.

Since almost half of the residents, there are living alone, in a cramped space adapted for one person per household, the shared space could hold resident parties.

The bottom level of Kaverös Centrum would gain the most benefits from crop yield on the rooftop, primarily in the supermarket where the crops would be sold on the supermarket's shelves. Moreover, the pizzeria and the salad bar could be provided with some greens grown on the rooftop farm.

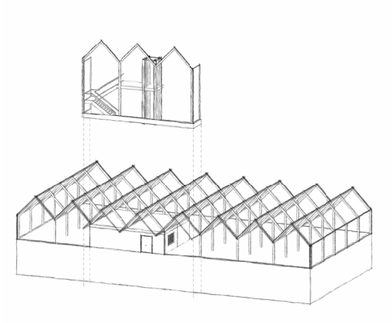
The communal shared space



INSIDE PERSPECTIVE

WELCOMING ENTRANCE

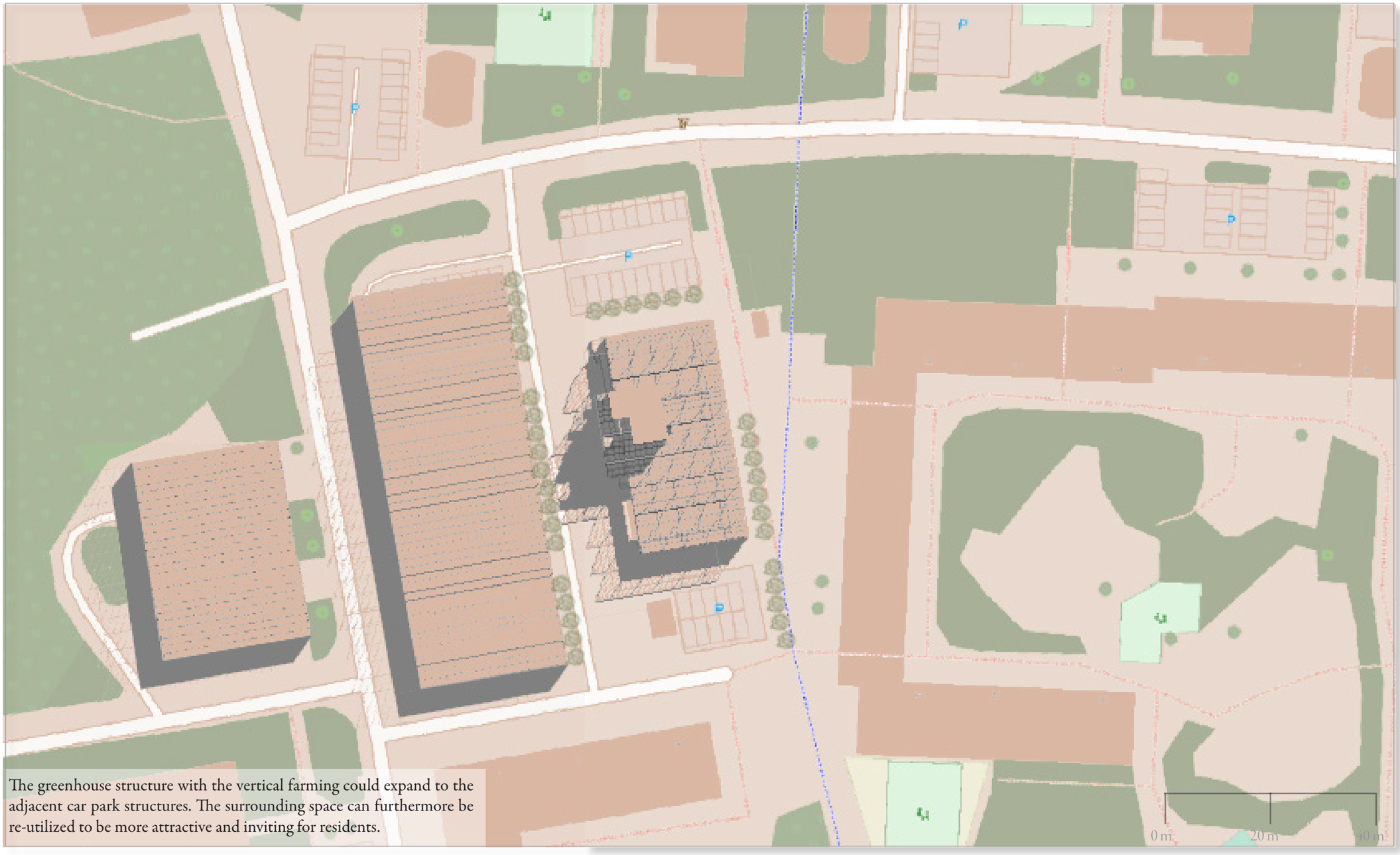
Turning a backside to a front side



One decision that tried to showcase the project's uniqueness was the appearance and placement of the extension of the building, where the staircase and the elevator work as a funnel to distribute people within the project.
The location at the backside of the supermarket has turned it into a front side. That solution has shifted the supermarket´s backside environment to a more safe, comfortable, and welcoming environment where the residents could spontaneously interact on their way.

SUSTAINABLE CITIES AND COMMUNITIES

SPACE MAKING



The greenhouse structure with the vertical farming could expand to the adjacent car park structures. The surrounding space can furthermore be re-utilized to be more attractive and inviting for residents.

6. DISCUSSION AND CONCLUSION

DISCUSSION & REFLECTIONS

The aim of this project was to investigate the possibility of retrofitting a supermarket ´s rooftop to grow its own crops in order to complement the food sales which is predominantly made up by imported fruit and vegetables. The thesis aim was to see how this could be incorporated into a supermarket and investigate how to use urban farming to promote sustainability.

Vertical farms have significant competitive benefits in terms of distribution, efficiency, crop variety, flexibility, and high yield per Square meter. The capacity to produce crops of constant quality and quantity year-round near consumers provides a distinct competitive advantage over traditional farming methods.

On the other hand, to supply plants with nutrients, vertical farms require specialized synthetic liquid fertilizers. Production of this type of fertilizer is unfortunately high in CO2 emissions. There is a need for huge investment in finding more sustainable methods of nutrient solution production and their delivery systems. Also establishing local production without the need for transportation. This investment contributes to overcoming this circularity gap and ensuring that urban agricultural solutions are indeed regenerative at scale. Furthermore, the initial costs of establishing, equipping, and running a vertical farm are higher than traditional farming, which may be a skeptical move to taking the lead in food production from an economic standpoint.

To fully capture the environmental benefits of greenhouse accompanied by vertical farms, farms should strive to follow the guidelines of the UN Sustainable Development Goals and the Gothenburg Environmental Management "Miljöförvaltningen", which are named in previous chapters, such as: using renewable energy, looping water, and avoiding synthetic pesticides to name a few. This implementation of these goals would be a crucial step toward rapidly improving the underneath supermarket's role in terms of sustainability. Renewable energy has been highlighted as a requirement for vertical farms to grow crops on a long-term basis. Furthermore, vertical farming can save up to 99% on water. Moreover, pesticides are fully avoided due to the controlled and closed environment generated by the greenhouse structures. The greenhouse accompanied by vertical farms can be linked to the district heating and ventilation systems of the buildings in which they are situated. A linked system reduces overall energy expenses and improves air quality in the underneath building.

In addition, a series of decisions were made in order to attempt a proliferation of local engagement in the surrounding area. The concept was that rooftop farming on a grocery store could be a catalyst for sustainable encouragement. That physical and aesthetic design could help to inspire a sustainable lifestyle. The location of functions and visual relationships, for example, might send out signals that may influence public perceptions of the project as a whole.

The placement of the greenhouse on the top made it very visible. Hence becoming a symbol for local food production. It can also reinforce the locals' identity and

strengthen the cohesion between the people and the building. The greenhouse structures with the vertical farming could expand to the adjacent car park structure. The surrounding space can furthermore be re-utilized to be more attractive and inviting for residents.

Furthermore, another design principle was to use wood as a construction material and reused glass from leftover windows. Using materials with a low carbon footprint strengthens the project in terms of sustainability.

In fact, cities become sites for both providing and consuming food crops when food is produced within them. Crop consumers are individuals who live close to the producing location. This endeavor at localization assists in the reduction of expenses, pollution, and a variety of other issues. It promotes a 'local for local' lifestyle that shortens the path between food production and consumption, this eliminates food spoilage as well as the need of packaging agricultural crops. Thus, the environment remains protected whereas more energy is saved.

To reduce the fundamental risks of establishing an urban rooftop farm, the author believes that actors aiming for large-scale output should first consider small-scale farms. A small-scale rooftop farm is easier to monitor and operate, and it can respond to customer need more rapidly. Connecting the farm directly to an established sales channel can help small-scale farms reduce their high initial costs and enhance their profitability. Small farms take advantage of their ability to build deeper ties with their consumers and save distribution time.

Since there are no other year-round alternatives to locally grown foods in Sweden, the threat of competition in the targeted grocery market is now quite low. While the number of vertical farms in Sweden is growing, none has reached the stage where it prevents competitors from entering. However, it is also difficult to say which organization would be interested in running the food production and subsequent activities such as organizing lectures and renting out the communal shared space. There is a general interest from people to act locally and hopefully this will attract new green businesses to establish themselves in Gothenburg.

CONCLUSION

During the research, I realized that urban rooftop farming entails a complicated set of interconnected issues and factors. Many interdisciplinary viewpoints and approaches contribute to a broad and complex understanding of the effects of urban farming on us individuals, the environment, the city, and society. On both small and large scales, many stakeholders should be involved in the design process. This includes a more difficult task to deal with at a rooftop farm on a grocery store, but it also has great potential to reach many goals in terms of sustainability.

To conclude, a basic knowledge of greenhouses accompanied by vertical farms can significantly improve food security and viability. Aeroponic systems, for example, have not only revolutionized the greenhouse industry but have as well as opening up new avenues for new types of farming, such as rooftop farming. The industrial application of this approach, with a larger yield and better circumstances, would be a crucial step toward rapidly improving food production in an urban environment.

Furthermore, vertical farming has paved the way for architecture and urban design. Architects and urban designers have spoken out about how important it is to make cities green, resilient, and safe. Vertical farms contribute to the construction of multi-functional buildings by merging food production with architecture. This is complemented by several social and environmental benefits.

This thesis indicates that Sweden is a promising country with the proper conditions to integrate and adapt new technologies and build on the success of vertical farms worldwide. Greenhouse accompanied by vertical farms would be a step advance in decreasing the environmental damage of traditional agricultural techniques while also allowing for the continuous production of high-quality greens in urban settings.

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