growing maribor

a research vertical farm for the city maribor

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THANK YOU

Thank you Univ.-Prof. B.Sc.(Hons). CEng MCIBSE Brian Cody and Mag.arch. Daniel Podmirseg for guiding me through the thesis and supporting me.

Special thanks to my boyfriend who had to keep up with me during the thesis. I would also like to thank Nea, who supported me during the work. Thank you, my friend and family. I could not finish the thesis without your support.

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growing

growing food for the growing population

GROWING...

In 2008 the world's urban population outnumbered the rural population for the first time. Urbanity is becoming the prevailing way of living. Considering the fact that by 2030 60 % of the world's population will be living in the cities and this process goes together closely with the growing urban poverty and insecurity, there is another quality that the city of the 21. Century should have- the ability to secure food for its inhabitants in a sustainable way. [1]

People are becoming more and more aware of the problems we will face in the near future due to the rising population and at the same time the increasing urbanisation. For example it is expected that by 2050 the cereal area will decrease below 0.08 ha per capita, below the global (not just regional) critical threshold of food security. Import of increasingly scarce amounts of food per inhabitant of the planet will therefore be very difficult especially for countries with low geopolitical weight.

1 cf.Food for the cities, 2.

Considering that by now we are already using 80% of the arable land. Today the 7 billion inhabitants need an area of entire South America (17.840.000 km^2) to feed them. It is estimated that by 2050 the world population will reach 9 billion inhabitants and will need an additional area of Brazil (8.515.767 km^2) to satisfy their need for food. [2]

This means that with the rising population we are slowly running out of land suitable for food production and we must look for alternative ways of food production.

Dušan Plut, one of the leading environmental experts in Slovenia sees potential in food production in the urban areas:

"It should be noted that the present expansion of agricultural land caused excessive felling of tropical forests, the spreading of deserts salted soils. Certain possibilities are also in food production on urban land (private gardens, the roofs of buildings)."[3]

More recently, urban agriculture (UA) is experiencing a renaissance. Significant amounts of food are cultivated by entrepreneurial producers, community gardeners, backyard gardeners and even food banks, in vacant lots, parks, greenhouses, roof tops, balconies, window sills, ponds, rivers, and estuaries. The poten-

2 cf.Despommier 2010, 96
3 Plut 2011, 2.

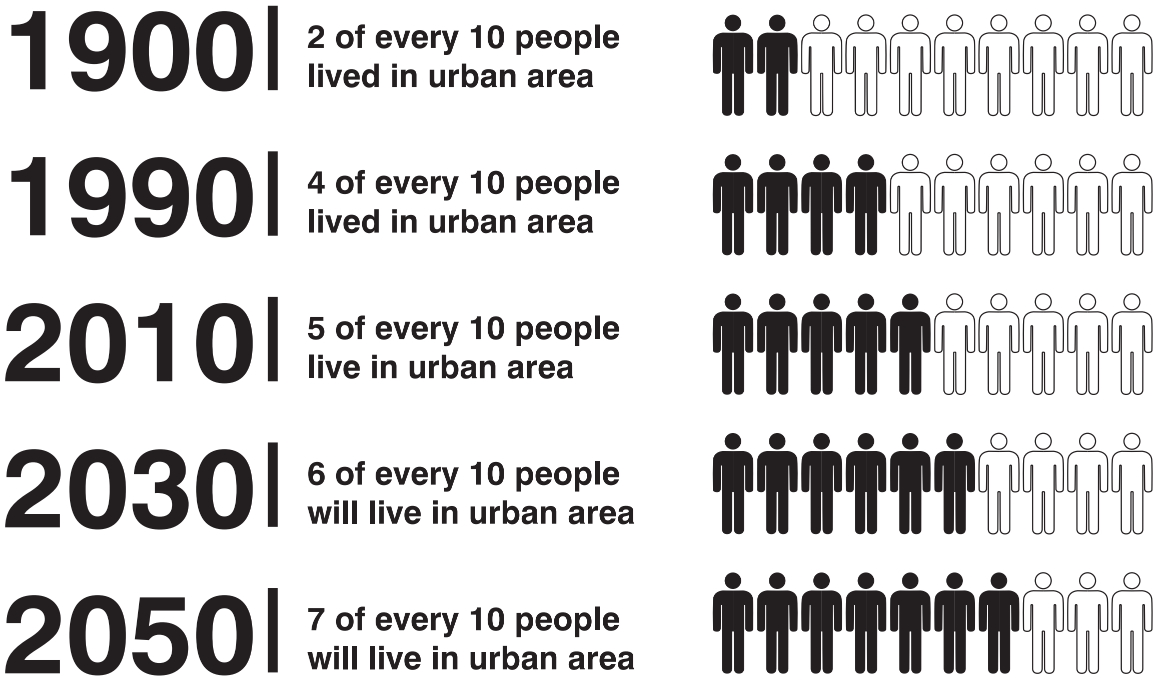


FIG 1 Increasing urbanization

tial to expand urban production is enormous. One third of the 2 million farms in the United States alone are located within metropolitan areas, and produce 35 % of U.S. vegetables, fruit, livestock, poultry, and fish.[4]

Urban area food production can operate at a for-profit farm scale, producing high quality fresh foods (including protein-rich production) on relatively small amounts of space that include aquaculture, hydroponics, and greenhouses.

Luc Mougeot, one of the world's leading experts, defines urban agriculture as follows:

"Urban agriculture is located within (intra-urban) or on the fringe (peri-urban) of a town, a city or a metropolis, and grows or raises, processes and distributes a diversity of food and non-food products, (re-)uses largely human and material resources, products and services found in and around that urban area, and in turn supplies human and material resources, products and services largely to that urban area." [5]

Urban agriculture tackles the problems the two global challenges: urbanization and food security. It can provide an important contribution to sustainable, resilient urban development and the creation and maintenance of multifunctional urban landscapes. In the globally emerging research field of UA, a European approach to the subject needs to be created. It has to integrate the unique European context regarding its urban and landscape pattern, the important role of the Common Agriculture Policy (CAP) and the needs of the European society. [6]

The development of cities, agriculture and architecture should respond to the upcoming challenges of urbanization and should be able to provide food security. By integrating urban agriculture new ways of creating cities and architecture are offered. A new kind of urban agriculture was proposed by Dickson Despommier. He suggests that crops could be grown in a multi-story building in a controlled environment save from severe weather, insects and diseases. These so called vertical farms (VF) could be in the urban areas reducing food miles and the carbon footprint of the produce.

In the following work we will discuss the development and perspectives of vertical farming in the city Maribor. The goal of the master thesis will be creating a research vertical farm in combination with other functions that would help to revitalize the selected area and that would offer now knowledge on vertical farming. We would like to rethink the current image of a vertical farm as an laboratory for growing food into an image where a vertical farm in an vital part of the community living.

4 cf.Kaufman/Baikley 2000.

5 Profitability and sustainability 2007, 6.

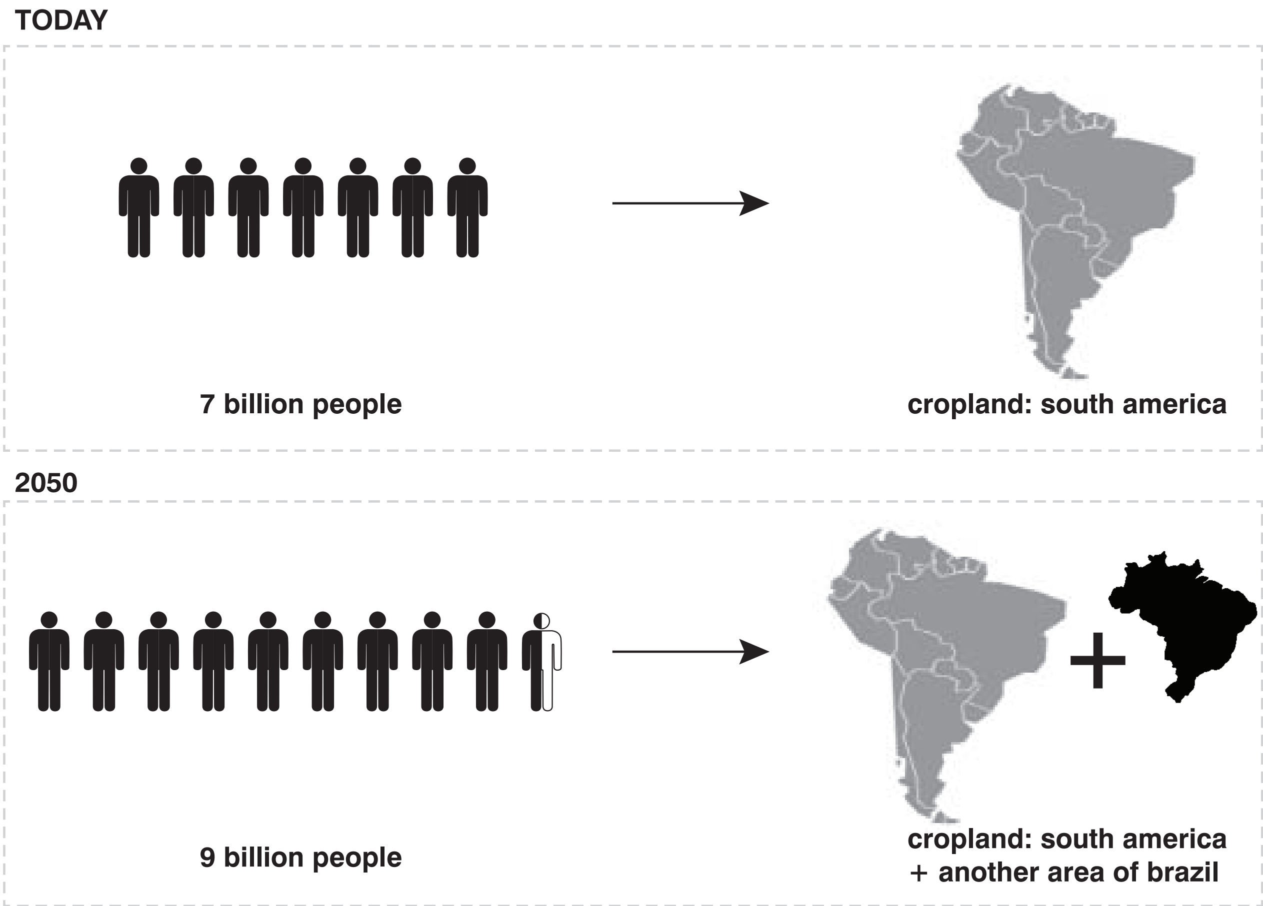


FIG 2 Increasing population and cropneeds

about urban agriculture

URBAN AGRICULTURE AND ITS IMPACTS

Since vertical farming is a way of urban farming, main characteristics of urban farming will be introduced in this chapter.

Urban agriculture (also peri-urban agriculture) is growing plants and raising animals within or around the cities. It provides food products as well as non-food products (herbs, ornamental plants, tree products, etc.). It contributes to food availability, provides employment on a local scale, creates income and contributes to food security and nutrition quality of urban and reduces global food scarcity.

In the following part we will examine the impacts of urban agriculture on different areas:

- Environmental
- Social
- Economic

ENVIROMENTAL IMPACTS

The current problems in modern agriculture are high energy costs and resource input for the production of food and its transportation. It is been calculated that an average food item in America travels 2400 km. This phenomenon is described as **food miles**.[1] By the time the imported food reaches our dining table it will have used hundred times as much energy as the calories it actually contains.

But it is not just the food transport that uses so much energy. Frozen fish form Atlantic embodies some 100 times more energy than its caloric value. Also meat produced nearby our homes can embody 50 times more energy. The average fossil energy input for all the animal protein production systems is 25 kcal of fossil energy input per 1 kcal of protein produced. This energy input is more than 11 times higher

1 cf. Pirog/Benjamin 2003, 3.

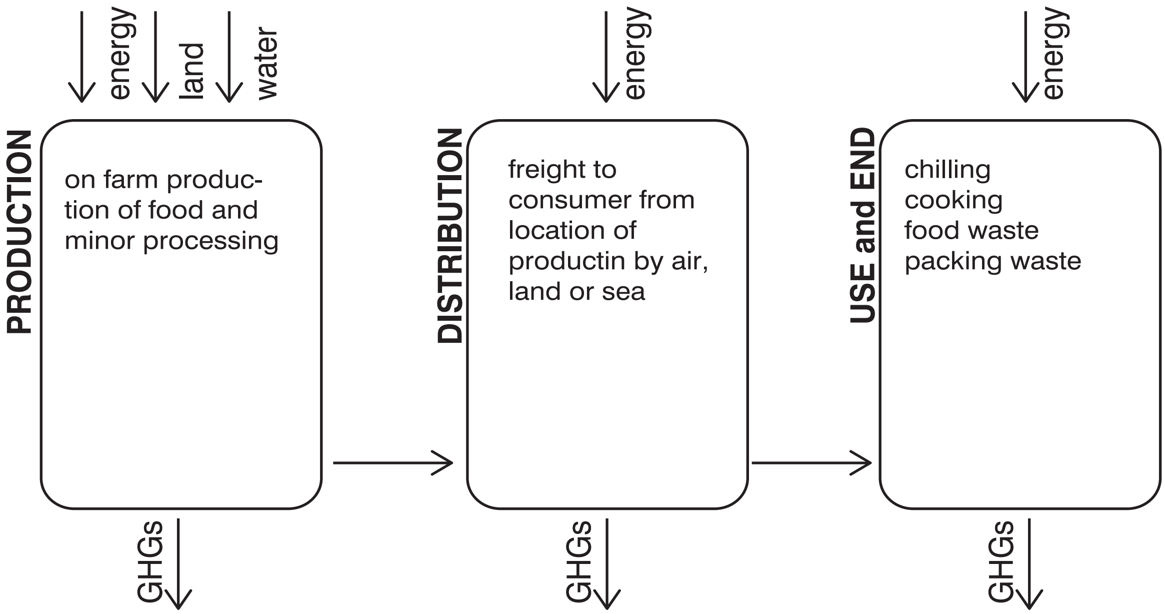


FIG 3 Life Cycle Assessment of food

than that for grain protein production, which is about 2.2 kcal of fossil energy per 1 kcal of plant protein produced. **The production of food often uses more energy than the products kcal value.**[2]

A positive impact of urban farming is that it reduces the amount of C02 emissions by **reducing the amount of transport needed.**

Plants grown in cities **act as carbon sinks.** The plants absorb Carbon Dioxide and release breathable Oxygen in exchange. According to the research of Bradley Rowe 1 sqm of green roof can offset the annual particulate matter emissions of a car.[3] In addition the plants in the city also reduce the amount of particulates and ozone gases and contribute to the health conditions of the citizens.

Urban farms often have to **decontaminate the soil** before getting started. We can briefly divide the methods of decontamination in physical (excavation of contaminated soil, using geotextiles to provide a barrier, soil washing, soil vapour) and biological (degrading contaminates with microbes, using plants or fungus to extract contaminants, adding compost). UA is also preventing that plots become illegal dumping places.[4]

2 cf.Girardet 2005,33
3 cf.Rowe 2010, 1-11.
4 cf.Heinegg, 2-6

Modern agriculture is a big consumer of fresh water. Western agricultural irrigation accounts for 85% of the fresh water consumed. The water required to produce various foods and forage crops ranges from 500 to 2000 L of water per kilogram of crop produced.

Producing 1 kg of animal protein requires about 100 times more water than producing 1 kg of grain protein (8). Livestock directly uses only 1.3% of the total water used in agriculture. However, when the water required for forage and grain production is included, the water requirements for livestock production dramatically increase. For example, producing 1 kg of fresh beef may require about 13 kg of grain and 30 kg of hay. This much forage and grain requires about 100 000 L of water to produce the 100 kg of hay, and 5400 L for the 4 kg of grain.[5]

UA although often **use water more efficiently.** For example by harvesting rainwater or grey water from the nearby buildings. UA is using techniques like sheet mulching, forming swales and basins, drip-irrigations, etc. to reduce the quantity of water.[6]

Waste, among also organic waste, is representing a big problem for the cities. Urban agriculture **offers the possibility to reduce especially organic waste** by implementing it in the scheme of urban agriculture. Not only

5 Pimentel, 1.
6 cf Nolasco.

that we can reduce the amount of waste, we can also reduce the waste miles by treating waste in the city. The advantages of UA in using waste are the number of jobs created in the waste management sector, lower collection and final disposal costs as the result of recycling, lower production costs by using the organic compost instead of agrochemicals and the reduction of risks to public health by decreasing environmental pollution in the reduction of the volume of waste. Waste treating can also be used as a tool to produce heat and electricity.[7]

7 cf Recycling organic wastest in urban agriculture.

SOCIAL IMPACTS

With the term social impacts of UA we are thinking on the way something influences the social relationships in the community and among its residents. It can regard the relationships between humans or between the people and the build environments.

Urban farming is **creating save places**. Community gardens and urban farms offer safety and improve the physical space of neighbourhoods. Researches have been made that show how UA beautified the neighbourhoods and improved the conditions in the area offering employment and better health conditions by providing fresher and healthier crops to the locals. The residents developed more local pride and became more attached to the space. The result of these was also the decrease of vandalism.

Urban agriculture offers the residents **access to land which is sometimes limited in urban areas**. It is difficult to secure space for residents to grow food and gardens since most of the urban land is owned by corporations or is private. Also in peri-urban areas the farmland is constantly threatened by profit-yielding commercial and housing development. Therefore, in some places a special system is developed where nearby living people become stakeholders and invest in the nearby farms and in return they always have access to fresh products near their homes. The piece of land which the urban farmers can call their own for a season develops a sense of pride and ownership.

It is observed that urban farming goes beyond just growing food. At the same time it is **enhancing community development and building social capital**. Many papers analysed how the interactions in urban gardens involved decision-making and planning processes that required consensus, making community gardens important places for fostering democratic values and citizen engagement. Urban farmers improved skills like self-determination, self-reliance and activism and have improved self-esteem. Frequent interactions between consumers and producers fostered strong relationships between them. Also the farmers markets became an important place for gathering.

Another positive impact of urban gardening is the **providing a learning experience opportunities for youth development**. People became more aware of environmental issues and ethics, learn about food growing and sustainability. Residents became more actively involved in questions concerning these topics.

Urban agriculture is also a way to **promote cultural and cross-generational integration**. Different programs have been developed to allow immigrants to cultivate and sell food. A positive effect of these is that other residents become familiar with the habits of the immigrants and at the same time the immigrants have contact with the local resident and can infiltrate easier. These gardens are also an ideal opportunity that the seniors can pass their knowledge to the youth.

Urban agriculture also leads to **community food security** not only in conflict times like war but also in overcoming crises by sharing food with family, friends and needy members of the community. Many programs have been launched to support this kind of generosity.

The benefits of urban agriculture on health are gaining increased recognition of health professionals. Growing food and other crops **contributes to a healthy community by engaging residents in work, providing recreation, spending time outside and improves individual and public well-being**. At the 1996 United Nations International Conference on Human Habitats in Istanbul, urban agriculture was formally recognized for the first time for its contribution to the health and welfare of fast growing urban populations worldwide. Since that time, related research, practice, and policy development have blossomed, although an acceptance of urban agriculture proved faster originally in the global South than in the North. [8]

8 cf Golden 2013, 6-11.

ECONOMIC BENEFITS

The economic value of UA is difficult to put out in numbers. It is not just a simple exchange of money against the products; UA also offers a different approach to life and food and is competing against supermarkets on many other than just economic levels. It is an important income for a large number of people, especially in the countries in development. The households are able to increase their income from sales of the produce and are at the same time saving money on household expenditures by growing their own food. Especially poor people spend a big part of their income on food. The profits cannot be generalized due to different seasons, cities and the policy conditions.

AT HOUSEHOLD LEVEL we are taking into account the direct economic benefits and costs that are involved with the agricultural production. UA is considered as **a profitable undertaking**, especially when producing products of high demand like green leafy vegetables, mushrooms, flowers and ornamental plants. UA can help to reduce the expenditures on food and raise some additional income. This is especially helpful for low-income groups.

Important **factors influencing the profitability of UA** are the degree of market orientation, the size, the labour availability in the household, choice of crops and animals, the availability and cost of basic inputs, the use of local resources such as wastewater and organic waste, the available technology, the possibility to access the market and to generate additional value to the produce through processing and marketing activities (for example food preparation, cleaning and packing the food for supermarkets, etc.).

AT CITY LEVEL UA can be an important strategy. In the time of growing urban population UA is able to ensure nutritious food, savings and additional income and offer the possibility to improve the living conditions for people operating outside the formal sector.

The economic benefits in form of **extra income and a higher employment** are weighted against t**he costs of the assistance supplied to the urban farmers**. The city can or should support the urban farmers by offering them training and knowledge, controlling the quality of the produced goods etc. External costs and benefits of the social, health and environmental benefits must also be considered.

The **city should have adequate policies, legislation** and support for urban farmers. By having a functional system for urban farming the positive impacts of UA are enhanced and the risks connected with it are minimized.

UA also contributes to the **development of enterprises connected to agriculture** such as the production of compost, bio-pesticides, small-scale irrigation equipment, but also enterprises connected with product processing (cooking, packing, marketing, etc) .

The access to healthy food and the urban food security are some of the most important asset of UA. They quantity of food produced in urban and peri-urban areas represents an important economic value. Because of the proximity of the production site and a shorter distribution chain **the food produced in urban areas can be cheaper than the food produced in rural areas**. There is less transport, cold storage, losses, processing and packing and at the same time the access to food is improved.

To be honest we must also consider the negative impacts of UA and the cost related to it. Eventual negative impact on the health include potential impact of polluted irrigation water, pesticide use, soil nutrient depletion and in some regions also malaria. The **external costs of UA can include pollution and remediation** where chemical inputs are used.

In review we see that that UA contributes to the economy in form of additional income, micro-enterprise development and employment and also contributes to food security and a better nutrition of the urban dwellers. It uses waste as a resource, but at the same times it can have negative impact (if not done correctly) on health and to a minor degree on urban environment (if chemicals are being use for example). There are not many information how to estimate the economic value. **If also the socio-economic effects are taken into account, the UA is clearly profitable on the city level**.

There are no accurate statistics about the effects of urban gardening **ON A MACRO-ECONOMIC LEVEL.** If we take into account that in the urban areas of lower income countries between 40-70 % of the household budget is spend on food and fuel it is clear that UA can make **a significant contribution to a city's aggregate demand and domestic product**. Also UA contributes to **the development of related industries** such as tool manufacture, storage and processing of food and is indirectly generating output and income. External benefits in form of cost-saving in the sector of waste and water management must also be taken in account. Improvement of air quality due UA may lead to better health of the population.

The **external costs of UA can include pollution and remediation where chemical inputs are used**. They can also include transport related activities although these are lower than those associated with imported produce. [9]

An important aspect of UA is that it can act as a buffer to domestic and economic shocks.[10]

9 cf Profitability and sustainability, 31-53.
10 cf Petts 2005, 75.

towards vertical farming

a historic overview from UA to VF

URBAN AGRICULTURE DEVELOPMENT

The idea of growing food in the city is as old as the civilization. It was in the last 200 years since that millennium old positive relationship has deteriorated into a further and further separation of town and landscape.

The earliest archaeological evidences of urban farming date back 4000 BC when Persians used aqueducts to guide water from the mountains to the city where intensive food production was conducted based on the use of urban waste within the settlement.[1] Before the Industrial Revolution it was necessary to grow food near to the town since there were no high capacity transport systems or preservation techniques such as refrigeration. The buildings were interspersed with kitchen gardens and farms that were delivering food to the inhabitants. Also it is to mention that the cities were smaller. For example, London was concentrated within a radius of 1,5 miles ensuring that virtually all of its inhabitants lived close to the countryside-their source of food.

The industrial revolution separated the city from its food production. The sheer scale of the industrial cities with their dense urban development was an unhealthy environment for its inhabitants. One attempt to reintroduce green back to the city was the development of municipal parks.

In the early 19. Century allotments were established in Great Britain with the function to provide a nutritional and economic safety net against unemployment or to supplement meagre incomes. A similar development was the Strebergärten in Germany.

Urban food growing, allotments in particular, featured prominently in Ebenezar Howard's Green Cities of Tomorrow published in 1898. In the book he envisaged the dispersal of the population form overcrowded industrial cities to new towns located near the parent city but separated trough a green belt. Food production within or around the city was a crucial element of the green city. Residential space was divided into plots of 20 by 130 feet, which should ensure food for a family of 5 people. The green cities like Welwyn and Letchworth never achieved self-sufficiency.

1 Viljoen 2005, ix.

Le Corbusier's work The City of Tomorrow and its Planning probably had the greatest international influence on architecture and urban planning of the 20 century. Among other things he describes how urban agriculture could be accommodated without reducing the overall density of suburbs. Analyzing a typical suburban housing plot of 400 m2 he proposes allocating 150 m2 to a communal market garden. He sees agricultural land as one of the city's layers.

Frank Lloyd Wright takes a different position. In his book The Living City he writes: »Architecture and acreage (agricultural land) will be seen together as landscape, as was in antique architecture, and will become more essential to each other«.

In both World Wars the threat of starvation stimulated the urban food production. In WWII the government of Great Britain launched the campaign Dig for Victory to increase the food production during the war. The allotments and gardens, even the parks, turned into fields and were covering half the nation's vegetable and fruit requirements. After the World War II there was a sharp decline of the urban food production. Allotments were associated with wartime and did no longer fit with the spirit of the new age.

Since the 1970 environmental awareness groups have promoted open urban space. The approach encouraged the design of new types of open space often benefiting smaller under-used inner-urban sites. The growing environ-

FIG 4 Development of urban gardening

mental ethic led to a renewed appreciation of urban food production. The new way of thinking led also to the development of new forms of urban food growing- urban farms and community garden movements. Most urban farms are multi-purpose entities with environmental education as a major part of their doing. Community gardens distinguish themselves from allotments by emphasizing their role as a focus for community regeneration. [2]

Due to the rising trend of urbanization ensuring food security in the cities is becoming a rising problem. The city offers a lot of potential space to produce food: parks, utility rights-of-way, bodies of water, roof tops, walls and fences, balconies, basements and courtyards. High-efficiency greenhouses in the cities can offer fresh produce independent of weather. Dickson Despommier proposed a new kind of farming in the cities, the vertical farming. He suggests cultivating food in the cities within skyscraper greenhouses or on vertically inclined surfaces using similar techniques as in green houses. Several vertical farms are being tested at the moment all over the world. The vertical farms are often seen as the future of urban agriculture.

2 Howe/Bohn/Viljoen 2005,95-108

THE VERTICAL FARM IDEA DEVELOPMENT

The concept of the vertical farm is now new developed, but in fact the vertical farming is not a new idea. One of the first ideas of vertical farming was published in 1909 in Life Magazine. This cartoon from A.B. Walker inspired Rem Koolhass. He described it in his book as a theorem that describes the ideal performance of the skyscraper. Each floor is a house with its separate garden to grow food. The same drawing inspired also James Wine and his firm SITE in 1980s. His project High-rise of Homes is also a way or arraying houses with garden in a vertical way.

Some of the built examples are documented in the canonical text The Glass House by John Hix. Among them are also the Vertical Farm at the School of Gardeners in Langenlois, Austria and the Vienna International Horticulture Exhibition in 1964.

"With the 252 -meter high Danube Tower was built to the highest building in Austria today. In Ruthnerturm, a 41 -meter-high glass greenhouse, thousands of plant pots were fertilized and watered automatically - the project is still considered important pioneering work in vertical farming , thus the agricultural production in

FIG 5 Development of vertical farming

multi-storey buildings."[3]

Despite the architectural precedents nowadays vertical farms are a lot more sophisticated because of the development of growing techniques and building technology.

Ken Yang, a Malaysian architect is probably the most widely known architect who has promoted the idea of mixed-use skyscrapers. This is a combination of function where people can work or live and where they also produce their food. He grows the plants in open air without a controlled climate or artificial lights to improve the productivity.

Dickson Despommier modernized the idea of vertical farming. He sees a vertical farm as a hermetically closed stacked greenhouse using the technological know-how. He also claims that the vertical farm can be energy independent using alternative energy power like solar panels, wind turbines or waste incineration.

Chris Jacobs, Andrew Kranis, Gordon Graff and Tahbit Chowdhury disagree with Despommier's assumptions regarding energy and water balances. They applied advanced industrial engineering design philosophies to modernize current greenhouse technology and showed there is sufficient technical ground to begin implementing the vertical farm idea.[4]

First vertical farms are already built.

3 Kocina 2014

4 Architakes

vertical farming

VERTICAL FARMING

»Vertical Farming is a promising concept that combines environmental considerations with sound economics. It puts the spotlight on the negative aspects of current agriculture and provides a solution in accord with future global societal structures. However, as with any novelty, improvements can be made, a lot of which comes with technological improvements of a concept in development« [1]

Today we face a rapid climate change. One particular concern is how the climate change will affect our ability to farm. The patterns of temperature and precipitation are changing. Greenhouse gasses have added their influence to the changing patterns and they had a significant effect on the acidification of our environment. The scientist have thought that plants will be the most severely challenged by the changes but researches show that plants can relocate easily by seed dispersal but farmers are bound to their land.

1 cf. Vöss 2013

The Stern Review on the Economics of Climate Change published in 2006 estimates, that over the next thirty years the climate change will cost the governments of the world around 74 trillion dollars. These expenses are associated with rising ocean levels, significant loss of crops, increases in disease transmission and increased health care costs. [2]

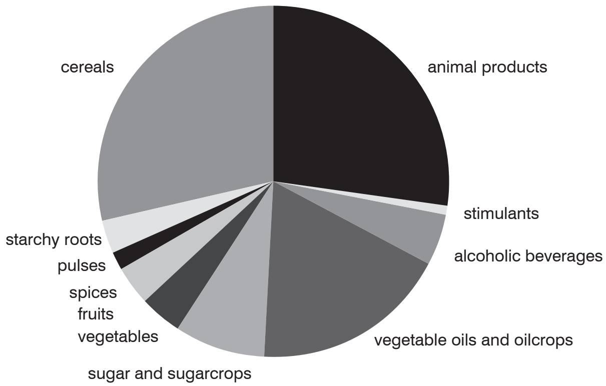
Another topic that the modern agriculture has to tackle is the growing mistrust of the consumer towards the food industry. People demand food free of agrochemicals. The phase “organically grown” and “bio” has become the new trend in the food consummation. The consumers have shown interest in supporting local farmers.

Due to the rising world population soil is not a long-term sustainable solution to meeting our population’s energy needs. Also the pesticides, herbicides and fungicides are not able to cope with unwanted weeds.

We are locked into an ancient system of food production that requires us to use more and more land to address the demands of a rising human population. In the region of South Europe we consume 3360 calories a day. To produce these calories we need approximately 3084 m2 to feed ourselves. This area does not include the area needed for raising livestock.[3].

2 cf Despommier 2010, p116.
3 cf Kastener et al.2012, p 6868-6872.

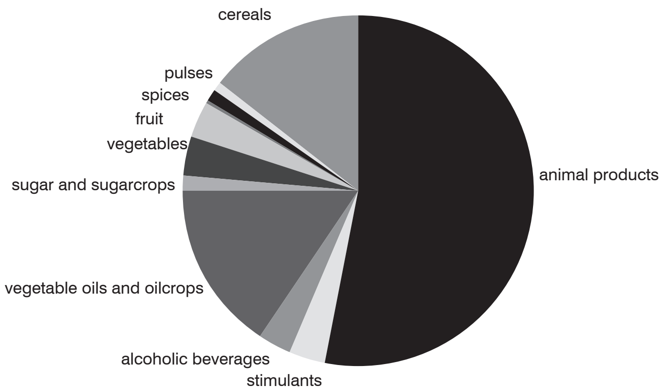
average per capita food supply
Unit: kcal/pers/day
source: FAOSTAT



Animal Products	921
Stimulants	23
Alcoholic beverages	162
Vegetable Oils and Oilcrops	609
Sugar and Sugarcrops	281
Vegetables	131
Fruits	119
Spices	3
Pulses	49
Starchy Roots	103
Cereals	959

together 3360 kcal/pers/day

per capita land requirements for food
unit: m2/pers/yr (area harvested)
source: own calculations



Animal Products	1.638
Stimulants	105
Alcoholic beverages	92
Vegetable Oils and Oilcrops	479
Sugar and Sugarcrops	51
Vegetables	111
Fruits	101
Spices	5
Pulses	38
Starchy Roots	27
Cereals	438

together 3084 m2/pers/yr

FIG 6 Calorie and land needs based on Kastner’s calculations

But we need a lot more land to cover our lifestyle. The ecological footprint is a measure of human demand ot the worlds ecosystems. It stands for the area of nature needed to supply the resources a human population consumes and to regenerate itself. With this method it is possible to estimate how much of the Earth we need to support a human. It is similar to life cycle analysis where in the consumption of energy, biomass, building material, water and other resources is converted into a normalized measure of land area called global hectares (gha). Per capita ecological footprint, or ecological footprint analysis, is a mean of comparing consumption and lifestyles, and checking this against nature's ability to provide for this consumption.

Slovenia has a footprint of 5.3 global hectares per person (calculated 2007). We exceeded the European average (4.7 gha / person). The demand for food, fuel, wood and fibre is twice the biological capacity of regeneration, which is 2.6 gha / person. This is mostly because of the use of non-renewable energy sources such as fossil fuels, particularly in the energy sector. The rate of consumption of natural capital, which is available in Slovenia, significantly exceeds demand. Therefore, we are dependent on imports from other parts of the world. Since 1999 we are exceeding the bio capacity and are in the state of an environmental deficit. [4]

4 cf.Ecological footprint.

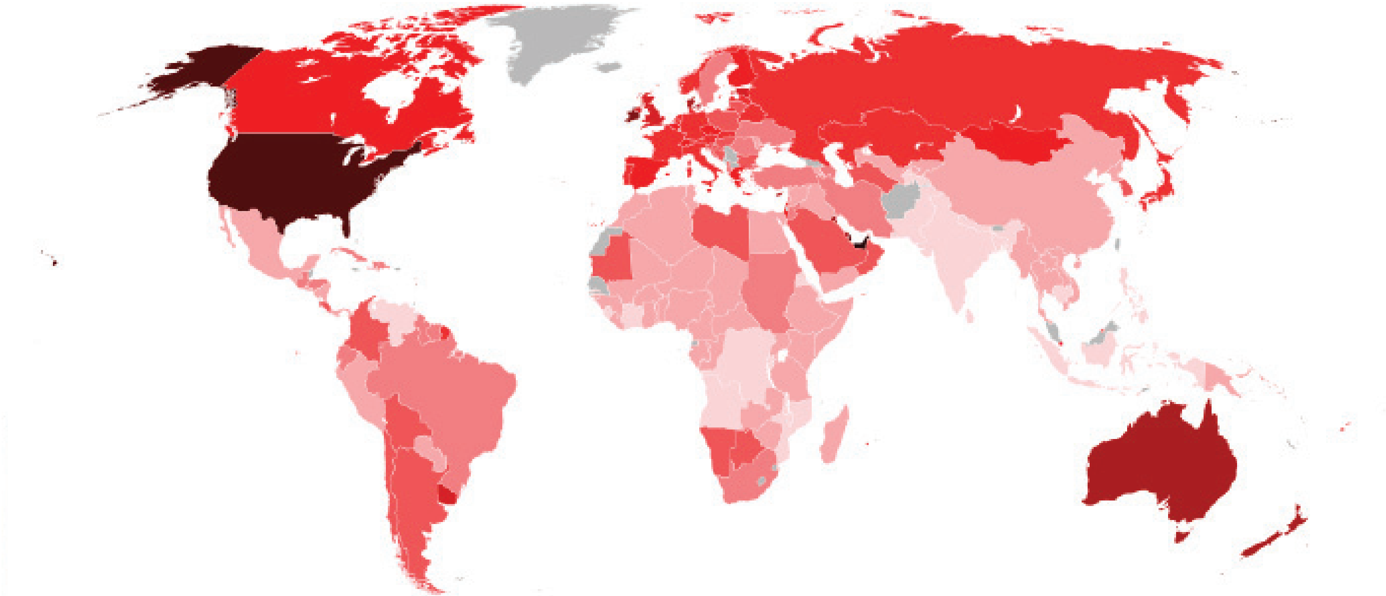


FIG 7 Ecological footprint

DICKSON DESPOMMIER

Despommier is convinced that we can solve current problems with vertical farms. High-tech greenhouse farming is already being deployed in many places, the irrigation methods like hydroponics, aeroponics and drip-irrigation are improving. He thinks that the only missing element is the urbanization of the concept. To link the agriculture with the city he suggests the vertical stacking of the crops. At the same time the vertical farm can help to tackle the problem of waste management and grey water.

In the book The Vertical Farm: Feeding the World in the 21. Century, Despommier lists the following advantages of the vertical farm concept:

- Year-round crop production
- No weather-related crop failures
- No agricultural runoff
- Allowance for ecosystem restoration (10-20 times of the acreage can be converted to hartwood due to the year-around production of crops indoors)
- No use of pesticides,herbicides or fertilizers
- Use of 70-95 % less water (using a hydroponic or aeroponic grow system)
- Greatly reduced food miles
- More control of food safety and security
- New employment opportunities
- Purification of grey water to drinking water
- Energy production and animal feed from postharvest plant material

And how does Dickson Despommier imagine the vertical farm?

"The farm would be modest in height, perhaps five stories tall and maybe 1/8 of a city block in footprint. The interior space would be highly flexible, allowing the expert team of controlled indoor-agriculture scientists the maximum freedom to configure and reconfigure the conditions the crops will be subjected to. They would work closely with the local consumers, a team of material scientists and structural engineers, and a state-of-art construction facility for the selection of crops and the custom manufacture of hydroponic and aeroponic equipment."

In his opinion the building should be constructed:

• to capture and disperse sunlight (using natural light if possible or energy efficient lighting systems)
• to capture passive energy (for example in form of PV panels, wind turbines, waste iincineration)
• to employ good barrier design for plant protection (avoiding and controlling the contamination of crops)
• to maximize the amount of space devoted to growing crops.[5]

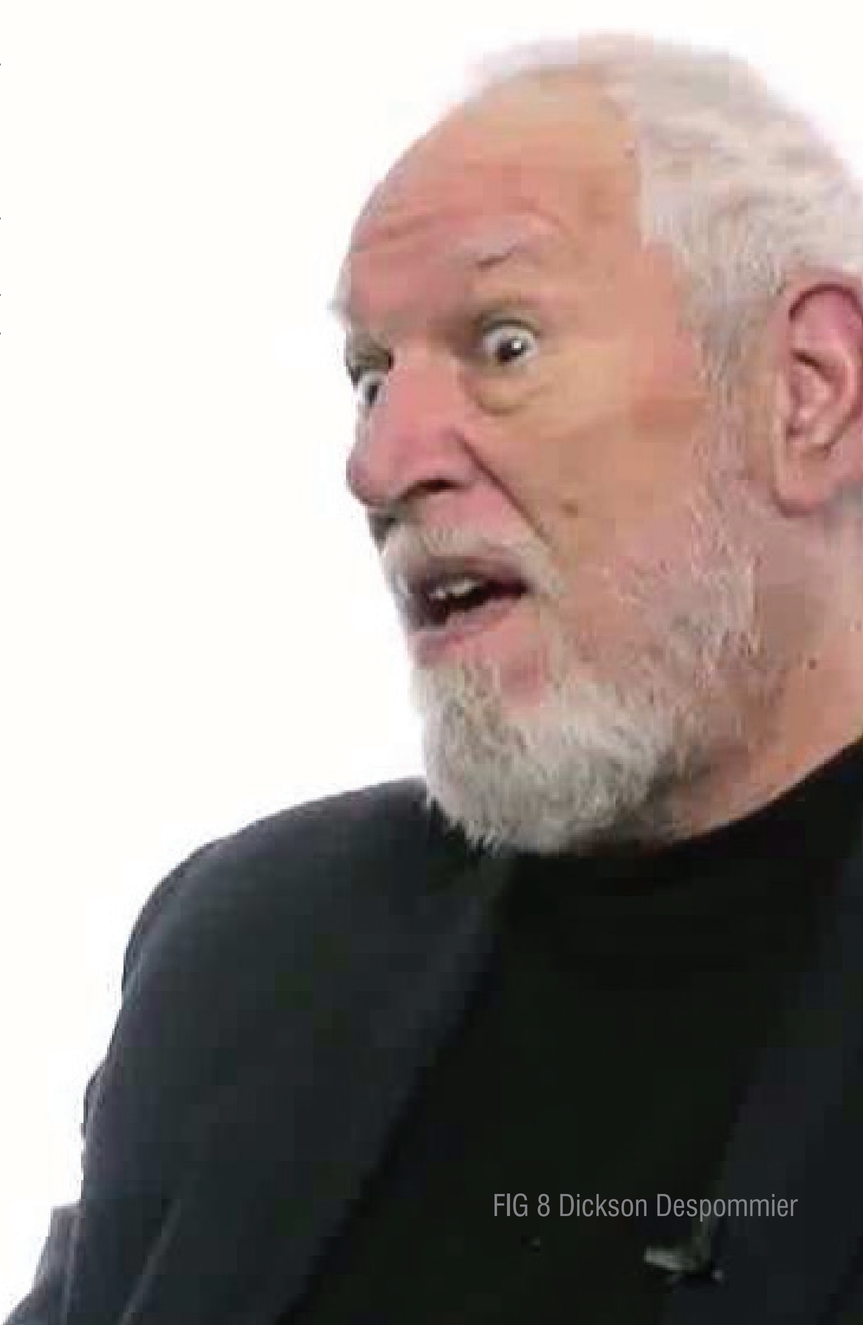


FIG 8 Dickson Despommier

5 cf Despommier 2010, p135-184.

EXISTING VERTICAL FARMS

There are several examples of greenhouses that use a similar technology as vertical farms, but only few vertical farms are built. Although we have to mention that a lot of vertical farms are in a planning phase.

FIG 9 Vertical farm map

LOCATION	OWNER	DETAILS	LOCATION TYPE	PRODUCE
Suwon, S.Corea	Rural development authority	Three stories tall Experimental Uses grow lights	Peri-domestic	lettuce
Japan	Nuvege (Spread) community of more than 50 plant factories	Commercial Half of them use a special developed light	Inside the city limits	lettuce
Singapore	Sky Gardens	Commercial Half of them use a special developed light Trays move vertical	Inside the city limits	naibai, cai xin, chinese cabbage, mao bai, lettuce, bayam, kai lan, kang kong, spincah
Chicago	The Plant	Three stories tall Non-governmental organisation Uses grow lights	Inside the city limits	arugula, lettuce, herbs, strawberrys, squash, tomatoes
Chicago	Farmed here	Commercial Uses grow lights	Inside the city limits	Lettuce, mint, basil, arugula, kale
Linköping	Plantagon	Commercial-in planing Helix-shaped moving trays Uses grow lights and natural light	Inside the city limits	/
Vancouver	Alterrus	Four stories tall Uses sunlight Parking lot	Inside the city limits	/
Vancouver	Terrasphere	Artificial lightning	Inside the city limits	spinach, lettuce, possibly strawberys and herbs
Wyoming	Vertical Harvest	Three storyes tall Uses sunlight in combination with growth lights Next to a parking lot	Inside town limits	
UK	Paington ZOO	uses Verticrop system	Inside a ZOO	

SUWON VERTICAL FARM

The vertical farming system, developed in the Gyeonggi province, uses the back-up of solar energy, robot-based monitoring, application of LED lights and custom-made water recycling system among others. The studies conducted by engineers had found approximately 60% energy could be saved compared to conventional structures through active and passive technologies such as insulation, chilled beam and hybrid solar and geothermal heat. It is estimated that vertical farms could produce approximately 1,200 units of vegetables a day with a break-even point of 500 units a day commercially in a vertical farm that occupies an area of 400sqm. [7]

FIG 10 Suwon

6 cf Agritecture Korea, 2014.

FIG 11 Nuvege

NUVEGE (SPREAD)

Nuvege uses a hydroponic system of cultivation with a proprietary lightning network that increases the yield rate of vegetable growth by equalizing light emissions that also advance photosynthesis trough increased levels of carbon dioxide. The vegetable factory produces 7.3 million heads of lettuce a year. This is more than is produced by any other artificially lit vegetable factory in the world, and SPREAD has, by far, the leading market share in Japan.[8]

7 cf Agritecture Nuvege, 2014.

SKY GREENS

Sky Greens is world's first low carbon, hydraulic driven vertical farm. It uses sunlight.

Sky Greens patented vertical farming system consists of rotating tiers of growing troughs mounted on an A-shape aluminium frame. The frame can be as high as 9 meter tall with 38 tiers of growing troughs, which can accommodate the different growing media of soil or hydroponics. The troughs rotate around the aluminium frame to ensure that the plants receive uniform sunlight, irrigation and nutrients as they pass through different points in the structure. These results in at least 10 time more yield. Rotation is powered by a unique patented hydraulic water-driven system which utilises the momentum of flowing water and gravity to rotate the troughs. Only 60W electricity (equivalent to one light bulb) is needed to power one 9m tall tower. With the plants irrigated and fertilised using a flooding method, there is no need for a sprinkler system thereby eliminating electricity wastage, as well as water wastage due to run-offs. Only 0.5 litres of water is required to rotate the 1.7 ton vertical structure. The water is contained in an enclosed underground reservoir system and is recycled and reused. [9]

FIG 12 Skygreen

8 cf Skygreens,2014

THE PLANT

The former vacant building of the Plant is being transformed into a net-zero food business incubators. It holds demonstration farms and educational facilities. It occupies 650 sqm. The main goal is to test the system of vertical farms on a limited budget so that the farming methods would be financially viable to repeat elsewhere. Currently there are three systems housing approximately 600 fish each and about 280 sqm grow beds. Various lightning systems are being tested-T-8 fluorescents, donated LED lighting, and induction lights- determine the initial investment and the life-span from the economic point of view. The aquaponics farm also houses its own breeding system, where they are learning to naturally breed Nile tilapia. The water from the fish contains important nutrient for the plants raised.

The breeding tank houses two breeding chambers in which our male and female breeders produce between 50 to 200 tilapia each spawn, with an algae cultivation tank for nutrient scrubbing and fish feed production (tilapia are omnivores and benefit from the fresh food to get them into breeding condition). The tank is further filtered by two linked media grow beds where we are experimenting with fruiting plant production: raising strawberries, squash, and tomatoes on an experimental scale.[10]

9 The Plant, 2014

FIG 13 The Plant

FRAMED HERE

FarmedHere pioneered commercial vertical farming in Chicago. With their indoor aquaponic growing systems they create local produce and local jobs in a sustainable farming environment. It has an area of 90.000 sqm. The seeds germinate under energy-efficient compact fluorescent light. The lights run all the time and add about 18% to the overall costs of the facility. The plants are then transferred to a vertical grow system consisting of 5 to 6 layers of plant bed stacked on top of each other. The roots of the plants are completely submerged in water. That comes from big tanks with tilaphia fish. The fish are fed with organic feed. The fish grow 18 months until they are sold. The company will be producing around 500 000 kg of leafy green in 2014. The CEO is convinced they can raise any plant they want with the exception of potatoes. [11]

PLANTAGON

The Plantagon greenhouse, developed together with Sweco, is designed for vertical agriculture of vegetables in urban areas. In cooperation with several partners, Plantagon plans to develop integrated solutions for energy, excess heat, waste, CO2 and water. The basic idea is to grow plants in pots. The pots are then put into trays, which are transported around the growing helix where the cultivation takes place.

The trays are equipped with a light sealed nutrient solution reservoir. Excess nutrient solution is collected and reused after disinfestation. The machinery is located in the basement on one or two floors and the trays are transported to the top of the helix by a special tray elevator. The crops grow during the slow transport down the helix and are ready for harvesting when they reach the end of the helix at the basement level. Food is harvested automatically. The process then starts from the beginning. [12]

FIG 14 Plantagon

10 cf FarmedHere, 2014

11 cf Plantagon, 2014.

ALTERRUS

Alterrus was a high-tech greenhouse being built with the help of the city Vancouver on a parking lot. The city wanted to set an example of the booming clean tech sector. The farm was using a patented technology for growing called Verticrop.[13] The technology of suspended tray configuration on a moving conveyor system is still available and was selected as one of the world's greatest inventions. Unfortunately, the farm went bankrupt. The reason for the bankruptcy could not be found in any media.[14]

TERRASPHERE

Terrspaherre provides an innovative and sustainable solution to food supply. It was founded in 2003. The company operates in a pilot facility in Vancouver. The company grows various vegetables on a shelf system, using artificial lightning. In the early stage the seeds germinate in a solution of organic fertilizer and water. When the plants develop the roots, they are transferred to the main part of the vertical farm.[15]

12 cf Verticrop, 2015
13 cf Vancourier, 2014.
14 cf Terrasphere, 2015.

PAINGTON ZOO

Paington ZOO is often mentioned the first vertical farm in Europe. It is an experimental high density vertical growing facility in a ZOO. They system used for growing plants is developed by Verticrop. It is a hydroponic tray system moving on the conveyor belt around its horizontal axis. The farm grows 11200 plants on an area of 100 sqm. The crops are used to improve animal feeding requirements. It uses 87 % less land and saves up to 40% less energy compared with conventional farming. The energy consumption is assumed as 500 kWh sqm per year. The VC installation at Paingnton zoo is producing high yields of up to 7 kg m-2 for fast growing leafy crops and lettuce production of 112 plants per m2 of greenhouse (including service area) with fresh harvested weight of up to 125 g (14 kg m-2) each with minimal energy inputs and no supplementary lighting.[16]

FIG 15 Paington Zoo

15 cf Baley/Yu/Frediany: Sustainable food production Using High Density Vertical Greowing (Verticrop)

VERTICAL HARVEST

The tree storey high vertical farm is attached to an existing parking lot in Wyoming. The crops are grown on an area of 420 m2 but with the help of vertical stacking the produce are enlarged to 1672 m2. On this area they will produce 45400 kg of crops annually. The plants are grown hydroponically, using 90 % less water compared to traditional agriculture. Calculated on a year basis each sqm of the farm produces 108 kg of food, meaning 0,3 kg a day. Each sqm of cultivation area produces 0,07 kg crops daily. The farm is growing crops that are not produced by local farmers. The farm uses as much natural sunlight as possible. The aim is to use artificial lightning only if needed (like in winter etc). They calculated that the vertical farm would use just 3000 hours of artificial lightning per year- meaning it would need artificial lightning one third of a year. The farm is 9.1 m deep and 48 m wide.[17]

16 cf Vertical Harvest, 2015.

FIG 16 Vertical Harvest

CONCLUSION

Clearly, vertical farming offers a lot of advantages compared to conventional agriculture but also has disadvantages.

ADVANTAGES

It is a **preparation for the future**, when there will be no land available to satisfy the need of all people.

It **increases the crop production**. Dickson Despommier claims the yield is from 5 to 30 times higher than today's farming due year round production.

Despommier suggests that, if dwarf versions of certain crops are used(e.g. dwarf wheat developed by NASA, which is smaller in size but richer in nutrients), year-round crops, and "stacker" plant holders are accounted for, a 30-storybuilding with a base of a building block (5 acres (20,000 m2)) would yield a yearly crop analogous to that of 2,400 acres (9.7 km2) of modern farming.

Using new watering techniques like hydroponic and aeroponic **lowers the water consumption of farming** (modern agriculture consumes up to 70 per cent of fresh water. Plants also help to convert grey or black water to fresh water with evapotranspiration.

The **crops are save from weather disasters**.

They establish **new mixed use sustainable environments for urban areas** by inhabiting other functions like restaurants, offices, etc.

Each unit of a vertical farm allows up to 20 units of area of outdoor farmland to return to its natural state and thereby **helps to increase biodiversity**.

The controlled environment makes it possible to **avoid the use of pesticides, fungicides and herbicides** to grow organic food near the consumer. Vertical Farming reduces the exposure to most of the risks of outdoor framing (toxic chemicals, infectious diseases) providing a safer working place for workers and employees.

Vertical farms **have multiply ways to produce the energy the need for functioning**. They can incorporate a biogas waste plant, win energy trough bio waste incineration, solar panel or wind turbines.

Because the plants are grown near the consumer **less transportation and packing is needed**. Also there is less spoilage of food because of the quicker transportation chain. This means that less oil is use (also because vertical farms do not use herbicides, fungicides and fertilizers on the petroleum base)

Vertical farms are **flexible in placemen**t.

DISADVANTAGES

The **buildings are very expensive because they need a lot of technology, the plots in the city are more expensive**, etc. Maintaining also requires a lot of energy, especially if using artificial lightning.

Bruce Bugbee, a crop physiologist at Utah State University, believes that the power demands of vertical farming could be too expensive and uncompetitive with traditional farms using only free natural light. **Heating and ensuring enough energy is one of the biggest problems of a vertical farm.**

Vertical farming causes pollution. It requires a source of CO_2 and this gas can also leak out of the building. It can also cause **light pollution**.[17]

17 cf Villanova Prades 2013, p75-82

Although first vertical farms are already operating, we have to emphasize, that it is still an idea in development. Nowadays vertical farms still cannot compete with modern farming. The main problem is that they consume a lot of energy and the technique is still in the development phase and costs a lot.

“As far as the expenses incurred in the “invention“ of a vertical farm, I would venture to guess that any first edition of an invention is going to cost a lot. As the invention becomes accepted and the demand for it increases, the price of each one will go down.“[18]

18 Despommier 2010, p 144.

maribor

MARIBOR

country Slovenia
region Steiermark
elevation 275m
founded 1254

area 37 km2
inhabitants 95.586
density 2.333 p/km2
number of dwellings 41.409
avararge number of people in dwelling 2,5

MARIBOR

Maribor is Slovenia’s second biggest city. It is located in the region Štajerska, also known as Steiermark in the northeast of Slovenia. It is the capital of the Štajerska region.

It lies on the elevation 275 m with longitude 46.33’44 and latitude 15.38’38. From the geographical point of view it is an important crossing point between the river Drava, also known as Drau, the hills Pohorje, Kozjak and Slovenske Gorice and between the lowland Dravsko polje, which is an important area for agriculture.

The climate in Maribor has strong subpannonian features. The average annual air temperature is 9.4 degrees Celsius. The lowest monthly average temperature in January - 1.3 degrees Celsius, the highest in July to 19.7 degrees Celsius. Winters are quite cold, springs and autumns are warm, the summers are hot.

Average annual rainfall is 1050 mm; most of them in May, June and July. The autumn months are relatively dry.

The city has its own university and is the financial, governmental, cultural, tourist and trade centre of the region Štajerska.

In the year 2012 it was the European cultural capital and in the next year the European youth capital.[1]

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1 Maribor, 2014.

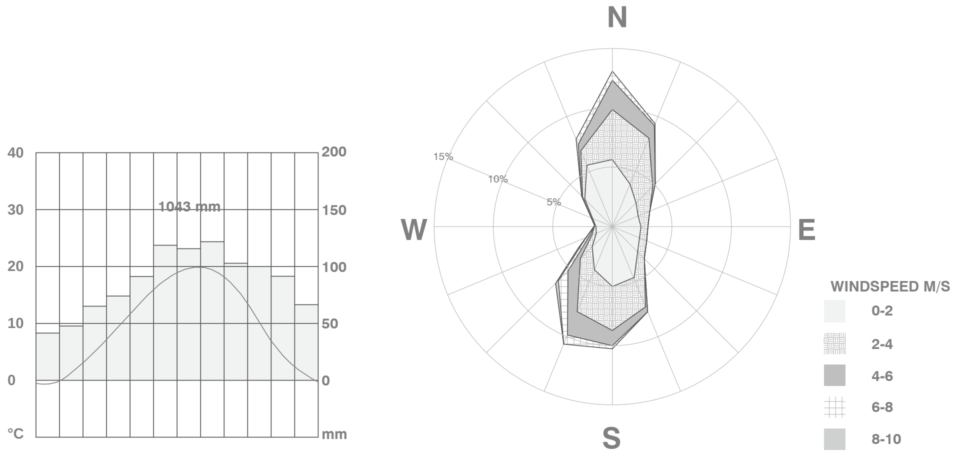


FIG 17 Climate Maribor

MARIBOR'S PROBLEM REVEALED

Before Slovenia became an independent country, the city had a very good developed industry. Big companies like Tam (car industry), MTT and Svila (textile industry), Metalna, Elektrokovina and Hidromontaza (metal industry) could not handle the loss of the Balkan market due to the independency and were closed or restructured. New smaller businesses were launched. Today, the most profitable sectors are smaller industries and service sector. Other well developed sectors are the commercial sector and banking.

The current economic crisis struck especially the banking sector. Since the entrepreneurs could not rely on the help of the banks for their investments and since most of the companies produce goods with low productivity, low added value and the low purchasing power caused a lot of companies went bankrupt. A very effected sector is also the building sector. All the big building companies also went bankrupt.

As the consequence of the crisis and the bankruptcies a lot of people in the city are unemployed. The once blooming city became less and less interesting for investments and companies.

The second largest Slovenian city meets the requirements to receive financial support from the state because of the statistics for unemployment in the city. This past three months the unemployment exceeds 17 %. According to the Agency for Employment in Maribor 18.6 % of registered residents are unemployed. The national average is 11.3 %.[2]

Maribor needs to find a new perspective for its development.

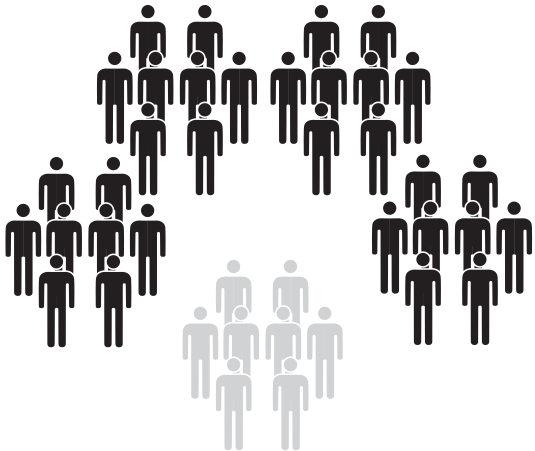


FIG 18 Unemployment in Maribor

2 Maribor prosi drzavno pomoc.

SEEKING NEW PERSPECTIVES

Today Maribor is seeking for a new perspective how to proceed. Considering the global trends one possible development for the city could also be vertical farming. Take for example Linköping, a city in Sweden with a similar size and density as Maribor. The city is currently working on the development of its new vertical farm planned by Plantagon. The city is known for its university and its high-technology industry. It wants to create a sustainable development for the city and achieve carbon neutrality by 2025.[3] Considering that Maribor also has a good university with influent faculties in the field of technics and agriculture, we could follow the example of Linköping and be among the pioneers in the vertical farming industry.

3 Linköping 2014.

As already mentioned vertical farming is a technology in development. Since there are only a few operating vertical farms and there are a lot of issues that vertical farming has to tackle, we suggest that the first vertical farm built in Maribor would be a research vertical farm operating on a smaller scale. A good example is Vertical Harvest in Wyoming, where they built a vertical farm with 420 sqm. The farm produces crops that are sold to the shops and restaurants nearby while generating new working places and testing new growing techniques.[4]

The research vertical farm would generate new working places and revitalize the industry of Maribor.

If the model of the vertical farm is proved successful, the research vertical farm could grow in size and grow more food.

4 Vertical Harvest, 2015

LINKÖPING

country Sweden
region Östergötland
elevation 45m
founded 12th century

area 42 km2
inhabitants 104,232
density 2.500 p/km2

vertical farm in progress

MARIBOR

country Slovenia
region Steiermark
elevation 275m
founded 1254

area 37 km2
inhabitants 95.586
density 2.333 p/km2
number of dwellings 41.409
avararge number of people in dwelling 2,5

vertical farm not existing

EXISTING URBAN AGRICULTURE IN MARIBOR

The importance of healthy food and self-supply, which was taken for granted in the past, but is meanwhile almost forgotten, is strengthening again in Slovenia. The awareness that eating high quality food is important that its path from field to plate should be as short as possible, has been an important guide for the development of projects described below.

CAAP- Maribor's center of alternative and autonom production

At the end of 2012 CAAP (Center of alternative and autonom production) opened. It is the first social and community centre of its kind in Slovenia. The centre works as a platform of connecting and founding of new economies, as an incubator for social entrepreneurship and ecological practices. It connects various smaller organizations and programs, for example a program for »desk-sharing« and various programs developed in the program called Urbane brazde (translated Urban Furrows)- a Seed Library of the association Guardians of Seeds, a store and distribution centre Dobrina connecting local farmers, Maribor's cycling network, socio-cultural associations Frekvenca and Rizom. In the future the centre aims to develop new social entrepreneurships and start new ecological and social initiatives.[5]

FIG19 CAAP

5 Caap 2014.

Urbane brazde (Urban furrows)

Urbane brazde is a program launched in 2011. It is now a part of CAAP. It consists of seven closely interrelated projects which purpose was to formulate an example of an integrated and sustainable development of the region in terms of environmental, social and cultural aspects. It was a part of Maribor's European capital of Culture program.

It can be divided into organic (sustainable local food, Urban Community Garden, Seed Library) and socially engaged projects (Etnomobil, digital nomadism, Teleport). Based on the processes through which researchers built up different communities and with them a new sociality in the city. Although the program Urban Furrows served with more than one hundred events, the majority of these targeted specific groups, their training, education, advocacy and strengthening.[6]

6 Caap 2014.

Urbani eko vrtovi (Urban Eco gardens)

Urban gardens represent the economical, ecological, cultural and social challenges of the local population. In addition to the space for socializing, exchange, interaction, they also offer self-care, learning, and social and cultural corrective, while re-connect life and human needs.

In Maribor, at the time of European Capital of Culture came to life first urban community organic garden. In the area of Maribor called Borova vas workers of the program Urbane brazde in cooperation with the residents launched a Community garden to enhance fresh produce, self-supply while also growing space recognition, socializing, learning and the promotion of community organizing. [7]

7 Caap 2014.

FIG20 Urban Eco gardens

Seed library

Parallel with the establishment of Urbani eko vrtovi and Zadruga Dobrina they built a seed library. Seed Library is an alternative approach for maintaining the diversity of crops. The primary mission of the Seed Library lays in protecting, preserving and promoting the production of old, locally adapted varieties of crops. The Seed Library has its own archive of seeds and its laboratory. The archives also keep all the samples collected seeds under conditions that allow the longevity of seeds. Since

a healthy and high-quality seed material basis is the basis for healthy plants, the laboratory disinfects seeds with hot water, runs germination testing, measurement of moisture in the beans and much more. Individuals, called guardians, are responsible for the maintaining of seed. With sowing, seed production and mutual exchange of seed they contribute to the preservation of the old Slovenian varieties of vegetables, cereals, vines and fruit plants in our gardens and fields.[8]

8 Caap 2014.

Zadruga Dobrina

Zadruga Dobrina is a cooperative for the development of sustainable food supply. It was founded in 2011. Its fundamental is the development of small farms, fair trade food and ensuring a fair payment for growers and producers. At the same time they enhance the connections of rural areas with urban centres, the promotion and development of organic farming. They connect the principles of sustainable local food security and socio-entrepreneurial activities in the production and processing of food. It was founded by small traditional farms with a desire to offer fresh, seasonal, local and healthy crops to the urban dwellers. The crops are produced with organic and integrated farming methods.

Today Zadruga Dobrina already supplies numerous caterers. All residents of Maribor can buy their products via a box-scheme. They also offer a catering service.[9]

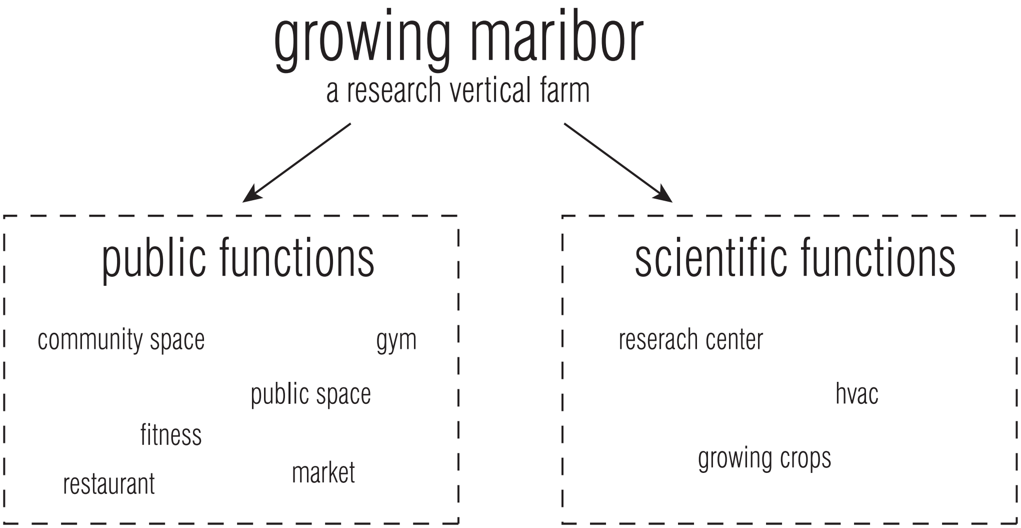
9 Caap 2014.

growing maribor

The growing population and urbanization is presenting one of the biggest problems for the upcoming generations. It is foreseen that by the year 2050 70 % of people will be living in cities and that we will need additional cropland in the area of entire Brazil to cover our food needs. Soon everybody will be involved in this problem. Every country on this planet will be involved in this problem: even if a county would have enough land to be self-sufficient in its food supply it will eventually have to produce a surplus to cover the needs of other counties. After all, this will not be a country based problem, but a global one.

Nowadays Slovenia does not cover its need for food supply. Concerning vegetables we produce only 31 % of what we need. In the case of cereals we produce around 56%. We produce 80% of our meat and eggs and hereby we have to say that in the Slovenians eat a lot of meat. Several programs are starting now enhancing the local food supply.[1] This would ensure national safety in times of crises; make Slovenia

1 cf Lokalna samooskrba 2015.



less dependent of import. Another positive impact of local food growth and supply are less environmental impacts (by reducing long distance transport using fossil fuels, less pacing and less use of artificial food preservatives) and improving the health of the population by growing healthier crops which need less time from the producer to the consumer and therefore have a higher nutritional value. So the first goal of Slovenia should be to provide enough foot for itself and if possible create a surplus.

A vertical farm could be the solution for the upcoming problems. The first vertical farms are already build or in development. But from the first vertical in Wyoming with 420 sqm to a 30 stories high skyscraper is still a long way to go. Vertical farming is still in development, but with the right technology and when we gather enough experience, it could be the solution to prevent food scarcity in the future. The project Growing Maribor sets another milestone in the development of vertical farming. It is 7 stories tall and designed to test different growing techniques, using natural lightning that minimizes the need of artificial lightning that consumes a lot of energy.

In the thesis we will choose a possible site for building a mixed use building combining a research vertical farm and other functions that attract the visitors. We will compare, how much food we can grow in a vertical farm comparing it with modern agriculture. The building is used to present the principle of vertical farming to the consumers. In combination with other functions it also attracts visitors that would not normally be interested in visiting a vertical farm. These additional functions contribute the quality of the neighbourhood. The produce of the vertical farm will be sold on the market where also local farmers can sell their produce. The markets provide fresh locally produced food for the people living nearby and the visitors of the building. New jobs will be provided the local industry would be enhanced by development of industries connected with vertical farming.

GOALS OF THE PROJECTS

- Finding out if the vertical farm is able to tackle the problems farming will face in the future
    - land scarcity
    - water scarcity
    - energy scarcity
    - climate change
    - pollution caused by fertilizers, pesticides, herbicides
- Creating a mixed use building that offers new activities for the neighbourhood
- Introducing the process of VF to the people
- Offering the possibility to experiment with different factors influencing the growth of plants
- Growing fruit and vegetables for the people living nearby
- Creating new jobs and enhancing the development of the industry

LOCATION

The location of our project is in Pobrezje. Pobrezje has 5711961 sqm and 13006 inhabitants.[2] The area near our site is one of Maribor's most **densely populated** areas. It has relatively good connections to the centre by bus. There is **no market near** our site. The only activity in this area is caused by the shopping centres. Beside the shopping centres there are **no free time activities** that would attract the people. The activities that attract people in Maribor are mostly connected with sport and shopping. Near the site there are 4 bigger shopping centres, but none of them managed to bring extra quality to the neighbourhood.

There are **2087 people living in the apartment in the radius of 12 minutes on foot**.[3] The housing building nearby have a lot of green but they have no other possibility to grow their food.

The selected site is in an area where mixed use building is planned.

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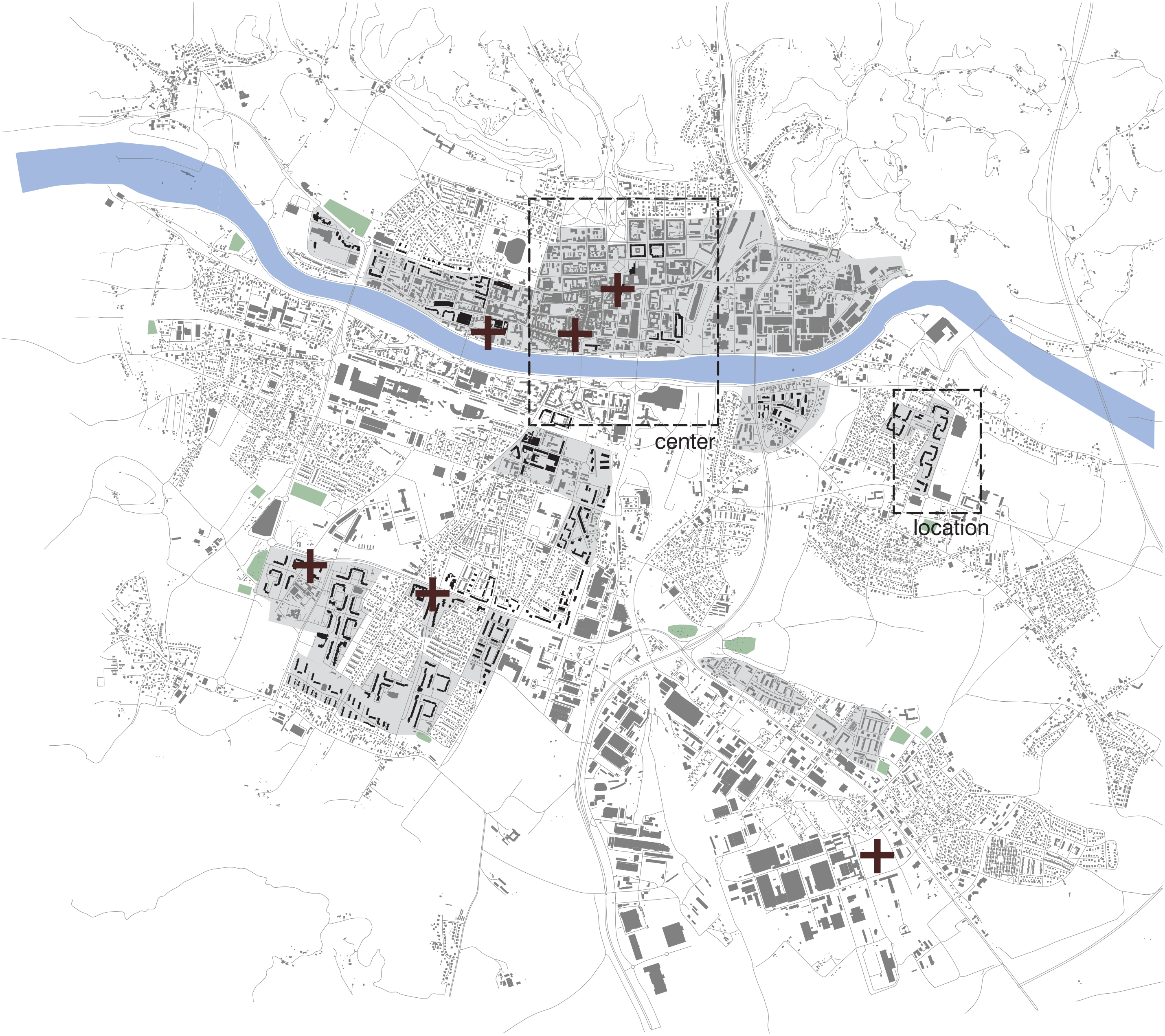
2 cf. Pobrezje 2015
3 cf. Kataster.

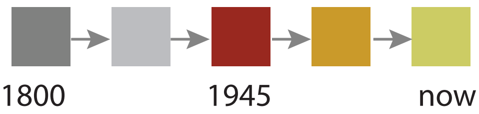

center
location

+ market

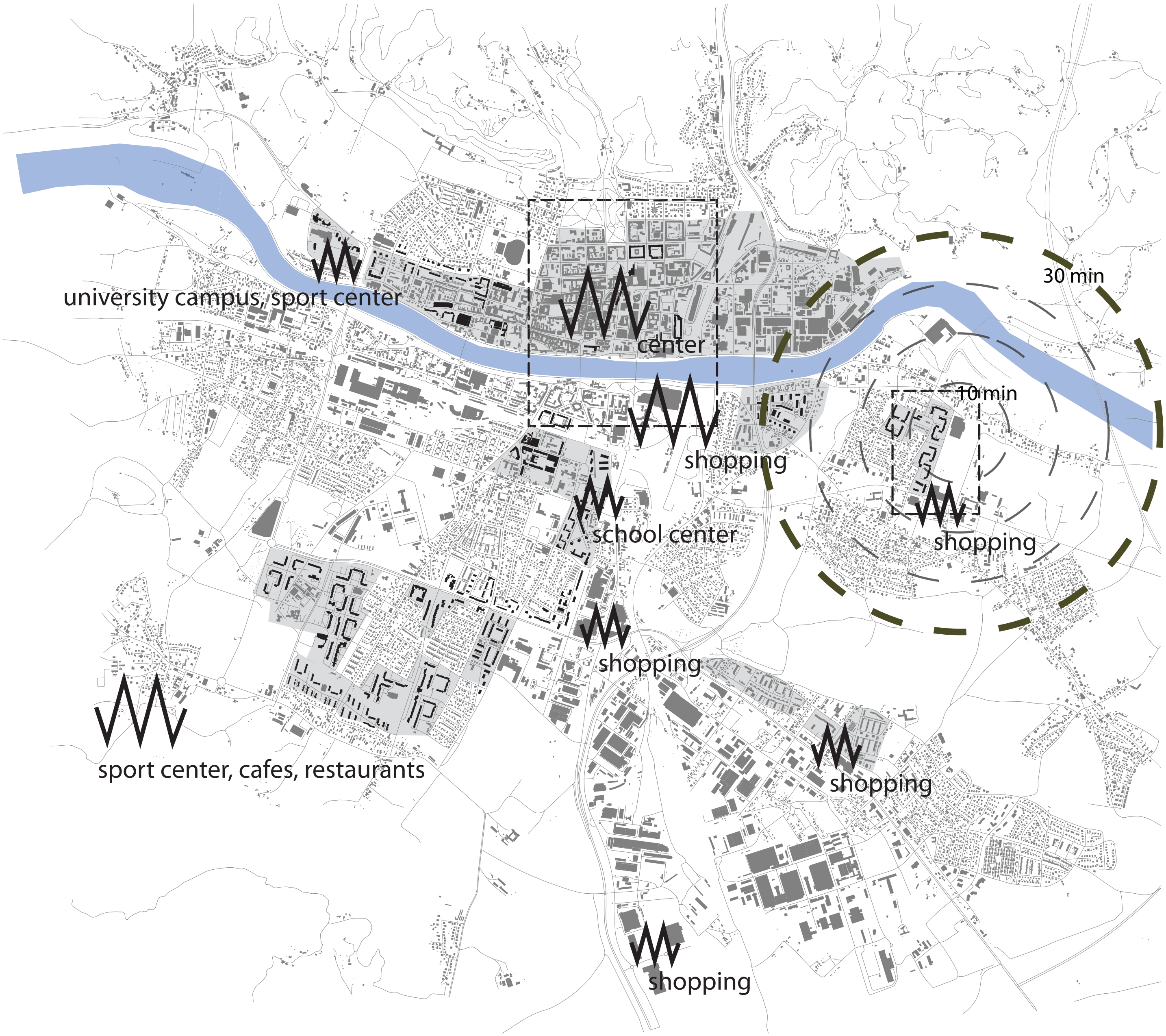
area with high density

existing urban gardens

WIDER AREA ANALYSIS
M 1:25000



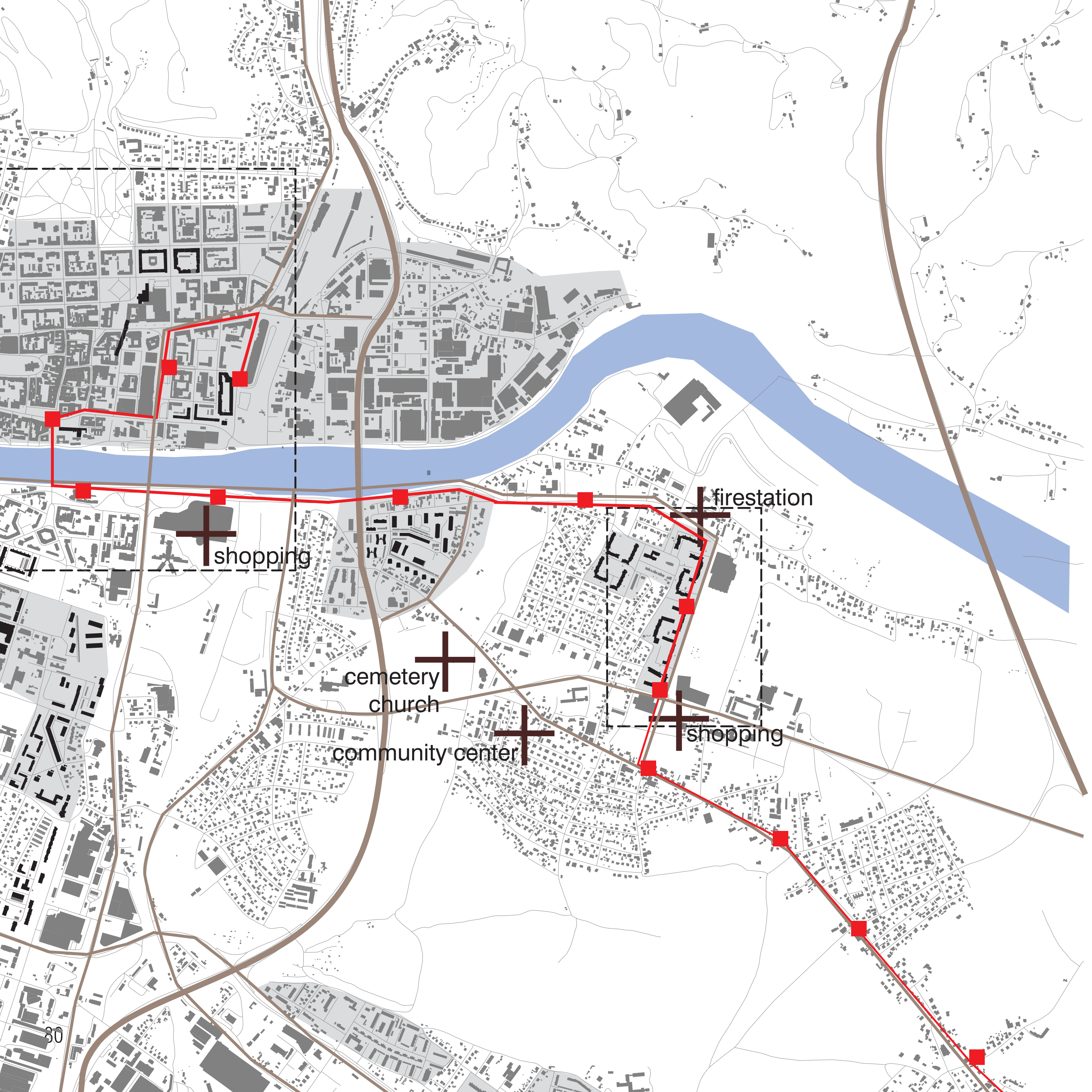
DEVELOPMENT
M 1:25000


university campus, sport center
center
30 min
10 min
shopping
school center
shopping
shopping
sport center, cafes, restaurants
shopping
shopping

high happening frequency

happening frequency

WIDER AREA ANALYSIS
M 1:25000

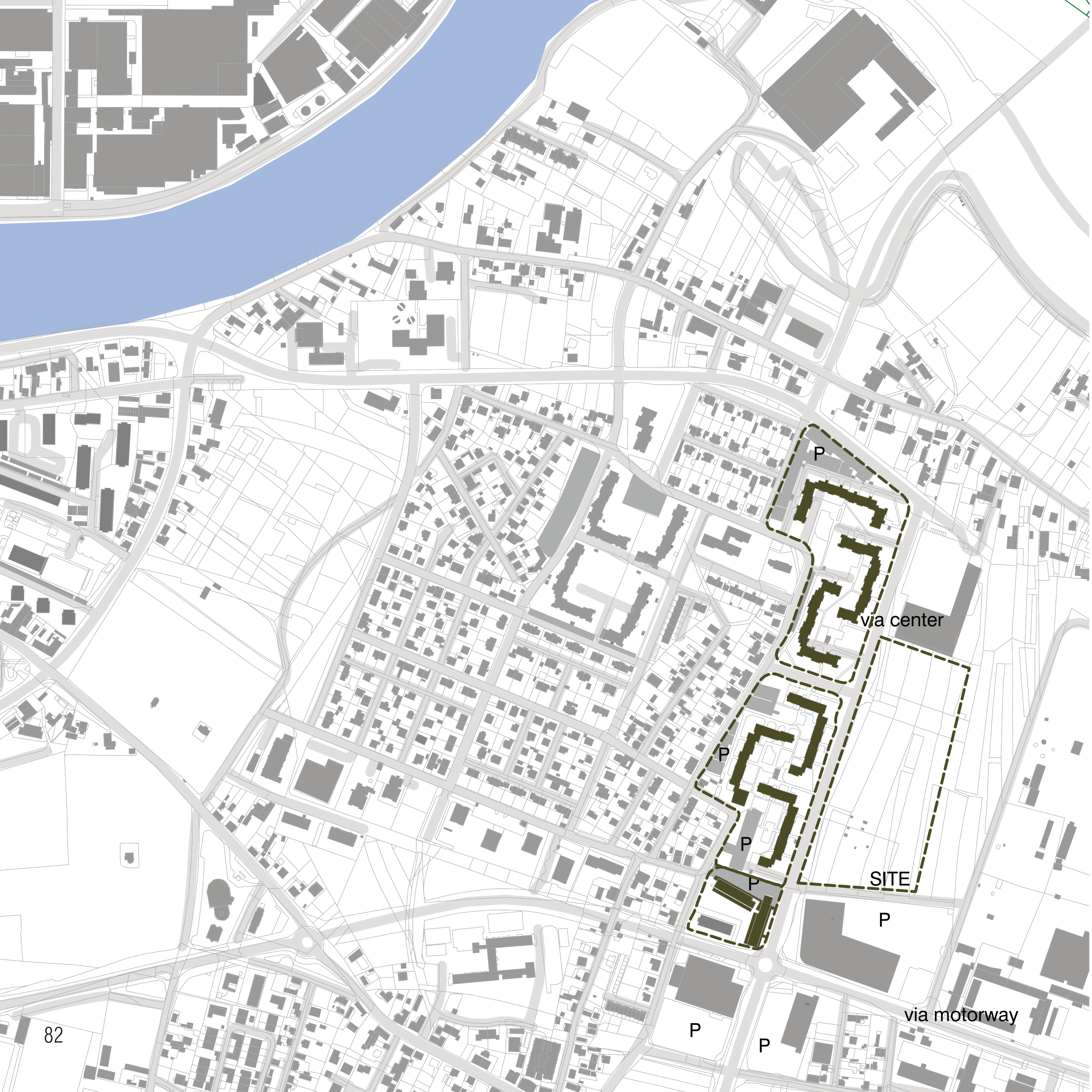

firestation
shopping
cemetery
church
community center
shopping

bus line with stops

main roads

motorway

WIDER AREA ANALYSIS
M 1:12500


P
via center
P
P
P
SITE
P
via motorway
P
P

parking P

streets

STREETS
M 1:1500


SITE

green

trees

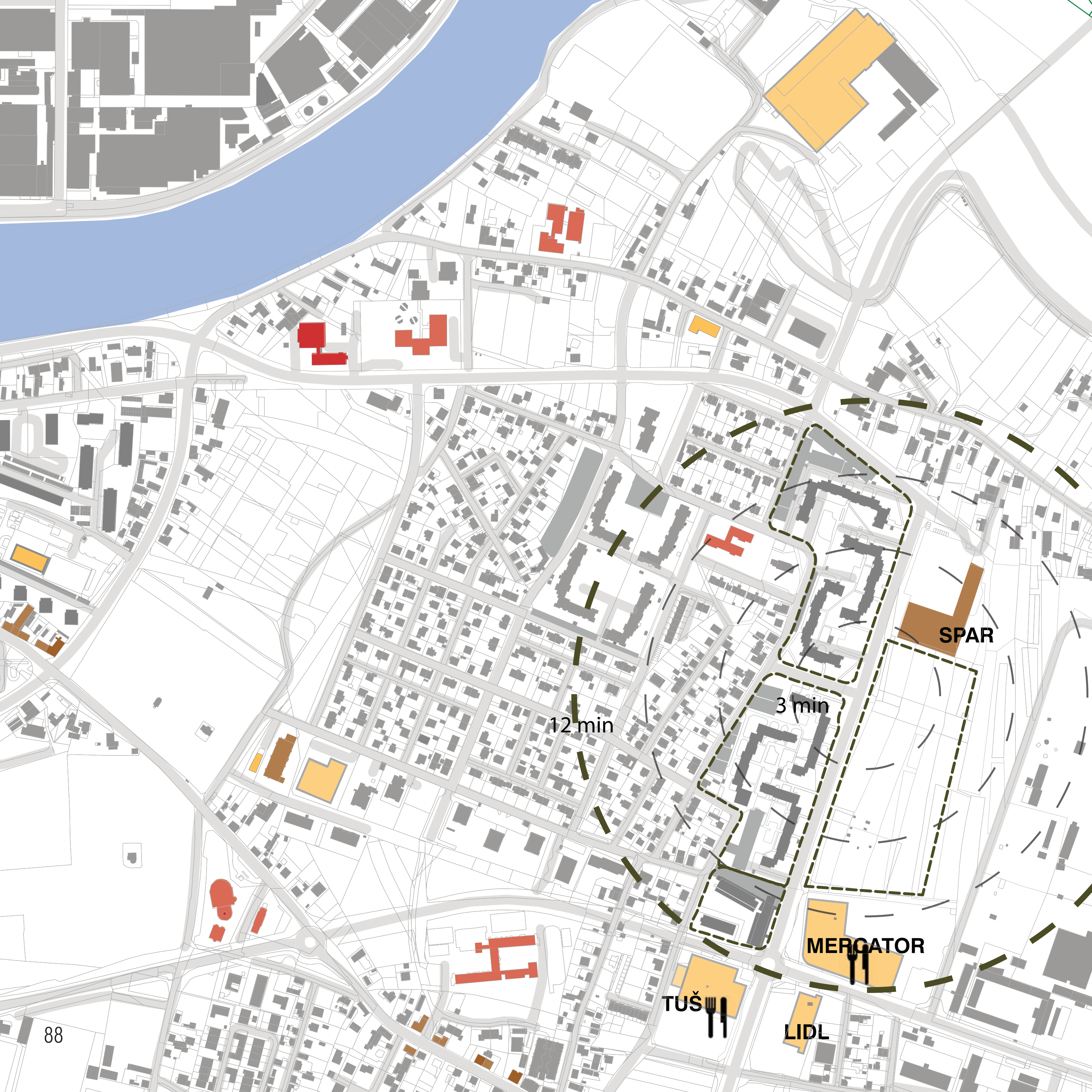
GREEN
M 1:750


1
2
3
4
5
6
7
8
9

BUILDING	APPARTMENTS	PEOPLE	BUILDING SITE	GREEN AREA
NR.1	112	291	2004	1681
NR.2	101	263	1919	
NR.3	112	291	1926	
NR.4	99	257	1640	
NR.5	95	247	1782	1351
NR.6	99	257	1659	
NR.7	36	94	668	534
NR.8	25	65	778	
NR.9	124	322	1478	
	803 m2	2087 m2	12854 m2	3566 m2

SITE AREA 33600 m2

PEOPLE
M 1:750


SPAR
3 min
12 min
MERCATOR
TUŠ
LIDL

supermarket SPAR

shopping center MERCATOR

supermarket TUŠ

discounter LIDL

living

living (houses)

living + commercial

commercial

public

restaurants

SURROUNDING
M 1:1500


area

residential

mixed use

public functions

green

cemetery

USE
M 1:1500

SITE

The building is placed parallel to the main street. Between the building and the road a plaza is created. The distance of the building from the street is enabling that the building can be better perceived from the people walking by.

The entrance is placed in the axis of the street joining the main street, where also the bus stations are located. On the left side of the entrance, in front of the sports hall there is an amphitheatre. There people can watch what is happening inside the hall or use it as a stage.

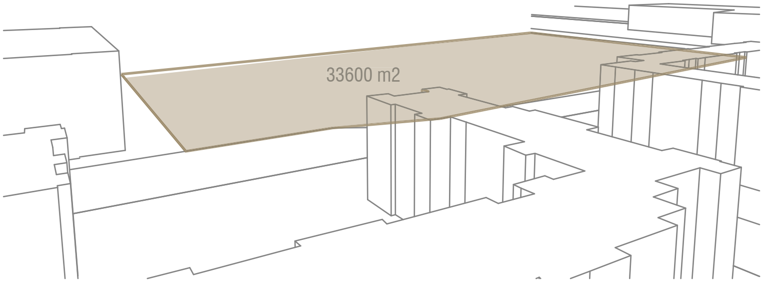
On the right side ot the entrance there is an open market.

Next to the market there is a ramp with access to the parking underground. Next to the ramp there is also short term parking. The parking is accessed from the street located on the west side of the plot. This street goes to the market so the local farmers can deliver their crops and the customers can pick up their crop-boxes.

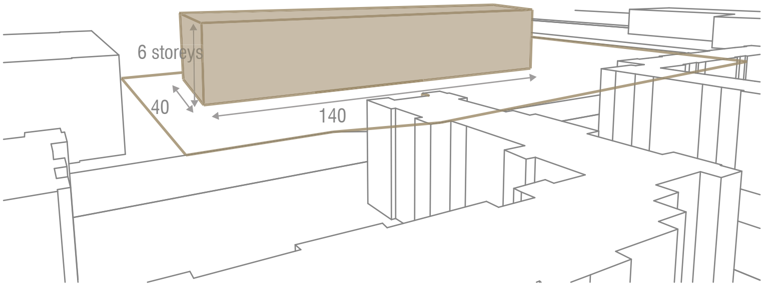
Between the parking and the main street there is a wheat field. It symbolizes the difference between conventional farming and the vertical farming in the building.


BUS STATION
AMPHITHEATHRE
BUS STATION
PLAZA
BOX PICK UP
FARMERS DELIVERY
GARAGE ENTRANCE
WHEAT FIELD
SHORT TERM PARKING
COVERED WITH PV
BUS PARKING
10
30
50

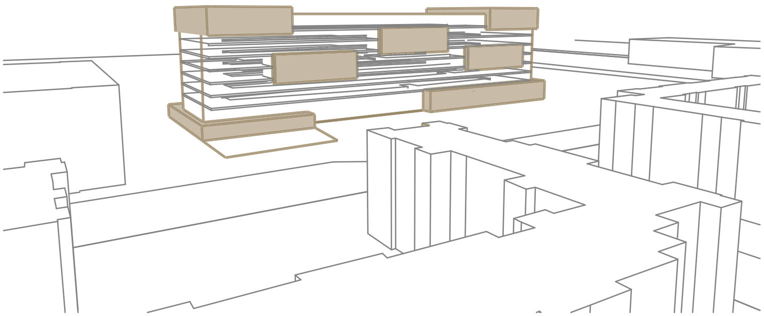
FORMFINDING



STEP 1: We have an plot area of 33 200 sqm.



STEP 2: We place the entire area of farming in a cube the size of 140 x 40 m, stacked 6 stories high. These are 33 600 sqm that we use for farming inside the building.



STEP 3: We intersect the building with additional functions.

FIG 21 Fromfinding

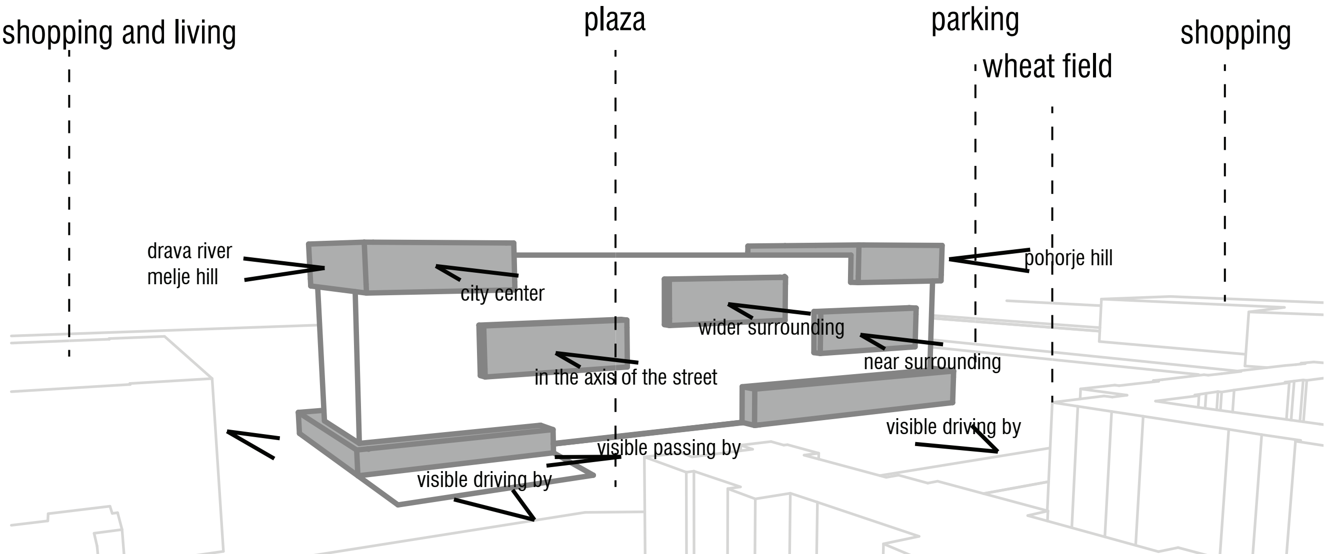


FIG 22 Views

The exact location of the functions and the cubes is based on the views.

FUNCTIONS

The additional functions are placed each in its own cube. These cubes are intersecting the main cube where the vertical farming is placed.

We divided the functions in those that are directly connected to the process of vertical farming and to the additional functions.

The additional functions increase the happening frequency in the neighbourhood and improve the quality of the neighbourhood.

The functions are connected between each other with ramps placed in the middle of the building forming an atrium. Otherwise this space would need a lot of artificial lightning to grow the crops.

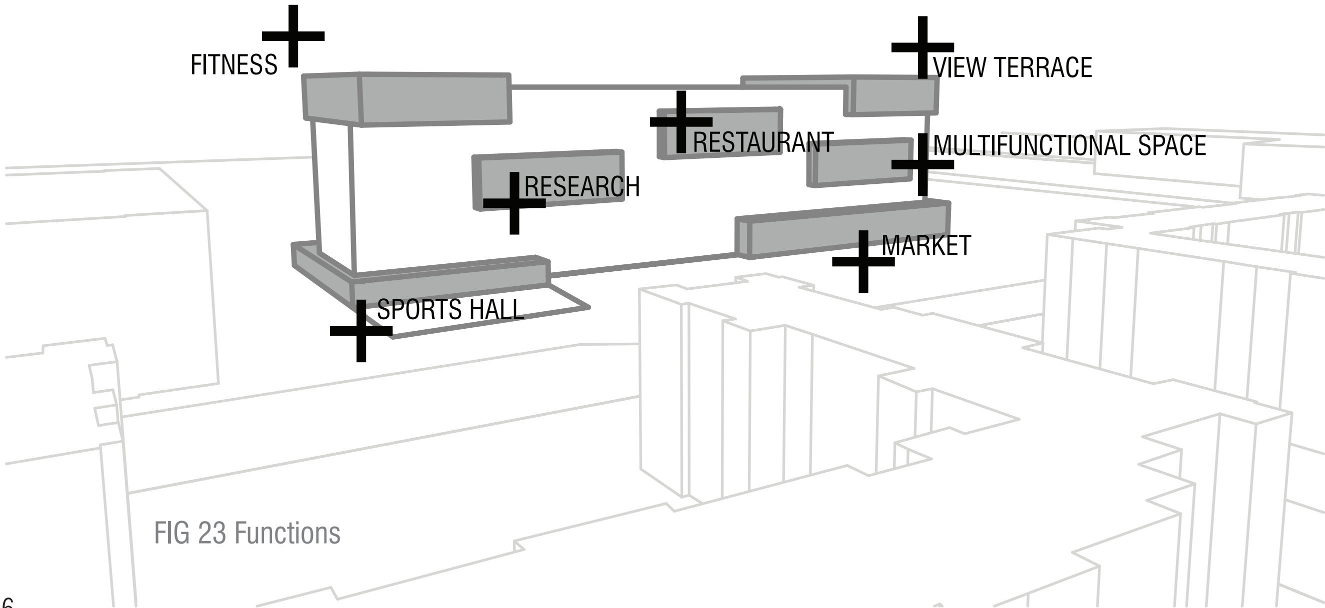


FIG 23 Functions

HVAC
1100 sqm
-heat pump
-biogas power plant

MARKET
2800 sqm
-food packing for box scheme distribution
-trading area for grown crops and local farmers
-seed library
-caffe and snack bar

RESEARCH
660 sqm
-implementation, control, development of the process
-germination of crops
-reducing energy use
-nutrition for the plants

RESTAURANT
580 sqm
-preparing food grown in the vertical farm
-cooking workshops

VERTICAL FARM
18500 sqm
-food growing
-testing different technologies
-testing different orientation and illumination for growing crops

connected to vertical farming

SPORTS HALL
1500 sqm
-sport
-additional amfitheather
-possible use for concerts and events

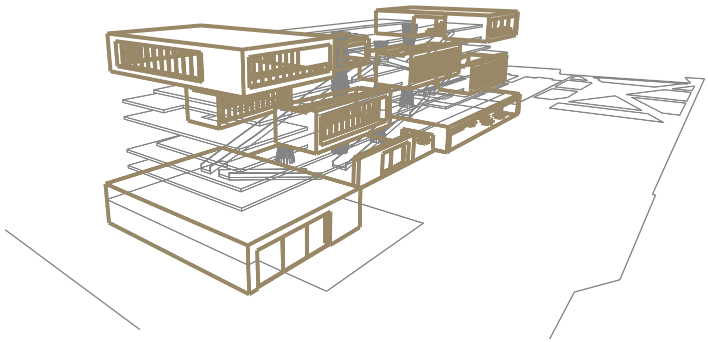
MULTIFUNCTIONAL SPACE
720 sqm
-community meetings
-occasional events
-sport

FITNESS
1100 sqm
-directly connected to sports hall
-running track
-smoothie bar
-indoor and outdoor

VIEW TERRACE
-910 sqm
-view
-outdoor events

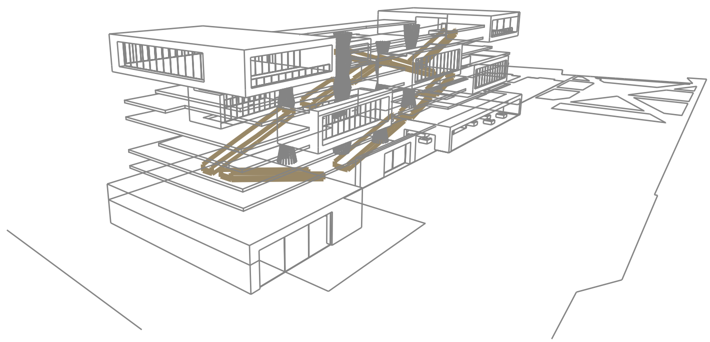
connected to leisure

The functions in the building are placed each in its separate box.



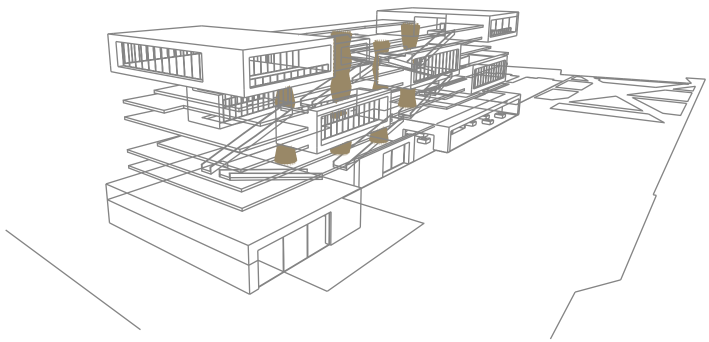
THE FUNCTION CUBES

These boxes are connected among each other with ramps. The ramps are placed in the middle of the building forming an atrium.



THE RAMPS

To compensate the space lost by the ramps a structure of tubes are placed in the middle. On these tubes we can grow food.



THE TUBES

FIG 24 Building parts

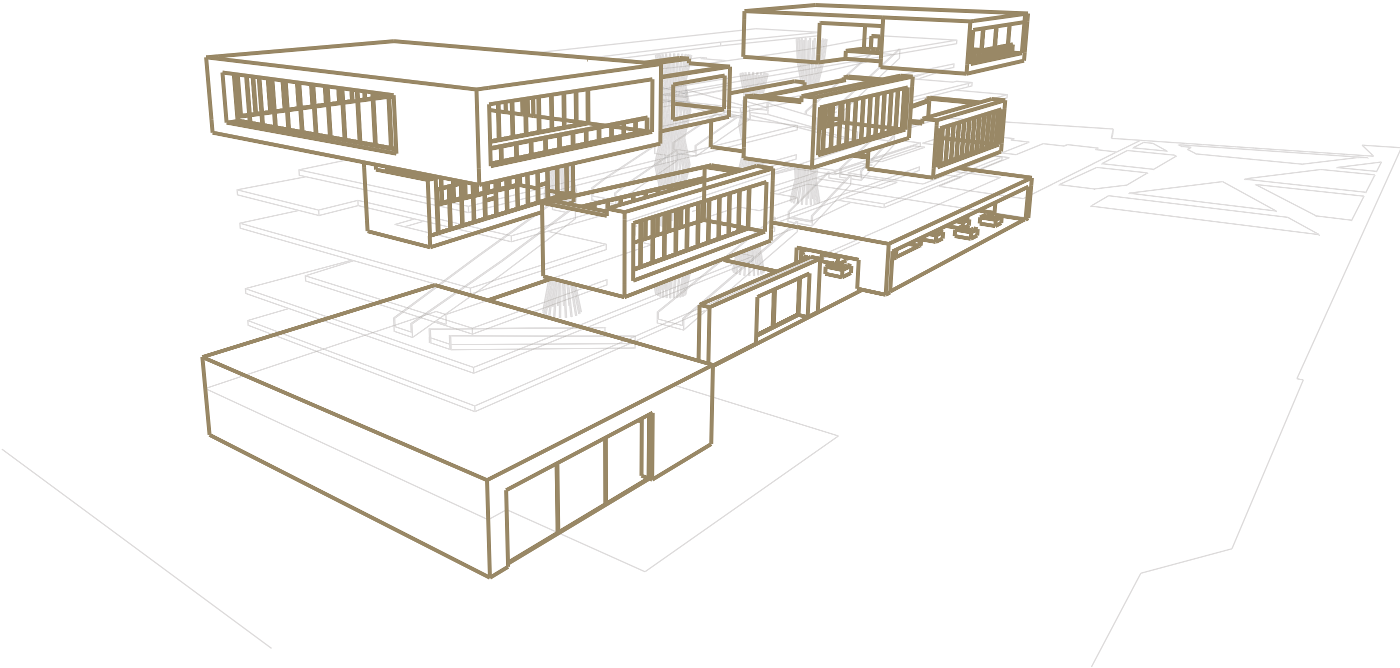


FIG 25 Function cubes

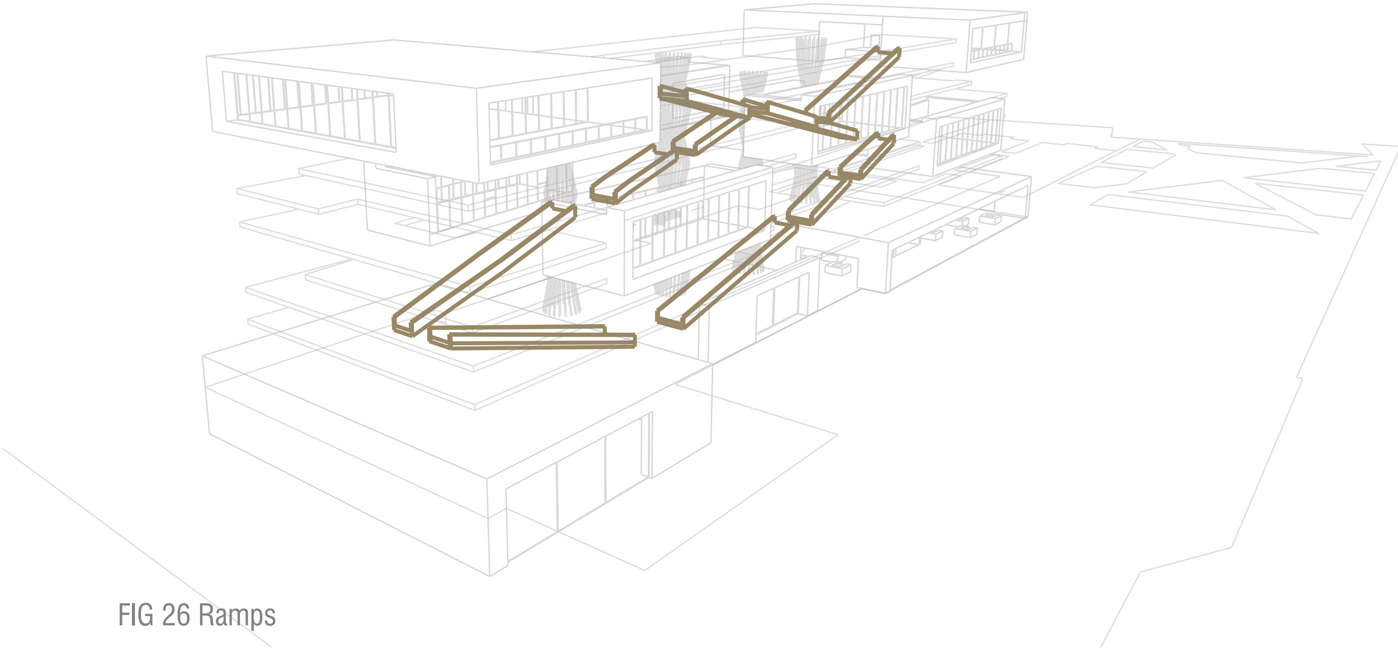


FIG 26 Ramps

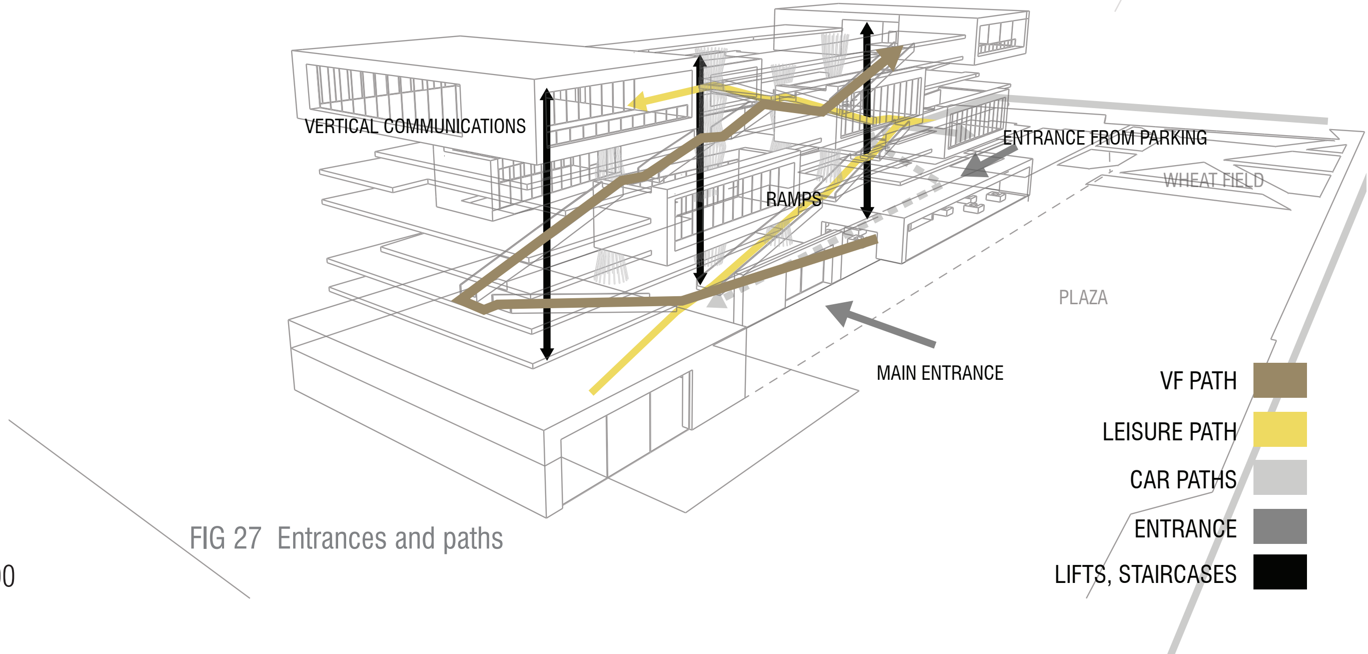


FIG 27 Entrances and paths

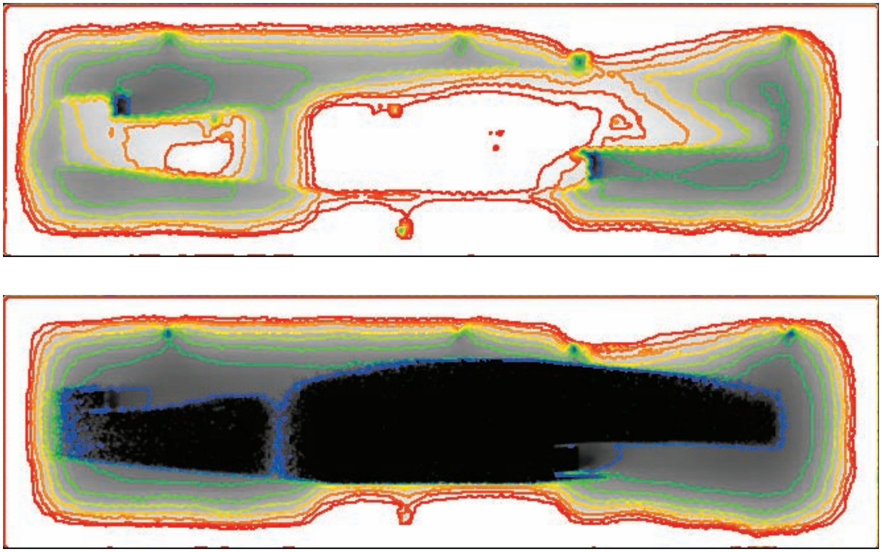


FIG 28 Daylight analysis with atrium and without atrium

The ramps are forming an atrium. Through the atrium sunlight can reach the inner part of the building. This reduces the need for artificial lightning.

The crops are placed in space regarding different amount of sunlight they need.

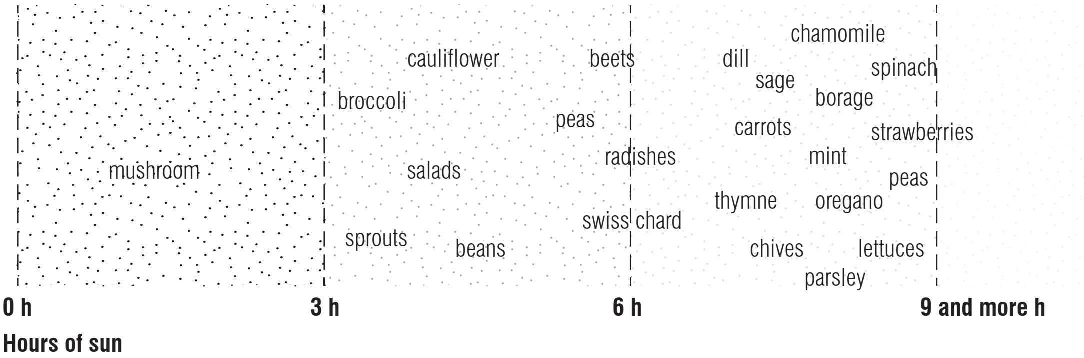


FIG 29 Different hours of sunlight needed by different crops

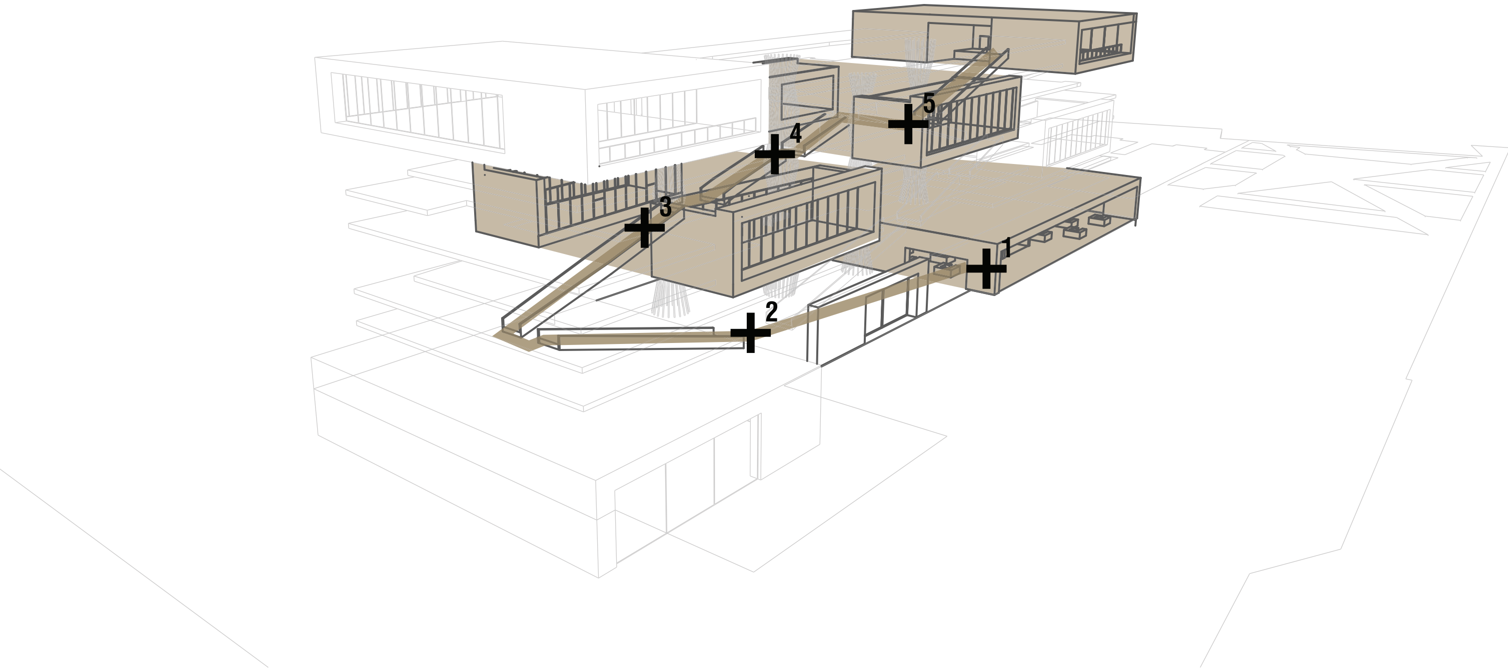


FIG 30 Walking through the VF part - Path

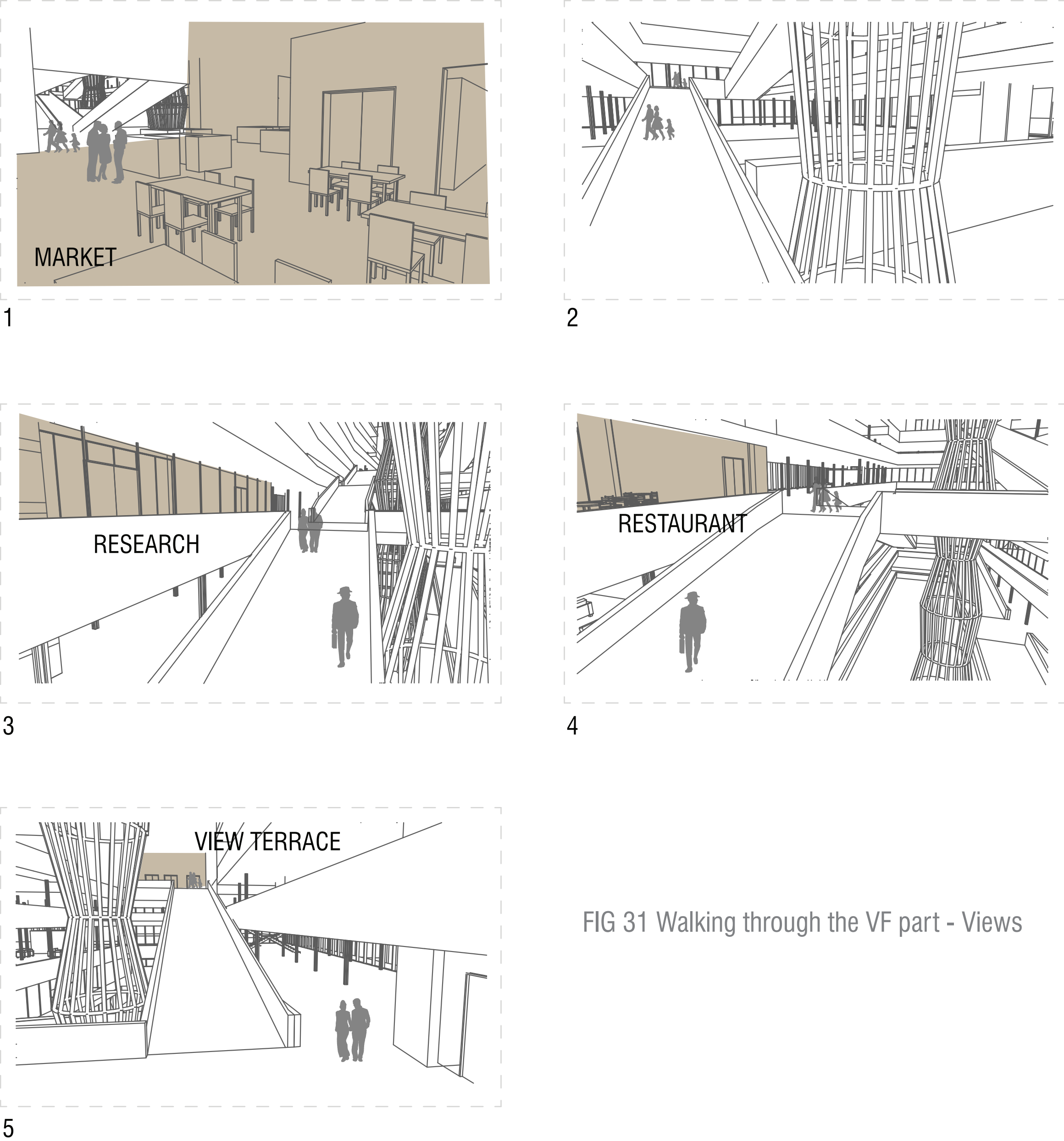


FIG 31 Walking through the VF part - Views

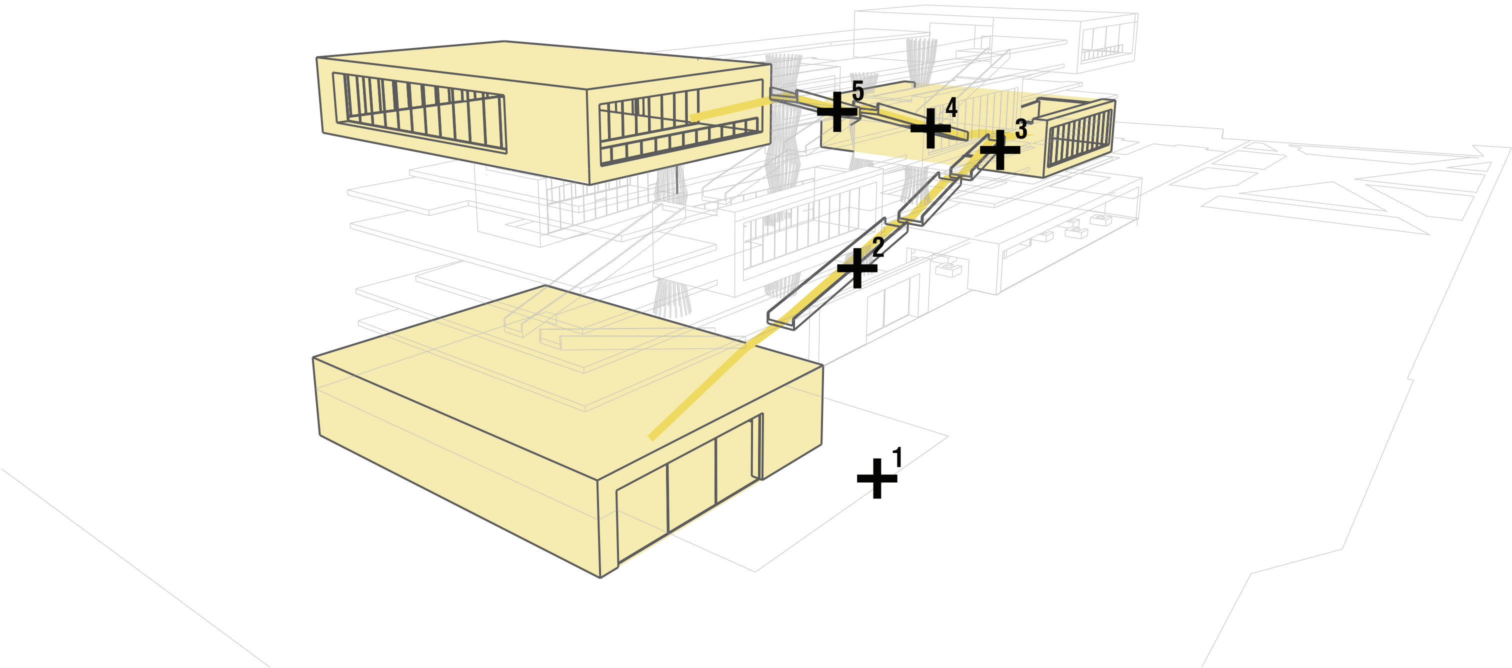
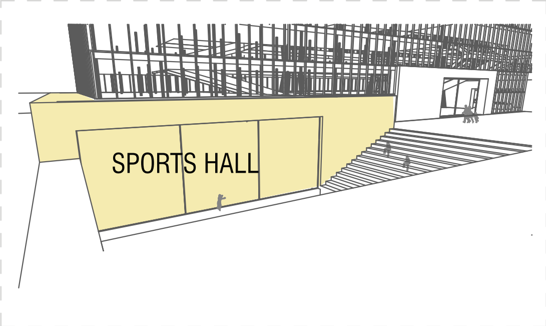
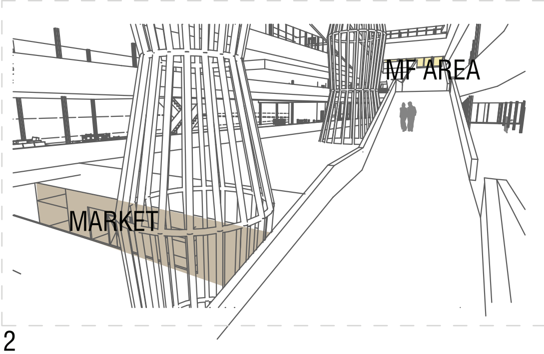


FIG 32 Walking through the leisure part - Path

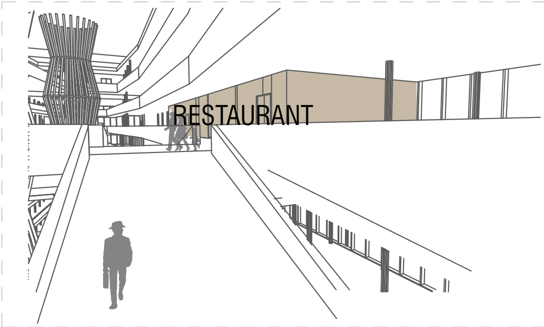


1



2

3



4

5

FIG 33 Walking through the leisure part - Views

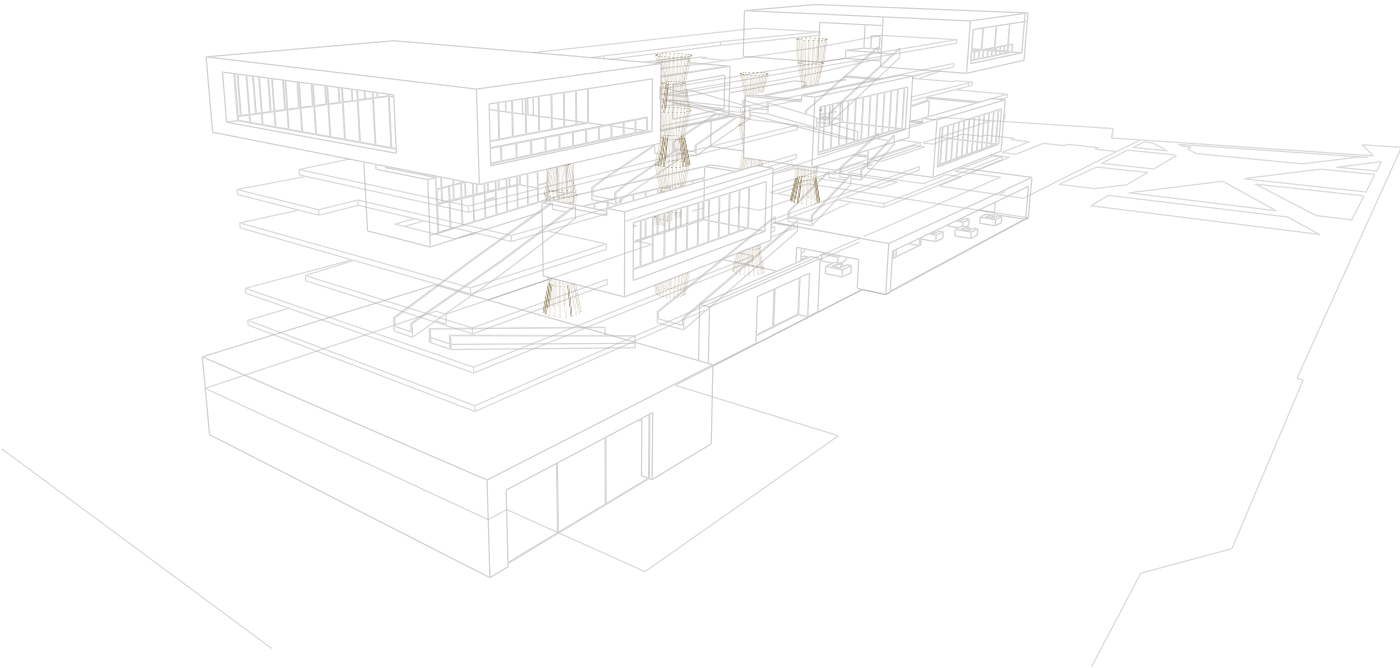


FIG 34 Tube installations

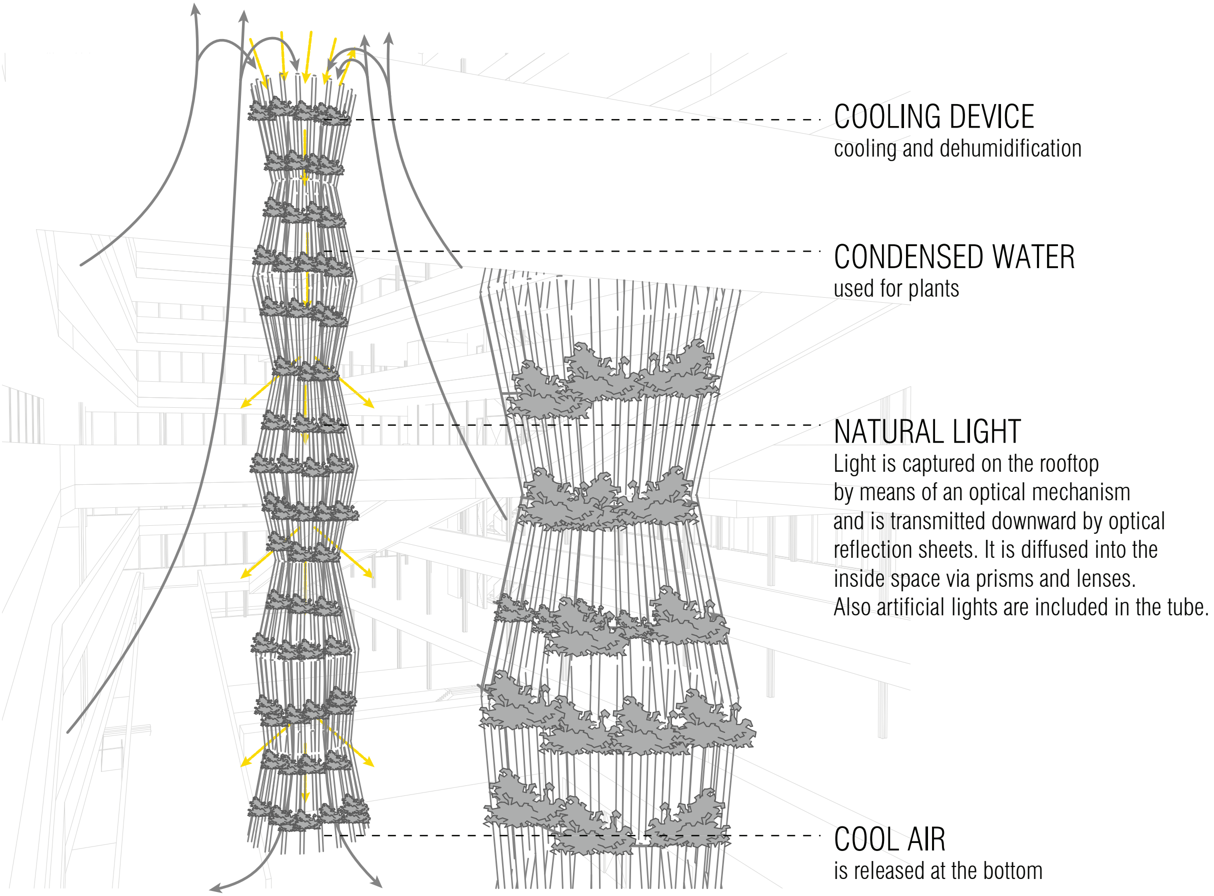
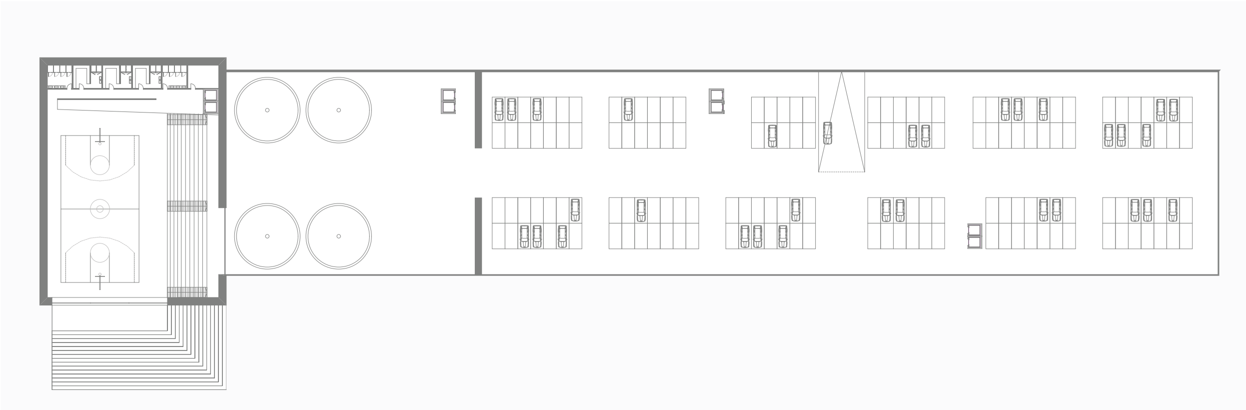


FIG 35 Tubes

The tubes have different functions: they are cooling and dehumidifying the building, inside them is a system to guide the sunlight into the building. The plant growing on the tubes are placed on a helix-shaped conveyor belt. They are planted on the top of the building and are ripe by the time they reach the ground floor.



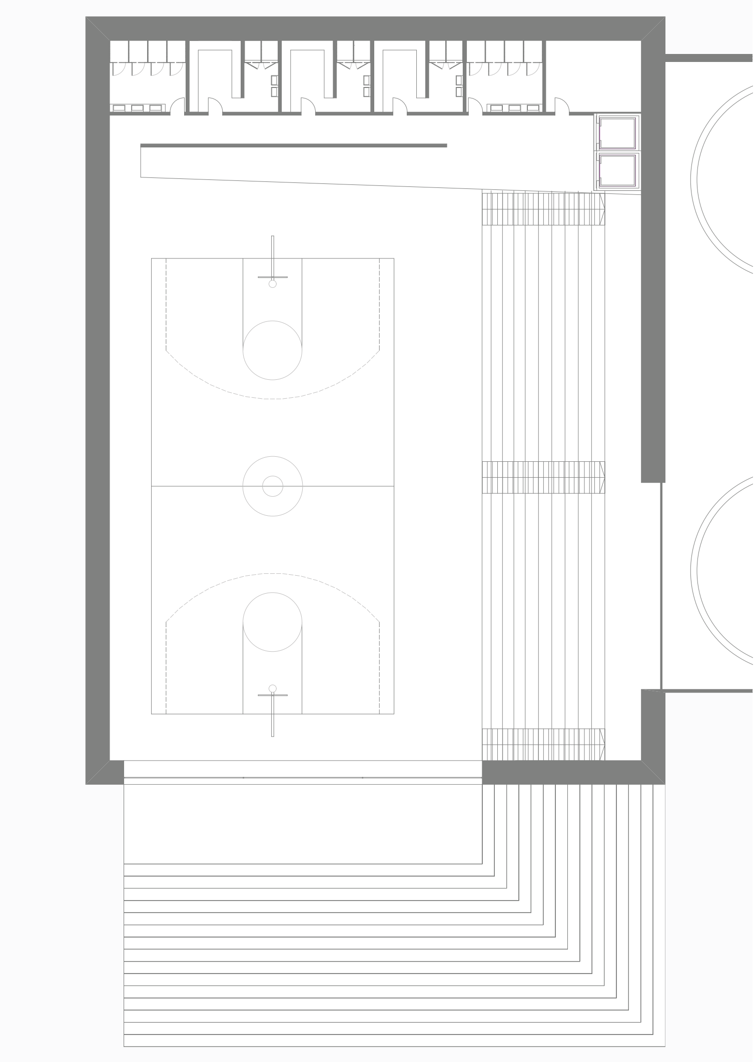
underground
m 1:1500

UNDERGROUND FLOOR

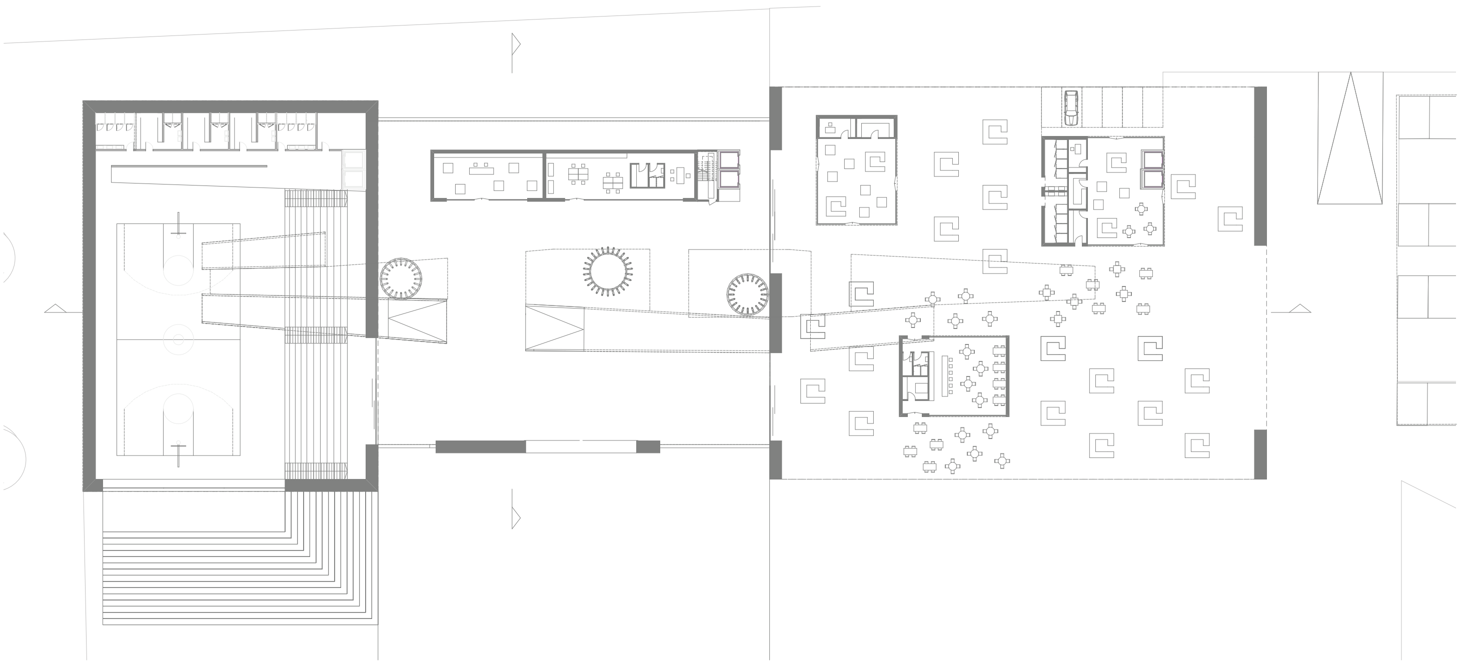
In the underground floor we have the sports hall. Although the sports hall is placed in the underground level, it is accessible form the ground floor. In front of the court there is an amphitheatre. The visitor from outside can watch th happening in the sports hall. The amphitheatre can also host different events.

Next to the hall we have the HVAC area.

In the underground levels there are additional parking places.



sport hall
m 1:500



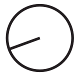
ground floor
m 1:1000

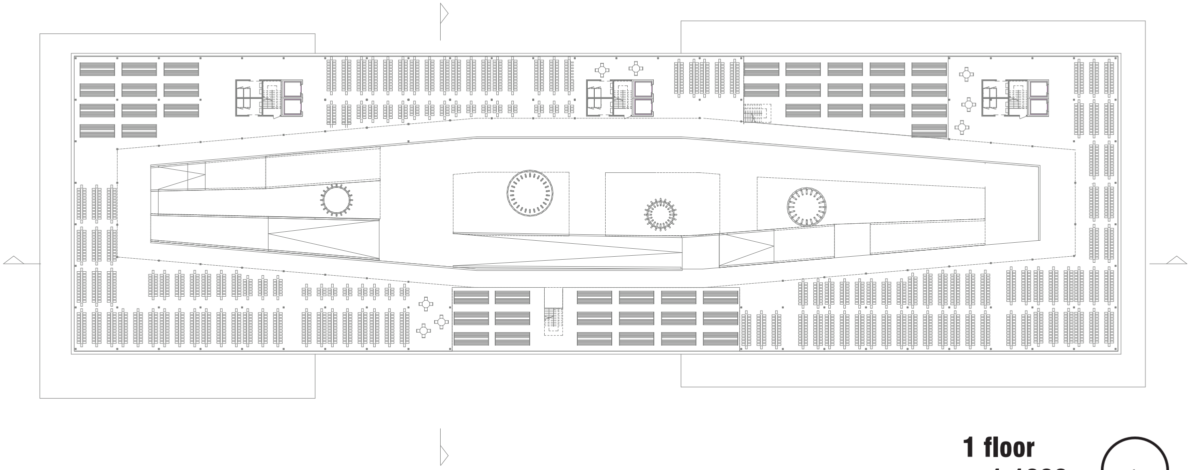
GROUND FLOOR

When entering the building we see the two ramps. One is leading to the sport part of the building and the second ramp is connecting the activities connected to vertical farming. On the left we can enter the tribune of the sport hall that is in the underground level.

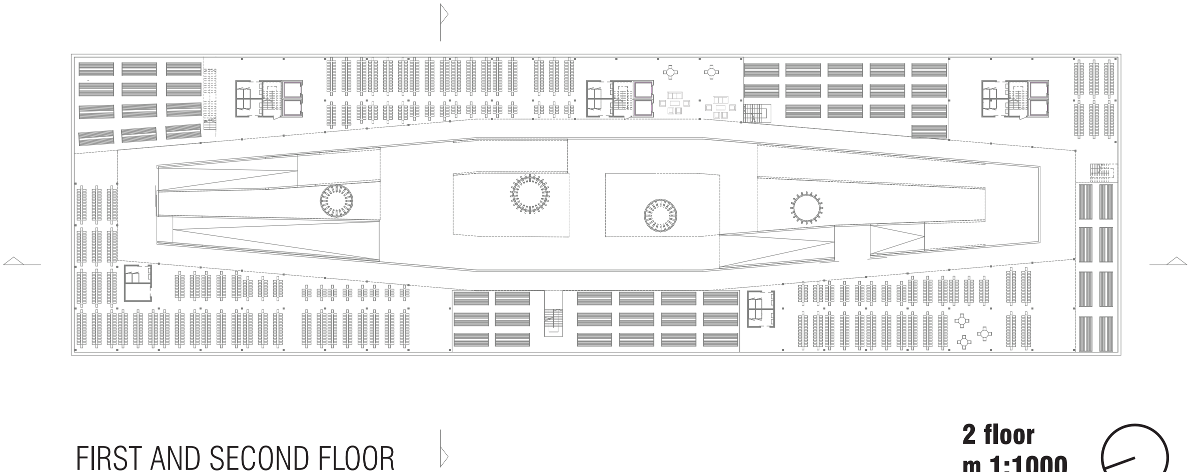
On the right is the market. The market is selling crops grown in the vertical farm. Also local farmers can sell their crops here. Between the stands there are three cubes. One cube is a café and snack bar. The second is a market selling products made from crops like yams, dried herbs and products that need to be cooled (like milk and meat from the local farmers). The third cube is packing the crops in boxes. It can be accessed by car, so the customers can pick up their boxes fast and easy.

market
m 1:500





1 floor
m 1:1000



2 floor
m 1:1000

FIRST AND SECOND FLOOR

The first and the second floor are used entirely for vertical farming. In some places the slab between the floors is intersected. The plants are growing between both floors. This generates an extra circulation between the floors beside the ramps.

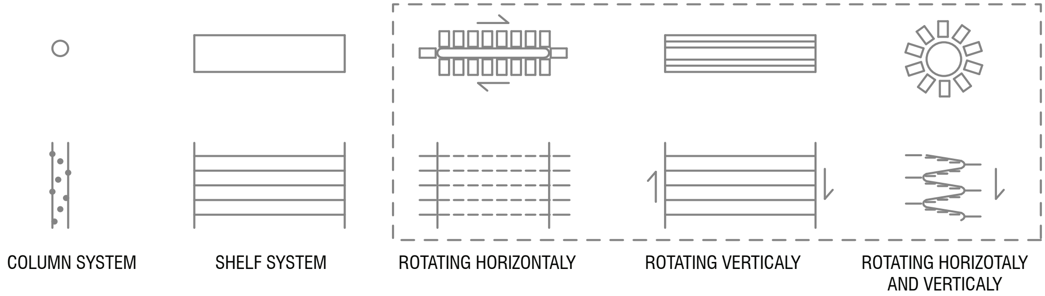
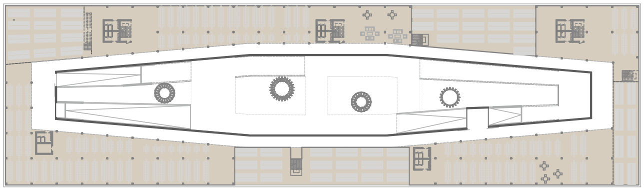


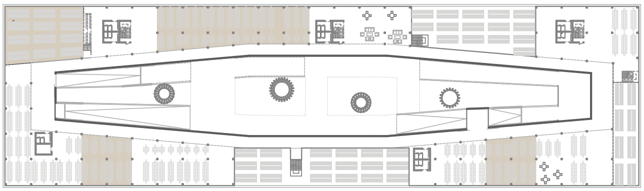
FIG 36 Different growing systems

There are different types of growing systems used in vertical farms. The non-moving systems are those where crops are growing on shelves or columns. These systems are often used but have the disadvantage that all crops do not receive the same amount of sunlight. When using artificial light, these systems are functioning very well. The moving systems are using the conveyor belt to move the plants either vertical, horizontal or on a helix shaped conveyor belt. These systems have the advantage that all the plants receive the same amount of sunlight. In the project we use the moving system because we try to use the maximum amount of sunlight.



example 1: whole floor is one area

The floor can work as one entity with the same humidity and temperature or it can be divided in smaller areas between the columns. In this case each space can have its own climate conditions for the plants.



example 1: smaller areas are forming

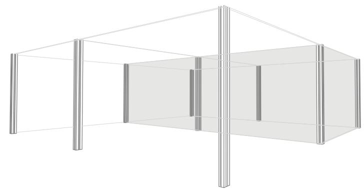
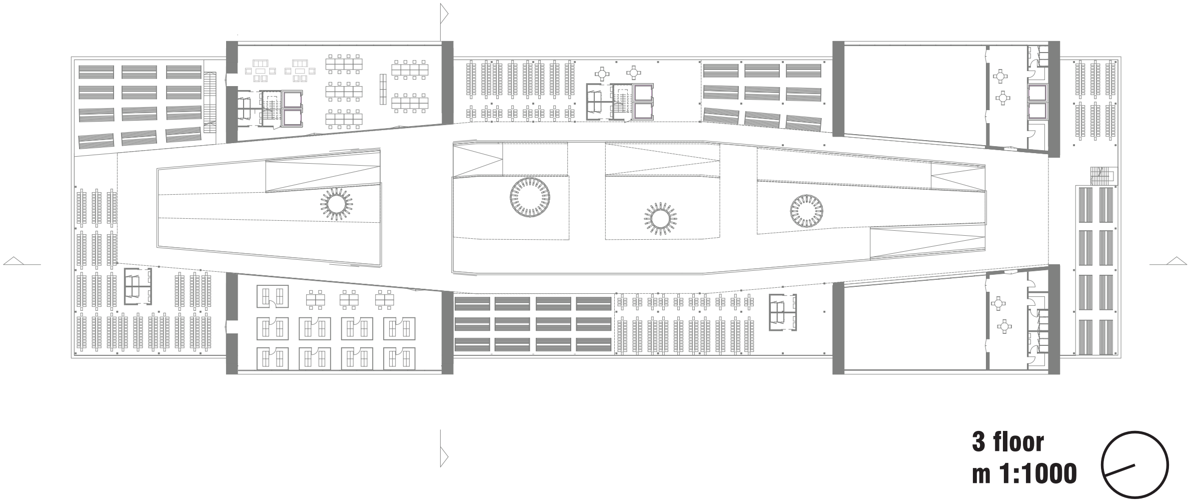
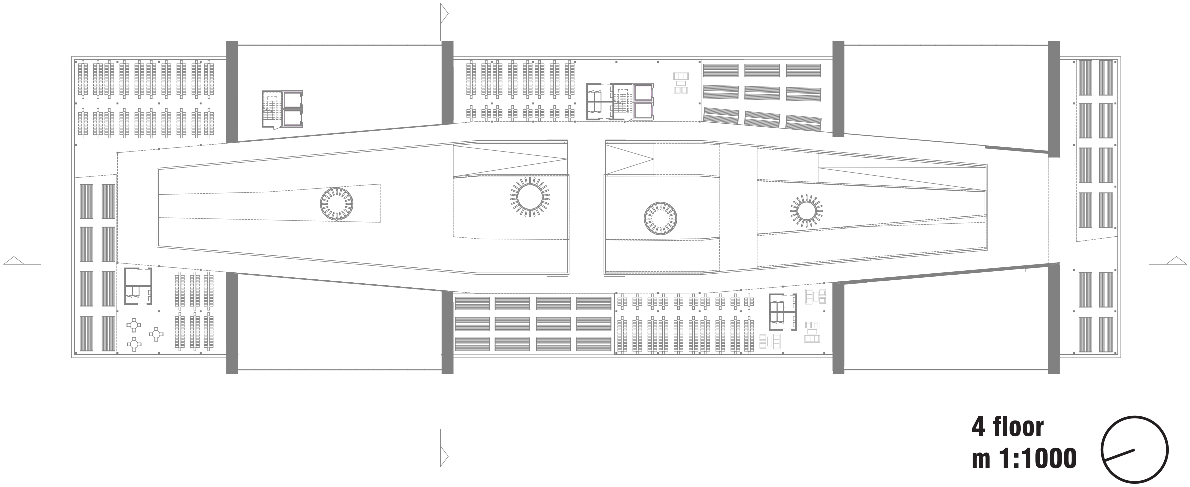


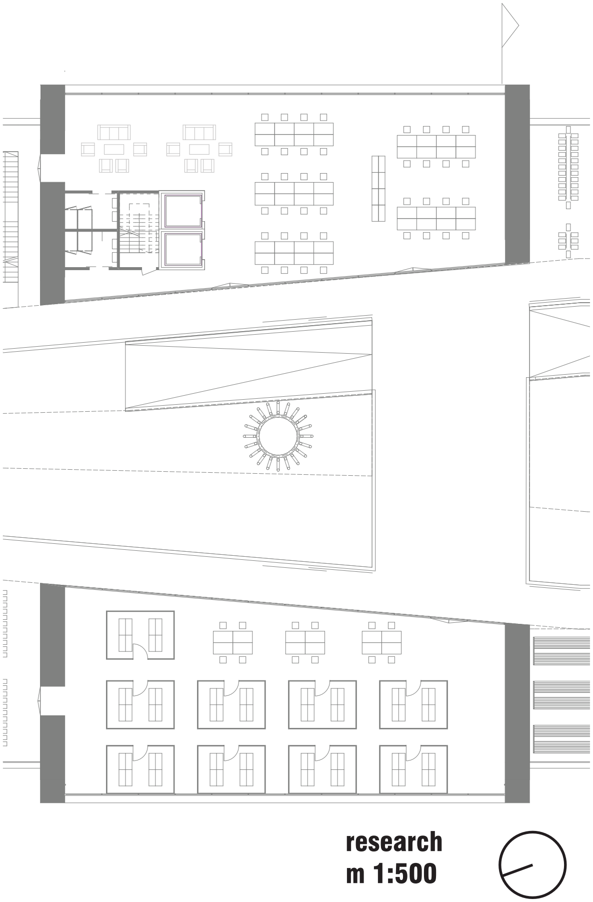
FIG 37 Placing walls between the columns

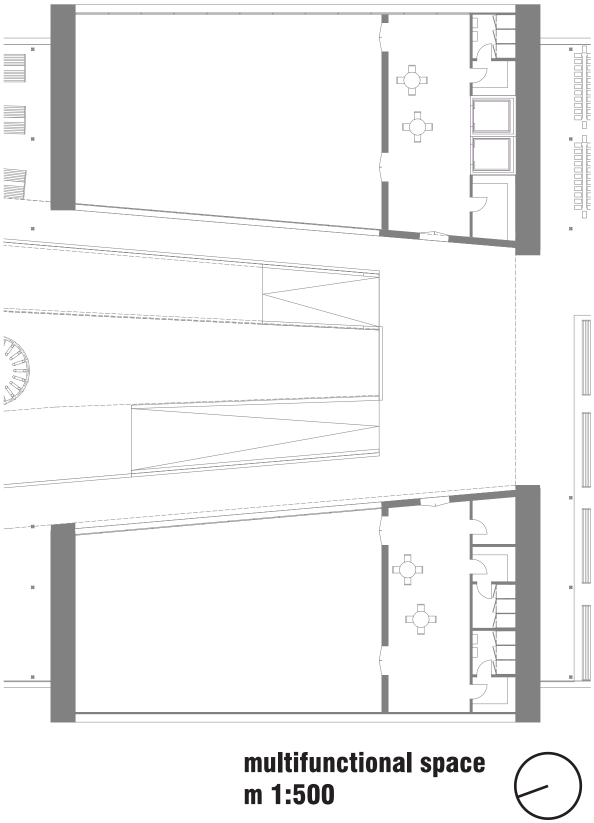


3 floor
m 1:1000



4 floor
m 1:1000



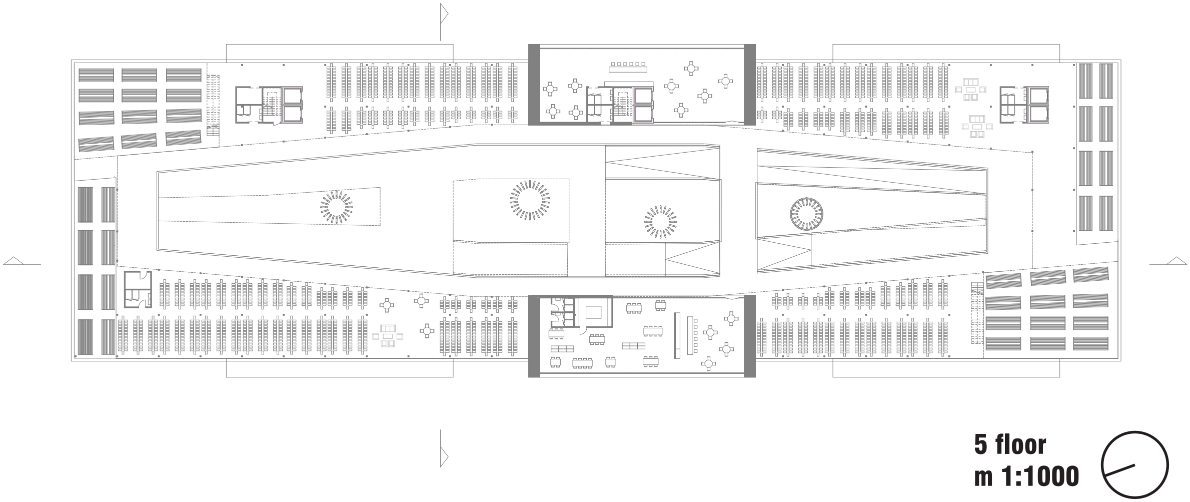


THIRD FLOOR

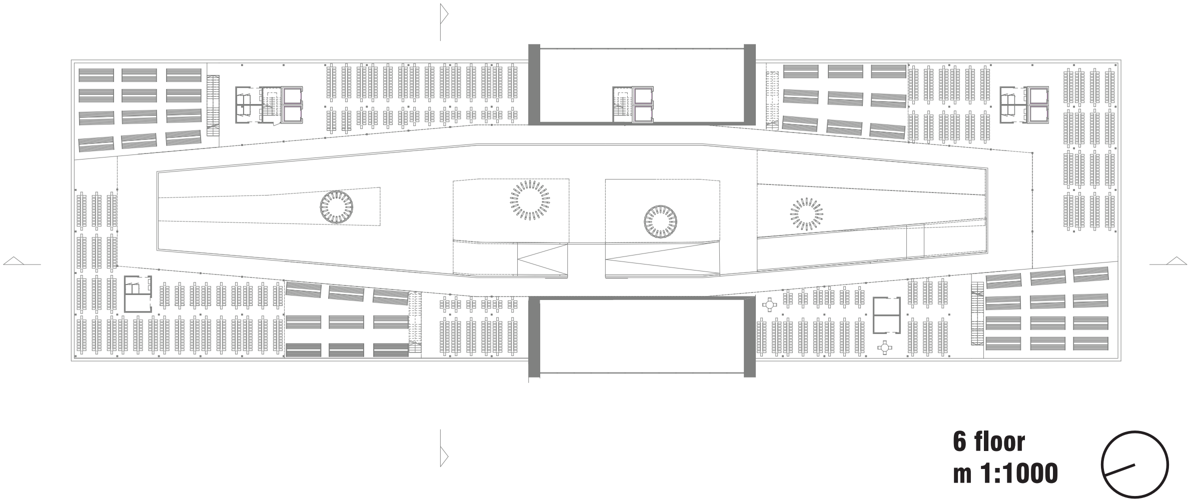
The research centre on the third floor is divided in two parts. In the first part the nutrition for the plants are produced and the VF process is being monitored. The second part of the research entity is where the plants are germinated.
The multifunctional place can be used as a gallery, as a smaller sport hall or to host different events.

FOURTH FLOOR

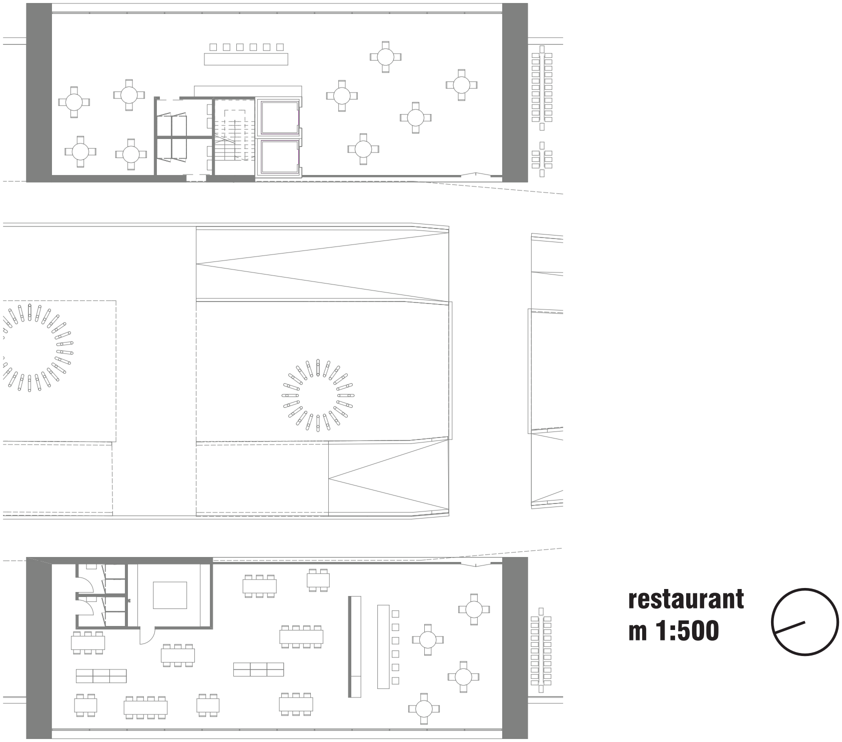
The fourth floor is used entirely for vertical farming.



5 floor
m 1:1000



6 floor
m 1:1000

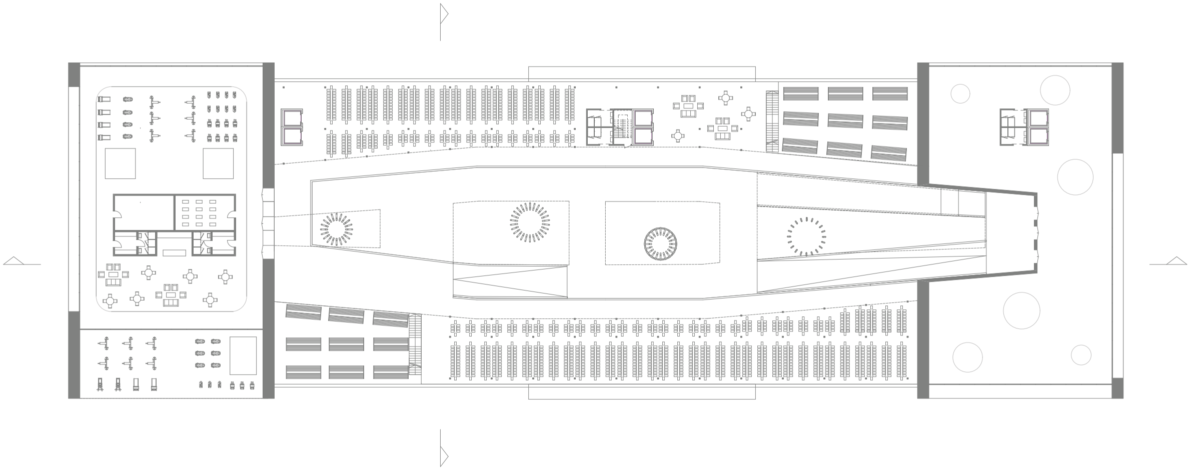


FIFTH FLOOR

The restaurant on the fifth floor divided in a smaller part where people can have a snack and a drink and the bigger part where there is a restaurant.

SIXTH FLOOR

The sixth floor is used entirely for vertical farming.

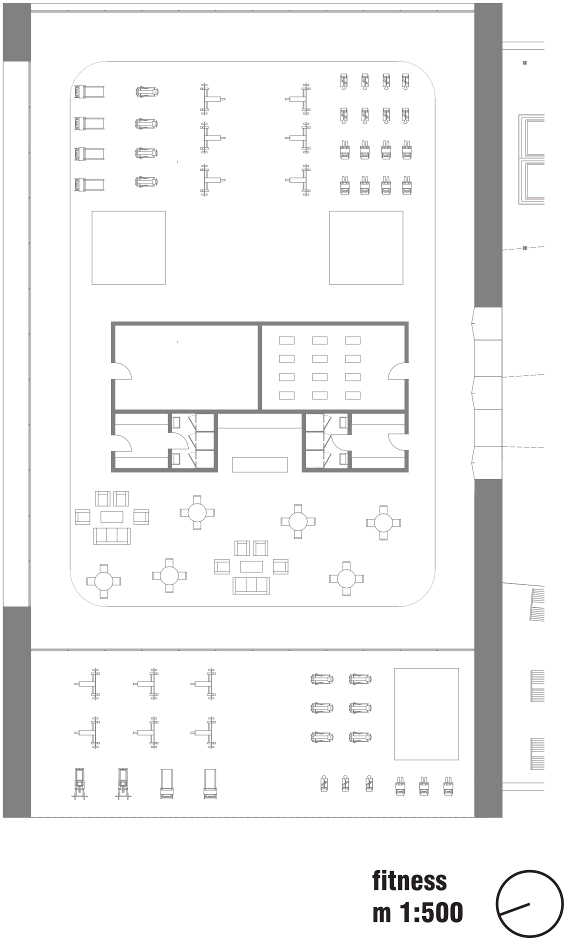


7 floor
m 1:1000

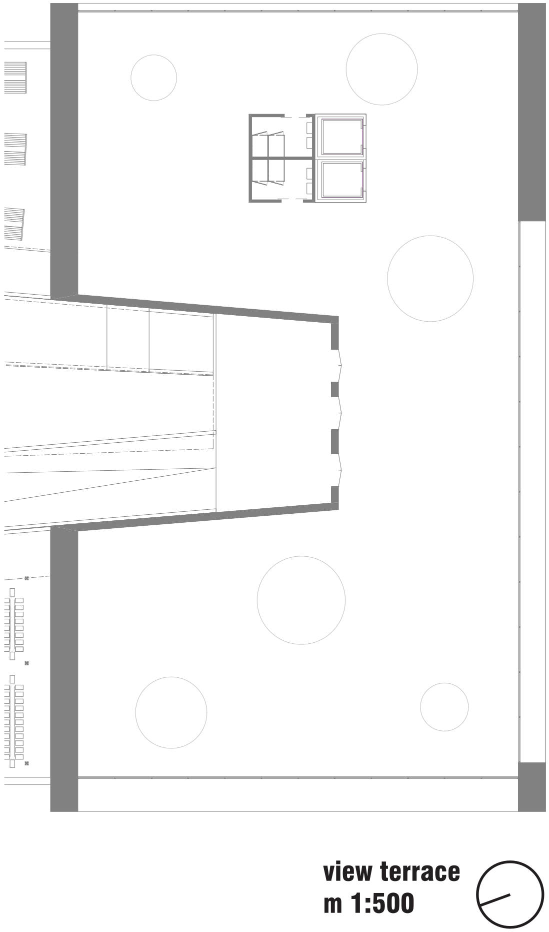
SEVETH FLOOR

On the seventh floor we have a big fitness that is connected to the sports hall by an elevator. The fitness centre has a big outdoor part.

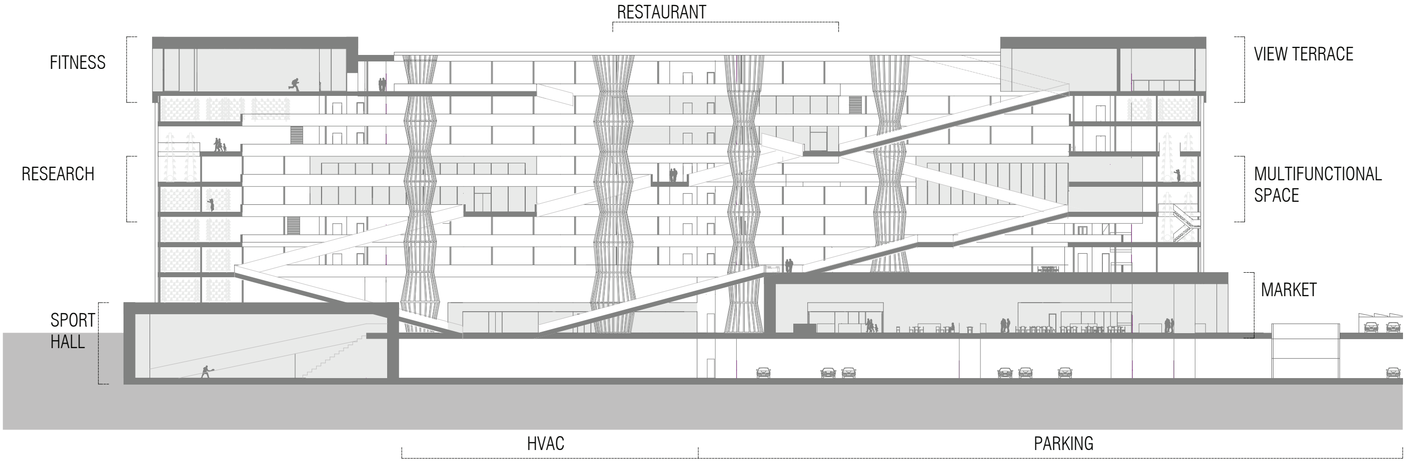
The view terrace is a big multifunctional outdoor space.



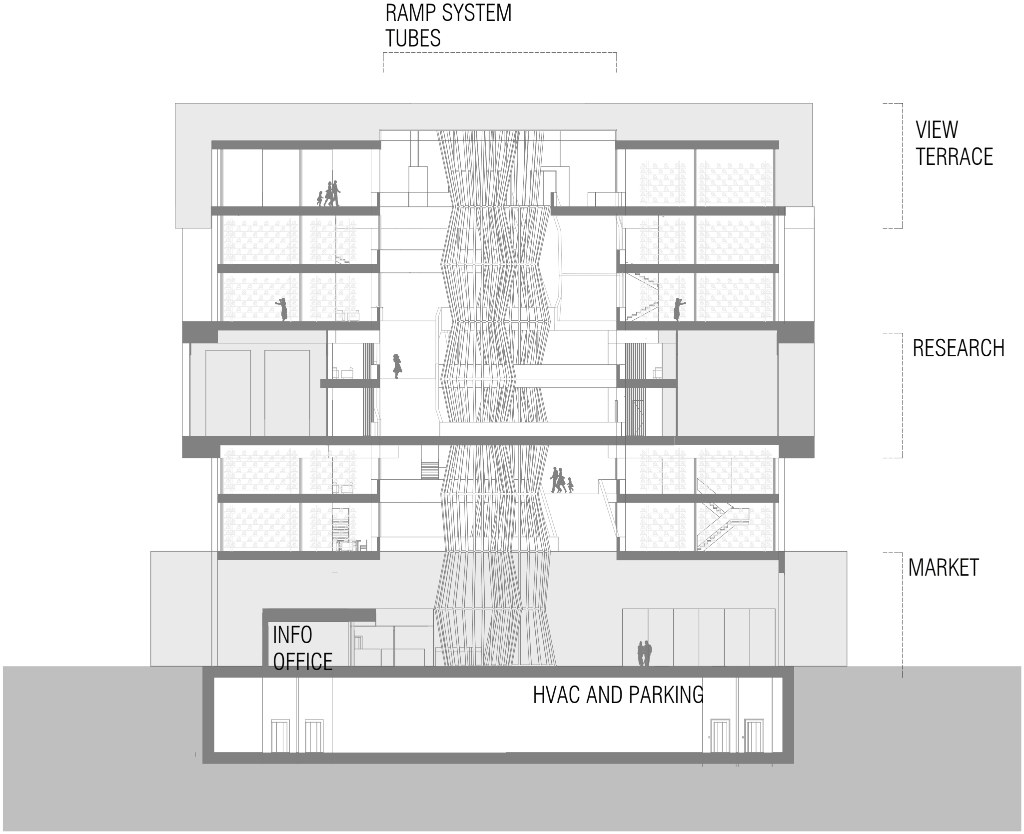
fitness
m 1:500



view terrace
m 1:500



longitudinal section
m 1:1000



cross section
m 1:500

THE SHADING AND THE VENTILATION

The building has an insulation glass facade. The vertical sun blinds between the glasses are covered with PV. They can be pulled together or can be partly or entirely closed depending on the weather conditions.

The building can be naturally ventilated through the façade and through the atrium. The tubes placed in the atrium help to dehumidify and cool the air.

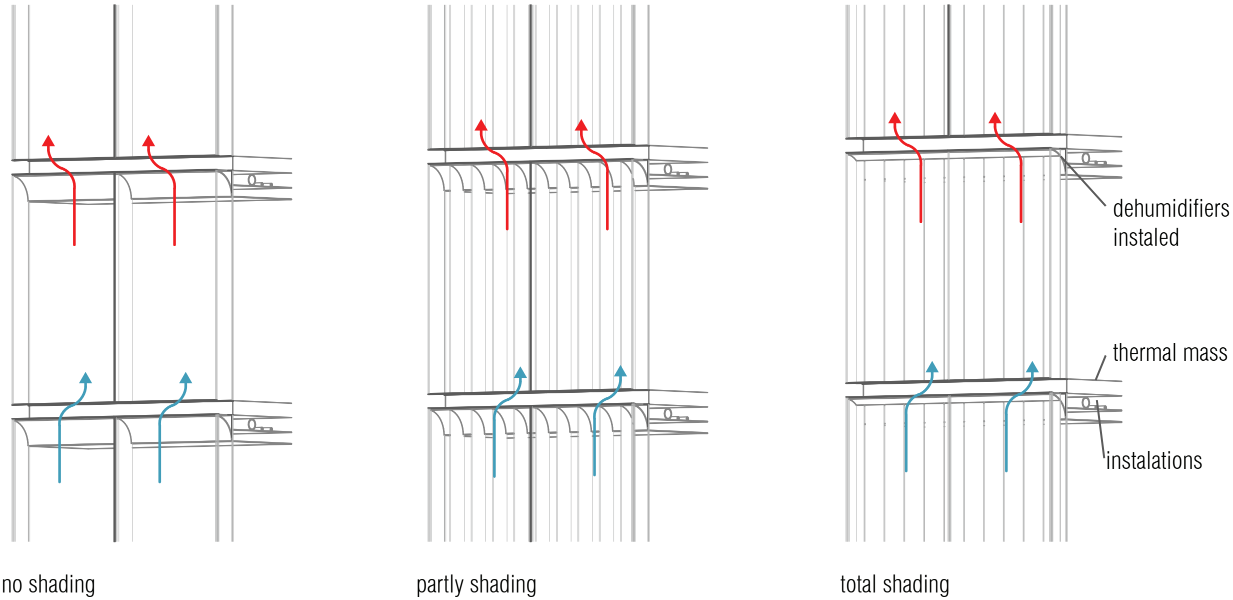


FIG 38 Shading and natural ventilation through the facade

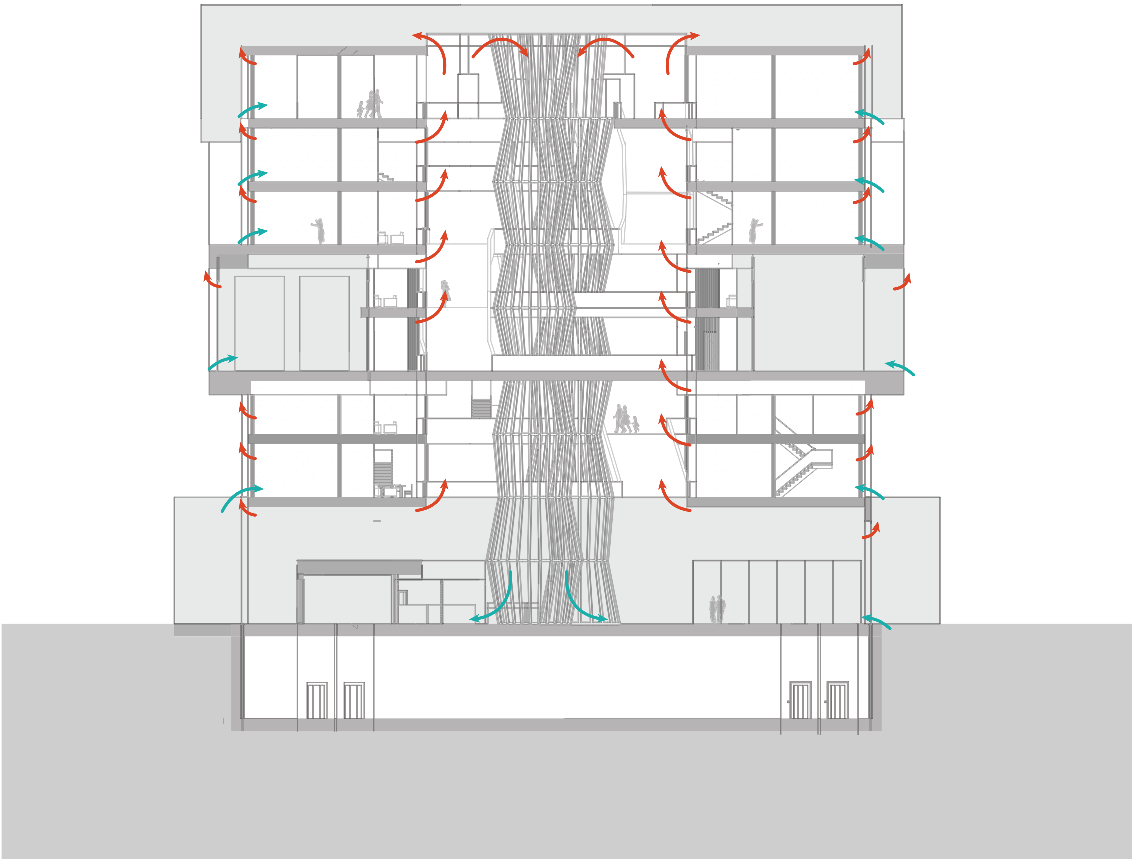
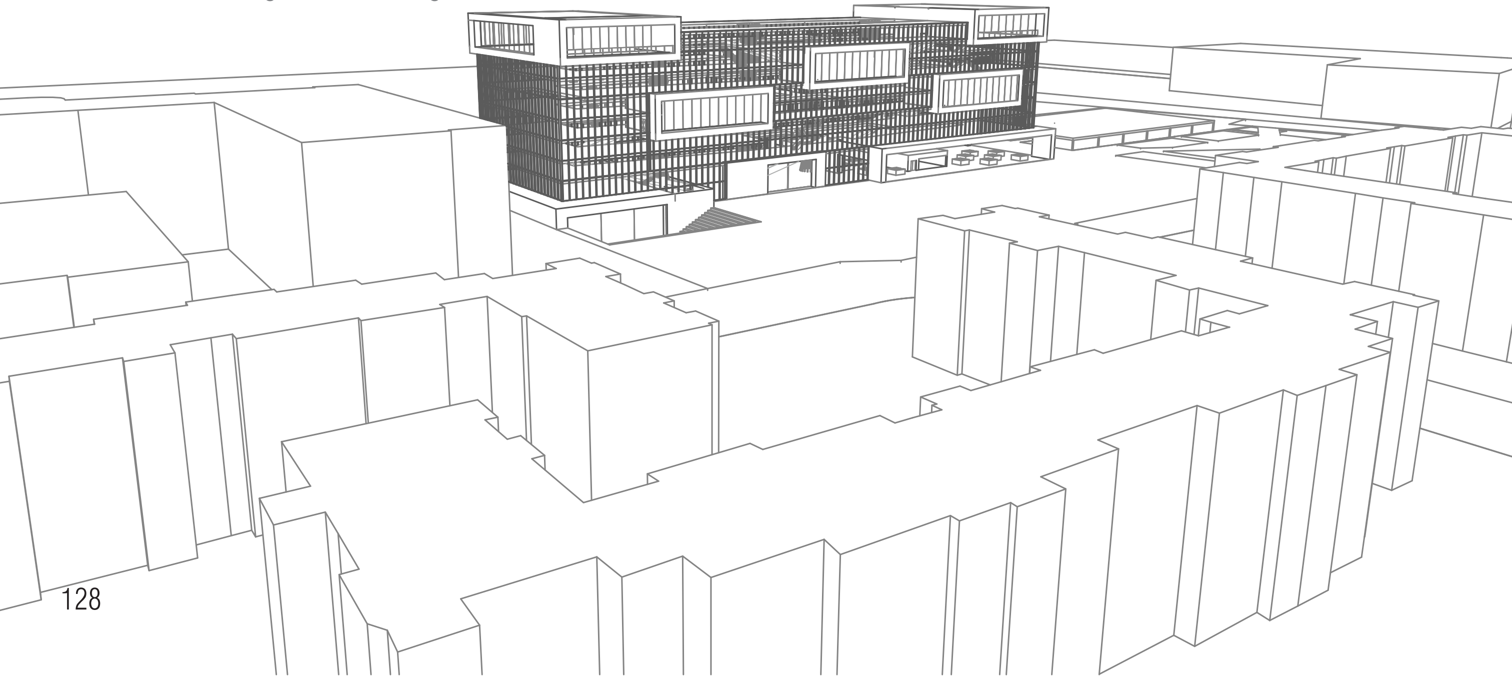


FIG 39 Natural ventilation through the atrium

FIG 40 Surrounding of the building



WHICH GOALS CAN WE ACHIEVE

LAND SCARCITY

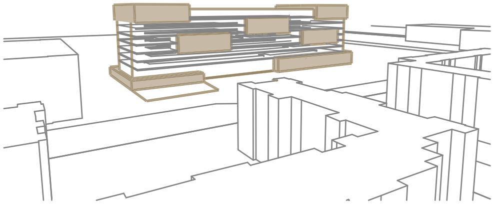
It is estimated that by 2050 the world population will reach 9 billion inhabitants and will need an additional area of Brazil (8.515.767 km^2) to satisfy their need for food.[4] Based on Nasa's calculations we could grow food for one person on a 2500 kcal diet on 50 sqm.[5] Today we need on average 2300 sqm to feed person.

Our vertical farm is growing food and vegetables. Based on Kastener's calculations we need 212 sqm of area to grow fruit and vegetables for one person (calculated for Slovenia's diet).[6]

If our site would be farmed with today's farming techniques, we would produce food for 313 people, while in our farm we can feed 2181 people, because we can stack the growing area and we can produce food all year. With the VF we would provide enough food for people living in the radius of 12 min.

4 cf Despommier 2010, 96.
5 cf Wheeler 2015.

6 cf Kastener et al.2012, p 6868-6872.



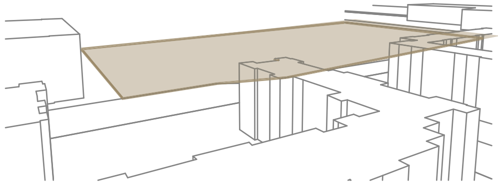
growing maribor
18500 m2 x 5 (stacking) = 92500 m2

how many persons can we feed

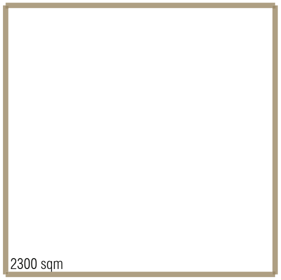
space required to cover the need of one person in a 2500 kcal basis based on Nasa's calculations

92500 m2 / 50 m2

1850



traditional farming
site 33200 m2



avarage space required to feed 1 person based on Kastener's calculations

(33200 m2 / 2300 m2) x 2 crops a year

28

how much vegetables and fruit can we grow

based on Kastener's calculation we need 212 m2 of space to provide fruit and vegetables for the Sloveniandiet

(92500 m2 / 212 m2) x 5 crops a year

2181

(33200 m2 / 212 m2) x 2 crops a year

313

WATER SCARCITY

Modern agriculture is a big consumer of water. Vertical farms are using watering techniques that reduce the amount of water used to 90 %.[7]

If the site would be farmed conventional techniques, 10 l of water per sqm would be used daily to water the crops.[8] The harvested rainwater would cover 29% of the water needed. In our vertical farm the harvested rainwater would fully cover the water needs.

7 cf Despommier 2010, p207.

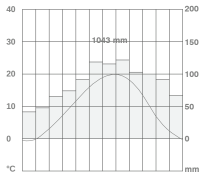
8 cf ow much water do we need for watering, 2015

CLASSIC IRRIGATION (SOIL)

HYDROPONICs
-70% less water than classic irrigation

AEROPONICs
-90% less water than classic irrigation

RAINWATER HARVESTED
1046 L/sqm



WATER USED IF THE SITE (33600 m2) WOULD BE FARMED TRADITIONALY
-ca. 10l/day/sqm
-rainwater harvested on 33600 sqm
-122640000 l/year needed
-29% of water is rainwater

WATER USED IN THE RESEARCH VERTICAL FARM
-ca. 1l/day/sqm
-rainwater harvested on 7250 sqm (roof, amphitheather)
-6752500 l/year needed
-100% rainwater
-12% of rainwater extra

ENERGY SCARCITY

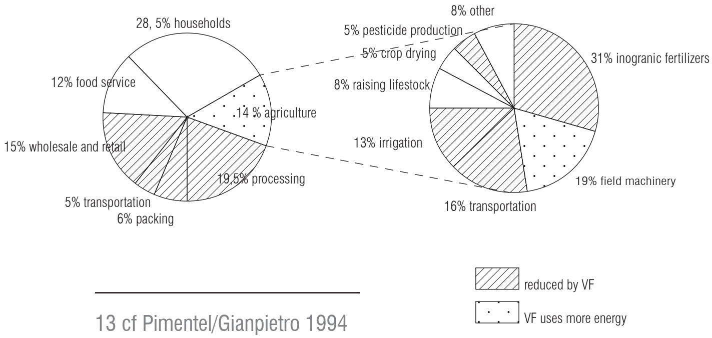
Modern agriculture uses a lot of energy. Giampietro and Pimentel found out that 10 kcal of energy are required to produce 1 kcal of food delivered to the consumer in the food system. This includes packaging and all delivery expenses, but excludes household cooking). This disparity is made possible by non-renewable fossil fuel stocks.[9] Only 14 % of this energy is directly connected to the farming process while the rest of the energy is needed to bring the food to the consumer and to prepare it.[10]

The vertical farms can reduce the energy used by transport. On the other hand vertical farming needs a lot more energy to grow the crops. The energy use is caused by the embodied energy of the building and equipment, the energy used for HVAC and the use of growing light. The amount of energy used for growing can be reduced by using natural light. In the case of Vertical harvest in Wyoming they managed to reduce the use of grow lights on 3000 hours a year.[11] If we take the most efficient growing lamps, that use 50 W/h, each sqm of the building would use 150 kWh of energy.[12] Today's agriculture is using 1000 l of oil to produce crops on hectare. This means that every sqm would needs 1,2 kWh of energy.[13] Although a vertical farm can produce a lot more food on one sqm, it has an enormous energy consumption comparing it to today's agriculture.

9 cf Pimentel/Gianpietro 1994
10 cf Canning et al,2010.
11 cf 11 Vertical Harvest, 2015.
12 Nasa forum, 2015.

But vertical farming has also one advantage compared to today's farming. While modern agriculture uses oil as its energy source, vertical farms can use greener energy sources, like biogas, PV cells and geothermal energy for heating. Gordon Graff proved that his concept of a vertical farm could actually work by using these energy sources.[14] But still we must add that his farm uses a lot of energy. Also our building has potential to produce enough energy to work, using heat and electricity generated by bio waste of the neighbourhood and using PV cells.

FIG 41 Energy use in conventional farming



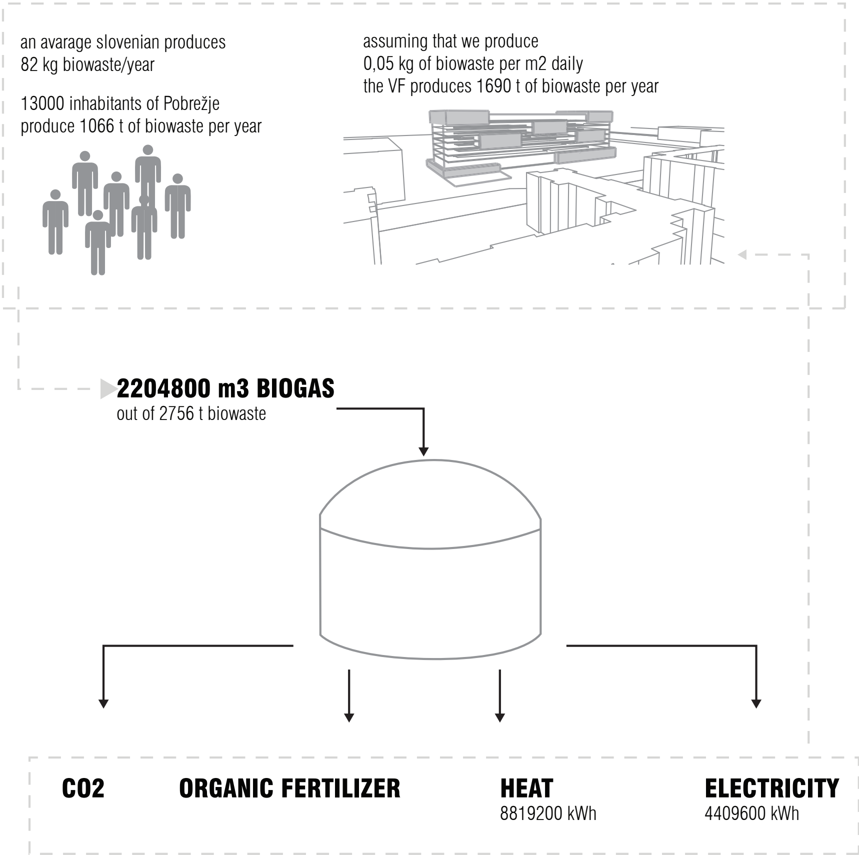
13 cf Pimentel/Gianpietro 1994
14 cf Gordon Graff 2015

BIO WASTE TREATHMENT

We can use bio waste to produce energy and heat for the building. If collecting bio waste from the 13000 inhabitants of Pobrezje (each producing 82 kg of waste a year)[15] and if we assume that our VF produces 0,05 kg of waste per sqm daily, we could produce 8819200 kWh of heat and 440960 kWh of electricity.[16]

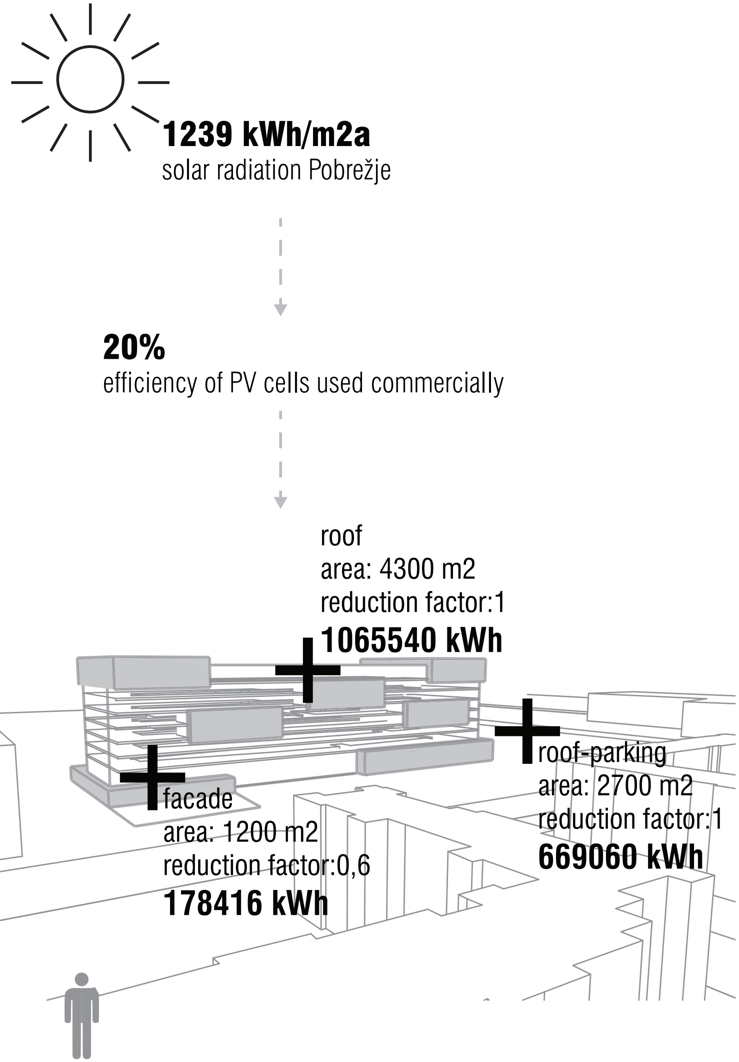
15 cf Zurnal 24, 2015

16 cf Electrigaz 2015



PHOTOVOLTAIC PANELS

Our site has an annual solar radiation of 1239 kWh/m2a.[17] By placing PV cells on the roof and on 20% of the façade, we could produce 1913016 kWh of energy by using PV panels with an efficiency of 20 %.



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17 Engis, 2015.

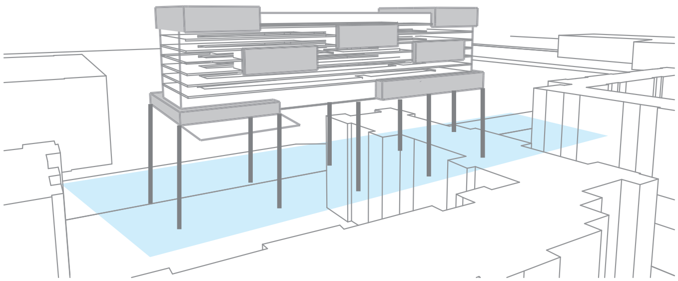
GEOTHERMAL ENERGY

A heat pump is used for cooling the building. If using a water/water hat pump, each kWh of energy would be converted to 6 kWh of cold.[18]

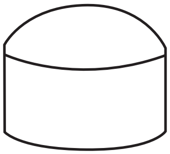
18 cf Zrmk, 2015.

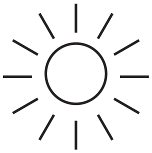
COP heat pump water/water : 6

1 kwh of electricity produces 6 kWh of energy for heating and cooling



energy produced

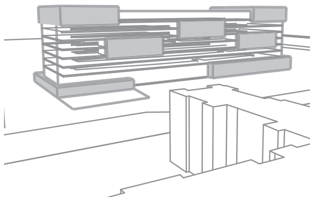




8819200 kWh
of heat

6322616 kWh
of electricity

energy produced



23060 m2 heated
80 kWh/m2a needed
(PHPP estimation)

100%
of heating needs covered
+6974400 kWh extra energy

92500 m2 of VF
150 kWh/m2a needed
for VF lightning

46%
of lightning needs covered

CLIMATE CHANGE

By crowing crops in closed environment the crops are not affected by climate change. By using cleaner sources of energy we do not contribute to climate changes as much as modern agriculture that is based on oil.

REDUCING POLLUTION CAUSED BY FERTILIZERS AND PESTICIDES

The crops are grown in a closed environment organically so there is no need to use fertilizer, pesticides or herbicides that are mostly produced out of oil.

OFFERING NEW ACTIVITIES

The building is providing public functions that improve the quality of living for the people in the neighbourhood. The building provides several spaces that can be used by the community. We have a multifunctional plaza, an open market, a multifunctional hall, a restaurant serving locally grown food, a sport hall, fitness and a viewing platform. These activities will increase the happening frequency in the area that is now reduced to living and shopping.

INTRODUCING THE PROCESS OF VERTICAL FARMING

The ramps connecting the different functions generate a path through the building. While walking on the ramps people can get to know how the vertical farm looks like and how it functions. The path connecting the functions is also an educational path.

OFFERING AN ENVIROMENT FOR RESEARCHING THE PROCESS OF VF

The vertical farm is designed so that the researchers have the possibility to test different growing systems. By placing walls between the columns the researchers can create spaces with different growing conditions for the plants. By experimenting with different conditions the process of vertical farming is further developed.

CREATING WORK

The building is generating new work places. Also the building is enhancing the industries related with vertical farming and is indirectly also creating work opportunities.

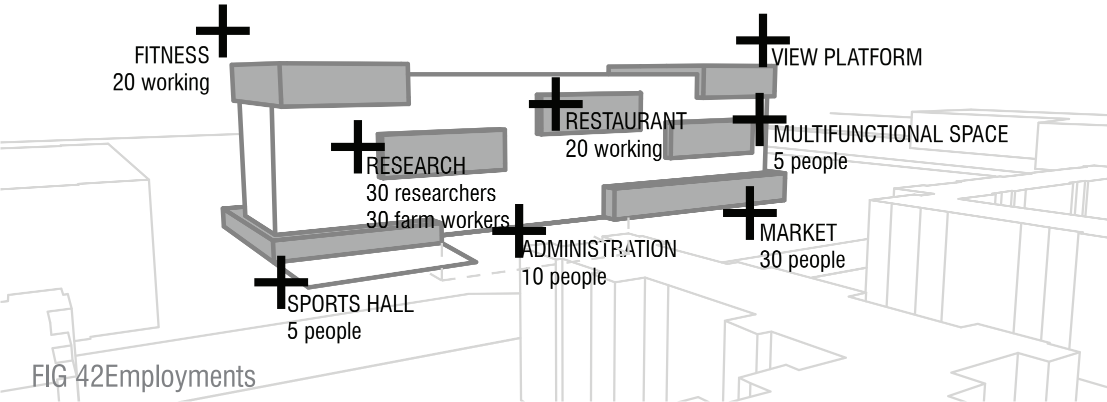


FIG 42Employments

CONCLUSION

Vertical farming is able to tackle a lot of the problems farming will face in the future. But it has one big disadvantage. It is a big consumer of energy. Although we can generate a lot of energy using bio waste, PV cells and heat pums, we do use a lot of energy compared to modern agriculture. Our research vertical farm could help to gain important knowledge how to reduce the energy consumption of vertical farms. Also we have to know that the agriculture of today is based on oil. We need oil to grow food and to transport the food to the consumer. Once we will run out of oil we will have to search for alternative ways how to grow food.

We must also consider that maybe in the future energy will not be the most import factor influencing farming but maybe land scarcity of water scarcity. In this case vertical farms could compete with today's agriculture. Therefore we should develop the process and therefor a research vertical farm is a good investment for the future.

If the concept of vertical farming is successful, our building can extend and produce more food for the people.

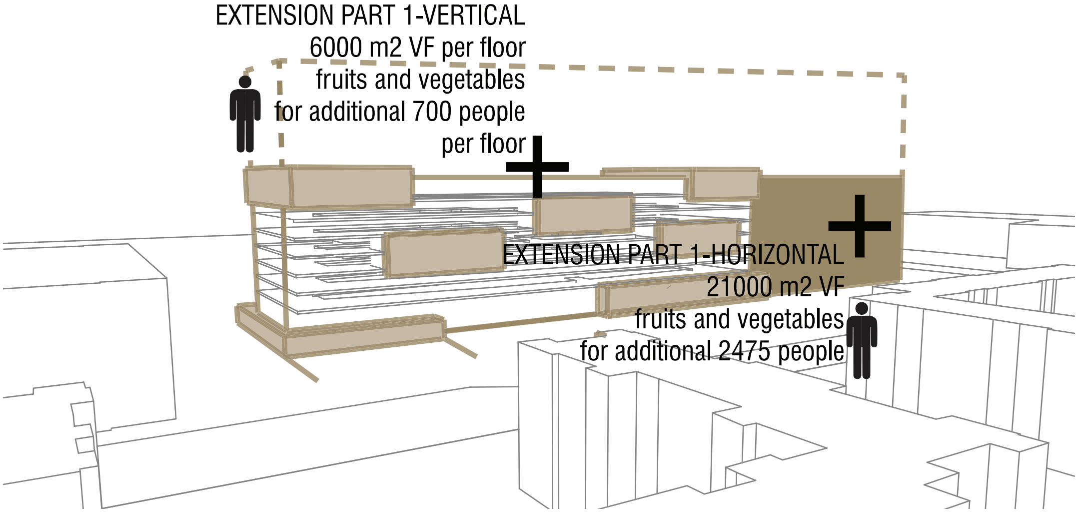


FIG 43 Extensions

appendix

FOOTNOTES

GROWING
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